Ninth International Symposium

Monitoring of Mediterranean Coastal Areas: Problems and Measurement Techniques

Livorno (Italy) 14th - 16th June 2022

edited by
Laura Bonora, Donatella Carboni,
Matteo De Vincenzi, Giorgio Matteucci

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MONITORING OF MEDITERRANEAN COASTAL AREAS:
PROBLEMS AND MEASUREMENT TECHNIQUES

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Preface

The Ninth edition of the Symposium *Mediterranean Coastal Monitoring: problems and measurement techniques*, held in Livorno from 14th to 16th June 2022, addresses scholars of the coastal areas of this Mediterranean basin, as it happens once every two years. The event, organized by the Institute of BioEconomy (IBE) of the National Council Research (CNR) in collaboration with the Italian Society of Silviculture and Forest Ecology (SISEF), is divided into the following Sessions: Flora and fauna of the coastal system: dynamics and protection; Morphology and evolution of coasts and sea beds; Coastal environmental engineering: pollution, energy production, economic-environmental monitoring and evaluation, regulatory context; Coastal and underwater cultural heritage; Geography and coastal landscape: dynamics of the territory and integrated protection.

During the consolidated three days, following the tradition, The Symposium with its interdisciplinarity intends to demonstrate the importance of multidisciplinary studies, underlining the need for integrated investigation approaches. Since the coastal system represents a complex and delicate natural structure, whose evolution is the result of delicate physical, chemical and biological balances, strongly conditioned by anthropic interventions, the aim of the Symposium is to contribute to the spread of knowledge, providing notions and information on dynamics and / or on the variations of marine-coastal ecosystems, in the hope that this can be useful to increase man's respect towards the land that hosts him.

Despite the COVID 19 pandemic, the success of this edition is attested by the 170 contributions selected by the Scientific Committee from among those received. Participation involved all the thematic lines envisaged by the sessions, involving many countries bordering the shores of the Mediterranean Sea. The importance of the event is also attested by the publishing house's request to turn the Proceedings of the Symposium into a Series, of which this volume is the first issue.

A personal thank you goes, first of all, to all those, colleagues and friends, who have invested time and energy in the organization. The same gratitude goes to all the participants, who, with their presence, have shown that they believe in our initiative.

The Editors

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Italian Society of Silviculture and Forest Ecology (SISEF)
Natural History Museum of the Mediterranean

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Presentation of Proceedings

As described in the Preface of this Proceedings Volume, the Symposium has been confirmed as a place to present the research carried out in recent years on the monitoring of the Mediterranean Coastal Areas and therefore as a space to present new proposals and promote actions for the protection of the marine and coastal environment.

The interdisciplinary of the Symposium has been the occasion for consolidating the scientific exchanges of scholars from Mediterranean countries and also for promoting a greater diffusion of the research and related results.

It is relevant that the Symposium is considering the Mediterranean Coastal Areas in all their aspects: from morphology and evolution of coastlines and seabeds to the landscape dynamics and integrated protection; from the dynamics and protection of coastal and underwater flora and fauna to cultural heritage, considering the challenges of pollution, energy production, environmental assessment and regulatory context of coastal areas.

In this 9th edition, in fact, we had more than 100 participants from 12 countries; this is a sign of great success and willingness of being in presence in Livorno to discuss problems and propose solution for the Mediterranean coastal areas. The international scientific committee supervising the Symposium, formed by 35 renowned scientists, did a great and hard work in selecting 42 oral and 100 poster presentation among the 170 contributions received.

It is important to underline since this year, the *Proceedings* will become a Series published by Firenze University Press: another step forward that underline the scientific and political relevance of studying and managing Mediterranean Coastal Areas.

For all selected works a *double peer review* has been carried out for the inclusion of the extended papers in this Volume.

This edition has been the occasion to establish a new collaboration between CNR-IBE and Italian Society of Silviculture and Forest Ecology (SISEF) in the organization of the Symposium.

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The aim of CNR-IBE and SISEF is to continue in their collaboration to organize the next edition, the 10th, of the Symposium and to involve an increasingly wide audience of scholars, supporting in this way the dissemination of scientific results obtained in the field of protection of the Mediterranean coasts.

The Director of CNR-IBE
The Vice President of SISEF
Dr. Giorgio Matteucci

INTRODUCTION

Several agreements for the protection of the coastal and marine environment are currently effective in the Mediterranean region. However, from a historical point of view, the attention to the "health conditions" of the Mediterranean is a concept born only recently. If we wanted to indicate a precise moment, we should identify it in 1975, the year of birth of the *Mediterranean Action Plan*[1]. The following year it was signed the Convention for the protection of the Mediterranean Sea against pollution (definitively entered into force in 1978), the so-called Barcelona Convention[2]. This agreement was revised and supplemented in 1995 (Convention for the protection of the marine environment and the coastal region of the Mediterranean). The Barcelona Convention is managed by the United Nations Environment Program (UNEP) with the aim of preventing, reducing, combating, and eliminating, as far as possible, sea pollution in order to protect and improve the marine and coastal environment and thus contribute to its sustainable development. The Treaty identified seven action protocols[3] concerning, for example, the protection of the sea from pollution of terrestrial or marine origin (including hazardous waste, exploration and use of the continental shelf), cooperation for the prevention and control of pollution from ships and Integrated Coastal Zone Management (ICZM).

Another important regulatory instrument for the Mediterranean, is the Framework Directive on the Strategy for the Marine Environment (2008/56/EC, Marine Strategy Framework Directive, MSFD).

Characterized by greater applicability than previous instruments, it provided that each State Member should develop a strategy for achieving or maintaining Good Environmental Status (GES) by 2020. In particular, it identifies marine monitoring as the first of the operational components in an appropriate governance system (Ferraro et al., 2017; Gianoli 2013).

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[1] https://www.unep.org/unepmap/

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[3] THE PROTOCOLS OF THE BARCELONA CONVENTION: 1. Dumping: Prevention of pollution due to diving operations of ships and aircrafts; 2. New Emergency Protocol: Cooperation to prevent pollution caused by ships and in emergency situations; 3. LBS (Land Based Sources): Protection from pollution of terrestrial origin; 4. SPA / BIO: Special Protection Areas and Biological Diversity; 5. Off Shore: Protection from pollution deriving from the exploration of the exploitation of the underwater continental shelf and of the subsoil (not yet entered into force); 6. Hazardous wastes: Cross-border handling of dangerous wastes and their disposal (not yet in force); 7. ICZM (Integrated Coastal Zone Management): Integrated Coastal Zone Management (defined by the Contracting Parties at the Conference of the Parties in Almería and signed in Madrid, Spain, in January 2008).

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However, today, when we talk about the Mediterranean Sea, we too often think about the millennia of history that saw it as a protagonist and about the many cultures that developed on its shores. We also consider that it was (and still is) a great source of sustenance and trade for many populations and, last but not least, we recognize the strategic role as a center of the world (at least of the western one) that this sea played for many centuries. Nevertheless, unfortunately, the Mediterranean is not always seen as an environmental entity that has been exposed, for a very long time, and particularly in recent decades, to enormous pressure on all the ecosystems that compose it: a pressure generated especially by the men who lived and still live along its coasts.

The coastline of the Mediterranean extends for a total of about 46000 km, with other 19000 km of the islands; of all coasts, almost half (46 %) is sandy and it includes important but fragile habitats and ecosystems such as beaches, dunes, lagoons, marshes, river deltas, estuaries, etc. (Gianoli 2013).

The main dangers for this complex and varied environment are represented by the fragmentation, the degradation and the loss of its habitats and landscapes. Among the various causes of degradation, population density plays a fundamental role, almost a third of the Mediterranean population (512 million in 2018, equal to 6.7 % of the world population) lives in the coastal areas and over 70 % in its cities. Nevertheless, the area demographic context is very different: Northern Mediterranean Countries (NMCs) are characterized by a low fertility rate, an aging population and a relatively low percentage of the workforce; Southern and Eastern Mediterranean Countries (SEMCs) are undergoing a demographic transition phase with a quite stronger growth, an overall younger population and therefore a larger active population (SoED 2020).

The population of the countries bordering the Mediterranean Sea was made up of about 450 million people in 1996 (EEA, 1999), it reached more than 525 million individuals in 2020 and, according to recent projections and estimates, it will reach 655 million of residents in 2050 (EEA, 2020). This steadily increasing population pressure is exacerbated by tourism. The mild climate and the natural and cultural heritage attract a large number of tourists, whose percentage, in fact, represents about one third of the world's international tourism. Moreover, tourism concentrates on a seasonal way in coastal areas, in particular on the coasts of the north-western basin (AEA, 2006). Furthermore, coastal tourism is one of the main factors associated with the production and management of waste, particularly marine litter. The strong spatial and temporal variations of tourism, mainly concentrated along the coast and with important peaks during the summer season, lead to an increase in waste production, untreated wastewater discharges and strong pressures on natural resources. Besides, the deterioration of the quality of the environment, as well as that of water quality, can in turn have an impact on the environment and on the development of tourism, reducing the attractiveness of tourist destinations (EEA, 2020).

In addition, the intensification of urbanization (between 1965 and 2015 about three quarters of Mediterranean countries doubled or more than doubled the inhabited area in the coastal strip 1 kilometer from the coast) left less space for natural coastal ecosystems, reducing the contribution of ecosystem services and increasing the risks for biodiversity and for people living on the coast (SoED 2020).

The Mediterranean Sea is home to more than 17000 marine species (between 4 and 18 % of the known marine species in the world), but it represents only about 1 % of the global volume of the oceans. Furthermore, the Mediterranean Sea has the highest rate of endemics on a global level (from 20 to 30 % of species), for this reason it is considered a biodiversity hotspot.

Another serious threat is the chemical contamination of marine sediments and aquatic, animal, and plant bio-communities, as a result of the pollution produced by urban areas, industrial settlements, petroleum refining and air transport. Often these are substances that deplete oxygen, or heavy metals, persistent organic pollutants (POPs), hydrocarbons and nutrients in the water. Although in recent years some of these factors have seen, on average, an improvement in the situation linked to greater controls carried out on land-based activities, the risks of contamination associated with hazardous substances still remain a significant problem in many areas of the Mediterranean. Moreover, the release of nutrients into marine waters as a result of human activities is at the origin of the problem of the increase in induced eutrophication, especially in coastal areas in close proximity to large rivers and cities. Clearly, these phenomena also lead to immediate socio-economic implications, since they affect the quality and quantity of the catch, the conditions and landscape value of the coastal ecosystem, the deterioration of water quality and, consequently, also on tourism.

Another threat for the Mediterranean ecosystems, often linked to the change of the water conditions (such as temperature, excessive presence of nutrients, etc.), is the invasion of non-indigenous species. In recent years this is a worryingly increasing phenomenon, especially in the easternmost part of the Mediterranean where its impact on biodiversity, on predation habits, on alteration of the chain and, in general, on habitat modification, has been documented. All that has had repercussions on fishing, aquaculture, tourism, and human health. Furthermore, the problem of over-exploitation of fish resources is very widespread, often well beyond the limits of sustainability. The macroscopic result is the change in biodiversity between species, especially in terms of endangered or threatened species due to intensive and indiscriminate fishing techniques.

Paradoxically, even the development of fish farming (recorded especially since the 1990s) has not alleviated the problem of overfishing but, on the contrary, has ended up adding further pressures to the marine ecosystem due to the release of nutrients, organic pollutants and sometimes antibiotics for livestock into the sea. There is also a conflict with the tourism industry over the use of small natural bays and a degradation of the habitats near the cages (AEA, 2006). Other problems relate to the impact of noise caused by marine biological communities from intense maritime traffic (especially in the western Mediterranean basin) and from industrial installations or offshore military activities in specific areas. Underwater noise is a problem of growing concern in important cetacean habitats such as the Pelagos Sanctuary (the sanctuary is between France, Côte d'Azur and Corsica), the Principality of Monaco and Italy (Liguria, Tuscany and northern Sardinia) or the Strait of Sicily. Besides, it is important to point out the integrity of the seabed, threatened by deep fishing, dredging or other drilling and excavation activities, which have the effect of increasing the suspended particulate matter, together with sediments. Consequently, this modifies the habitats of numerous species in the medium / long term. But above all, it remains the key problem: the risks for biodiversity. As a matter of fact, this is the element on which all the other pressure factors affecting the Mediterranean (Gianoli 2013) group together. The Mediterranean Sea is also one of the areas in the world most affected by marine litter. More than 730 tons of plastic enter the Mediterranean Sea every day; these represent 95 to 100 % of floating marine litter and more than 50 % of seabed litter. Single-use plastic accounts for over 60 % of the total marine litter found on Mediterranean beaches, waste normally produced by recreational beach activities. The main causes of plastic pollution include: an increase in its use, unsustainable consumption patterns and inefficient waste management practices. In fact, less than a third of the plastic produced each year in the Mediterranean countries is recycled. Even wastewater represents an important way of entry of waste into the sea of waste hitherto, less than 8 % of wastewater is subjected to tertiary treatment. Other important sources of marine litter are fishing, tourism, and shipping. Litter affects marine organisms primarily through strangulation and ingestion, but also through colonization and buoyancy. They also have important socio-economic effects through the costs of decontamination, as well as the potential loss of income and tourism jobs, and reduction in the value of land and recreational and fishing activities (SoED 2020).

Therefore, in order to "*prevent, reduce, fight and, as far as possible, eliminate sea pollution and in order to protect and improve the marine and coastal environment and thus contribute to its sustainable development*", as stated by the Convention of Barcelona, it is indispensable an integrated approach based on the knowledge about the different ecosystems and landscapes of the Mediterranean Sea.

Furthermore, in order to better protect the environment, it would be appropriate: to fill the gaps in terms of knowledge; to perfect management practices; to increase the socio-economic capacity for environmental management; to strengthen Integrated Coastal Zone Management (ICZM); to decentralize actions, so as to take into account the specific contexts as well as the specific pressures, impacts and particular needs of each country or area that persists in its waters; to improve monitoring and evaluation plans, in order to ensure informed and adequate policies. And the environmental monitoring is precisely the key theme of this 9th Symposium.

Environmental monitoring defined by the European Environment Agency (EEA) as "*Periodic and/or continued measuring, evaluating, and determining environmental parameters and/or pollution levels in order to prevent negative and damaging effects to the environment*" becomes the fil rouge of the Symposium with the aim of considering both the environmental quality and the effectiveness of the management of the *Mare Nostrum*, with an Integrated and multidisciplinary Ecosystem Approach given the complexity and the dimensions of the phenomenon to be examined.

With these premises, it is possible to achieve a resilient and sustainable future of the Mediterranean Sea only through a holistic and integrated approach and this new edition of the Symposium will be able to provide new knowledge, new tools, new case studies useful for good governance processes and for stakeholders, contributing to identify those cause-effect phenomena that link particular human activities to documented environmental effects and, consequently, to provide information that allows policy makers to adopt policies and strategies able to avoid, or at least reduce, negative effects on the environment.

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SESSION

MORPHOLOGY AND EVOLUTION OF COASTLINES AND SEABEDS

Chairperson: Giovanni Sarti
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MORPHOLOGY AND EVOLUTION OF COASTLINES AND SEABEDS

Coastal areas are the most inhabited zone around the world where social and economic interests are increasingly concentrated. During the last tens of years, the construction of river dams and the dredging of riverbeds have prompted, along the coast, a strong decrement of sediment supplies resulting in intense erosive processes. Moreover, in the framework of the greenhouse effect and sea-level rise, coastal zones are strongly subject to drastic and fast changes. These changes are especially evident, because of their low-slope degree, in sandy coasts where the danger of coastal submersion is increasingly close. Finally, warming of temperatures have serious l impact on ecosystems.

Within this worrying scenario the session "Morphology and evolution of coastlines and sea-beds" collect nine research articles. Eight are case studies coming from Italy, Spain Greece and Croatia while one is a research-review within the Mediterranean area.

The review in the Mediterranean area (*E. Anthony*) consists of the analysis of the continuity of flux sediment along the coast and river and how this has been interrupted, or strongly modified, by human activity. The intense fragmentation of flux, even more so in the context of climate change and sea-level rise, needs, according to the author, in an urgent effort to be re-established.

D'Ascola et al., along the coast of Castiglione della Pescaia, provide an example of the application of a method based on the utilization of the geo-database "Linea di Costa" performed by ISPRA. The authors underline how this procedure represents a simple and easy method for specialists and stakeholders to obtain both a quick framework of the current stage of the coastline along with its evolutionary trend in terms of erosion and accretion.

Lupicchini et al., proposed an innovative method to obtain shoreline identification using the topography, achieved from unmanned aerial vehicle (UAV) images. The authors have utilized the new approach along the strand-plain north of the Arno River that is currently affected by strong erosive processes. The comparison with the results obtained for the same stretch of coast through the classical methods of shoreline identification, based on topography, has allowed to evidence of the advantages of the new method.

The erosion process affecting the highly anthropized area of Porto Cesareo, located in a Marine Protected Area of the Gulf of Taranto (Puglia), is analyzed by means of an interdisciplinary approach by *Picciolo et al.*. Besides the typical approach based on the analysis of the aerial photogrammetry and satellite images,

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they also utilized underwater archaeological markers to identify and date the ancient paleo-shoreline.

Three study cases are from Spain. *Arriola Velasquez et al.* propose a study based on the use of radionuclides as tracers of marine sediment movement along the beach La Canteras located in Las Palmas de Gran Canaria. The data acquired, developed using statistical methods, show the influence of wave action in their concentration. The authors point out the effectiveness of this methodological approach and its reproducibility for other coastal zones.

Pagan et al., apply the Remotely Piloted Aircraft System (RPSA) and the Structure for Motion (SfM) image base computing techniques, to study both the dynamics of coastal dune systems and the coastal erosion process occurred along the Guardamar beach (Guardamar del Segura). The result shows how this low-cost approach is adequate for monitoring the evolution of the coastal zones characterized by the beach ridge systems.

Lopez and Pagan present a study on textural sediment analysis of the coarse sand feeding performed at Los Locos Beach (Torrevieja). This beach is instead naturally characterized by fine sand. The study shows how after a short period (15 months) the dumped coarse sands, as a result of wave movement work, became increasingly similar to those natural.

Finally, *Vandrakis et al.,* present a geomorphological approach to study, along the coast of Schinias - Marathon National Park (Attiki Greece), Posidonia Banquetts and their influence on coastal evolution and morphodynamics. The acquired data have demonstrated how the accumulation of Posidonia plays a significant role in the partial contrast to the erosive processes.

Also the study of *Pikely et al.* focuses on the theme of Posidonia. The authors analyze the effects of the continuous removal of Posidonia accumulations on the beach of Sakarun (Croatia), highlighting how this can determine a sedimentary deficit on the beach.

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IMPACTED FLUVIAL AND COASTAL SEDIMENT CONNECTIVITY IN THE MEDITERRANEAN: A BRIEF REVIEW AND IMPLICATIONS IN THE CONTEXT OF GLOBAL ENVIRONMENTAL CHANGE

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Abstract – Sediment connectivity refers to the continuity of the flux of sediment along transport pathways that may be fluvial as well as coastal. Clastic coasts built essentially from sediments supplied by rivers are abundant in the Mediterranean. This supply has been modulated by river catchment characteristics and human influence. Many pocket beaches in small bays in the Mediterranean directly trap bedload supplied by small streams or eroded from nearby bounding headlands, whereas fluvial bedload supply to more or less long open shores has been conditioned by longshore current redistribution from river-mouth bar deposits, many associated with deltas that have built up from fine-grained and organic sedimentation behind coarse-grained barriers. Sediment has also been derived from nearby abandoned delta lobes, older relict or actively formed nearshore carbonate deposits, and from shoreline reworking, but connectivity between shore and lower shoreface has always been limited in the Mediterranean because of the steep continental shelf. Significant sediment deficits along many of the Mediterranean's coasts have resulted from anthropogenic fragmentation of rivers that has generated loss of sediment connectivity. The most important human interventions are flow regulation by dams, sediment trapping by reservoirs, fluvial channel engineering and bank engineering, and sand and gravel extractions. These activities were largely preceded in many river catchments by multi-millennial climate and land-use changes. Because of the strong wave influence and low tidal ranges, longshore sediment transport from river mouths operates within the framework of one or several sediment cells. Many such cells are now characterized by artificial boundaries that block bedload transport and impair alongshore sediment connectivity. These include harbours and terminal groynes, products of coastal urbanization and economic development, especially over the last two centuries. Climate change and sea-level rise spell further increasing vulnerability of the Mediterranean's fragmented rivers and coasts and call for the urgent need to foster efforts aimed at re-establishing sediment connectivity.

Introduction

Sediment connectivity refers to the continuity of the flux of sediment along transport pathways, a concept pertinent to river water and sediment cascades down to the sea, but also to coasts, given the overarching importance of fluvial sediment supply to the formation of coastal deposits such as deltas, beaches and dunes. The concept of connectivity is increasingly permeating all spheres of environmental science as the impacts of breakdowns in nexuses among spheres are felt as a result of human activities and their effects on climate.

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This situation is especially pertinent in the Mediterranean coastal zone, largely bordered by steep mountain slopes, and where population and development pressures (Figure 1), notably associated with the exponential growth of tourism over the last 80 years, are among the highest on Earth, bringing enormous pressure to bear on the 46 % of clastic shorelines that make up the 46 000 km of the Mediterranean coast (Anthony et al., 2014). The Mediterranean captures up to 30 % of the world's tourists and although the developed areas are dominantly coastal, a long history of human occupation and exploitation of river resources in a zone of climatic stress has also meant that pressures have been high on the fluvial systems debouching into the Mediterranean (UNEP/MAP/Plan Bleu, 2020). The impacts of anthropogenic pressures and the need for an integrated management approach have drawn attention, as illustrated by UNEP/MAP/Plan Bleu (2020) and by thousands of scientific publications, reports and symposia dedicated to marine and coastal pollution, ecological fragmentation, and stress on biodiversity. These impacts have had, in turn, dramatic effects on economic activities and livelihoods around the Mediterranean. Although there has been awareness of the problems generated by the harnessing of river resources, the problem of sediment flow has received less attention than that of impacts related to pollution, fish resources, and biodiversity. Figure 2 shows an example of sediment connectivity from the fluvial through delta-plain transition onto the river mouth and adjacent coast in the Mediterranean. Invariably, any breakdown in sediment connectivity through the fluvial corridor, and alongshore, has serious repercussions on the stability of coastal deposits. The Mediterranean is iconic of this fundamental nexus, but also shows perhaps the best examples, at the world-scale, of how this nexus has been severely impaired over various timescales by human activities. Anthropogenic pressures through the ages and up to the current Anthropocene epoch have shaped the present status of Mediterranean coasts, especially through impacts on fluvial-to-coast sediment connectivity, generating further knock-on effects on perturbed shorelines through engineering efforts to maintain stability. This impaired connectivity is briefly reviewed in this paper.

Mediterranean rivers and coasts: the nexus

More than 160 rivers with a catchment size >200 km^2 discharge into the Mediterranean Sea, but only six have catchments larger than 50 000 km^2, thus highlighting the importance of small rivers. Mediterranean rivers have high sediment yields, comparable to those of catchments in tectonically active areas (Milliman and Farnsworth, 2011), but discharge can be variable, with impacts on sediment supply to the coast (e.g., Bini et al., 2021). River sediment supply is particularly important in the Mediterranean basin where shorelines, infilling lagoons and delta plains are mainly sourced by rivers. Although fluvially-supplied sediment has been the main source of sediment for the Mediterranean's coasts, the shoreface can be productive regarding carbonate sand and shells (Anthony and Aagaard, 2020). The Mediterranean seaboard faces a Heterozoan carbonate factory, a type that is generally quite productive and beaten by waves (Laugié et al., 2019), and that is also commonly associated with organic plant production, notably through seagrass meadows offshore, especially *Posidonia oceanica*. The importance of carbonate sediment for Mediterranean coasts, is, however, not known, and the overarching prevalence of terrigenous sediment, dominated by quartz, for the sand and gravel fractions, with subsidiary contributions from black, volcanic sands in certain areas (Corsica, Sicily), needs to be emphasized. Since the coastal hydrodynamic context is largely conditioned by waves in a low tide-range context, the alongshore supply of fluvial bedload by wave-generated longshore transport has been fundamental to the geomorphic development of open-coast beach, dune and barrier systems in situations where coastal morphology and wave fetch conditions favour unimpeded longshore drift. Shoreline development in these cases has generally been sourced by rivers with discharge strong enough to flush bedload to the nearshore zone, where this sediment forms a reservoir for wave-induced alongshore supply to adjacent shorelines. Suspension loads and organic sedimentation are typical of the delta plains and lagoons. High river discharge can lead to significant offshore transport of fine-grained sediments.

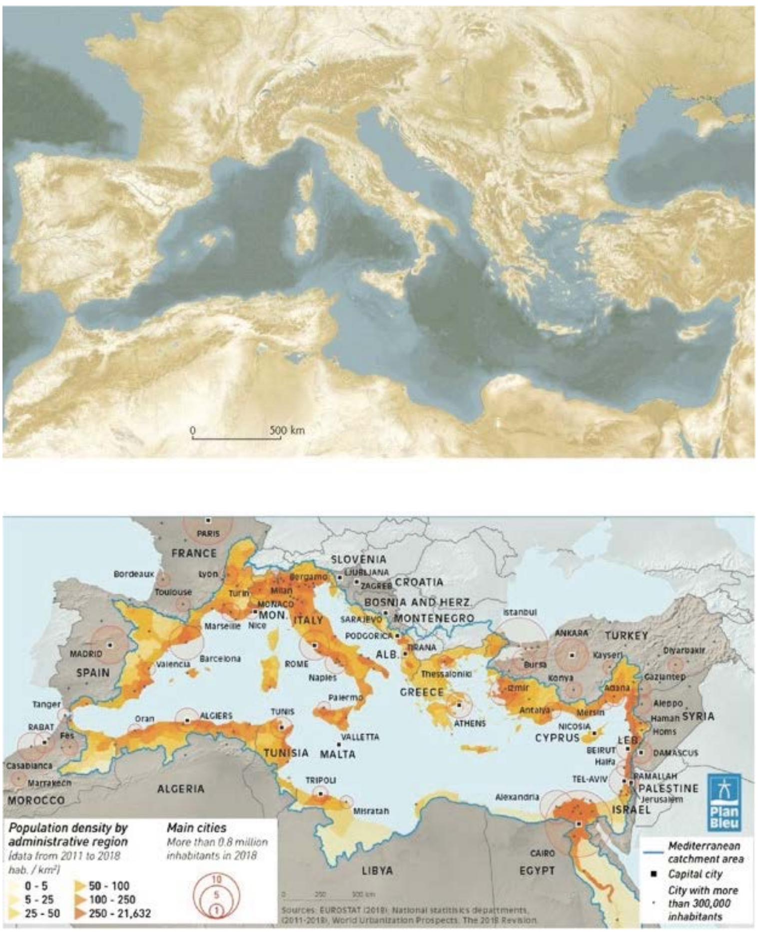

Figure 1 – Relief map of the Mediterranean (top), and population density (bottom, from UNEP/MAP/Plan Bleu, 2020).

River-mouth bar deposits are fundamental to the connectivity between fluvial bedload supply and longshore transport (Figure 2). They are the building blocks of most wave-exposed deltaic and adjacent barrier shorelines in the Mediterranean, as elsewhere (Anthony, 2015). The critical river-mouth area from where bedload is transported to feed the longshore transport system is also a complex hydrodynamic environment because of the diversity and space- and time-varying intensity of fluvial water discharge, tides, and wind and wave activity. Fluvial supply of bedload to the coast is particularly important in the course of strong river flood events. The river-mouth bar can, thus, be reworked by high river discharge and storms, but can also temporarily disappear when river outflow does not balance wave action, leading to smoothing of the shoreline and redistribution of bar sediments alongshore by wave-induced longshore transport. Where fluvial bedload supply is high relative to wave reworking, rapid river-mouth silting can ensue. Prolonged sediment accumulation of this type without correlative redistribution can lead to delta channel abandonment over timescales as short as secular, as Provansal et al. (2015) have shown for the Rhône in France. Sediment accumulation can also lead to navigation problems and recourse to dredging where yachting and fishing harbours are housed in river mouths, a common situation in the Mediterranean.

The mouth-bar deposits generally exhibit two morpho-sedimentary functions: (1) they mainly serve as sources of, and longshore transport pathways for, sand and coarser-grained deposits that contribute to the development of adjacent beaches and barriers or spits (Anthony, 2015); (2) they can also be built up directly by waves to form longshore barriers that provide shelter for fine-grained and organic sedimentation in delta plains, back-barrier plains and lagoons. Along the relatively arid southern and eastern shores of the Mediterranean, aeolian activity has also commonly generated large aeolian dune systems. Such dune systems are much less developed on the western shores of the Mediterranean.

In addition to open-coast barriers, the Mediterranean comprises a multitude of more or less deeply embayed shores of all lengths (< 10 m to >100 km) locked between the numerous bedrock headlands (Anthony et al., 2014). The smaller bays commonly have limited space for sediments to accumulate and are sediment supply-limited, with little or no progradation, but some are sourced by episodic inputs from ephemeral streams. Other bays developed as rias since sea level stabilized in the mid-Holocene (Vacchi et al., 2020). High fluvial bedload supplies and locally impeded longshore transport between headlands have favoured an abundance of infilled bay-head deltas in some rias, in addition to the numerous open-coast deltas, especially in the central and western Mediterranean. Short coarse-grained streams debouching from steep mountainous hinterlands are common, as in parts of Italy and the French Riviera. Along the steep Alpine margins, the shelf is dissected in many areas by deep fossil canyons inherited from the Messinian Salinity Crisis and some of which practically impinge on the coast, as in Nice, where the beach can lose artificially recharged gravel as a result of downslope transport in the small canyons during storms (Anthony et al., 2011).

The coastal sediment cell concept is commonly used in a sediment budget framework and to delineate eroding, stable and accreting sectors alongshore (Figure 2). The emphasis is, thus, on identification of each coastal cell, its segments and net sediment gains and losses (e.g., Pranzini et al., 2020; Bertoni et al., 2021). The distinction between swash and drift-alignment, which designates, respectively, shores associated with weak and strong longshore drift (Davies, 1980), is also a useful basis for considering process variations and long-term shore development patterns. In the Mediterranean, the numerous pocket beaches are likely to be swash-aligned.

Figure 2 – River-to-coast sediment connectivity in the lower Rhône river and delta in France. Top image shows engineered sediment flux diversion to the advantage of the main Rhône distributary. Arrows show sediment (essentially fine-grained) spill-over onto the deltaic plain, and divergent (erosional sectors) and convergent (depositional sectors) bedload-transport sediment cells along the coast, including reworking of an abandoned delta lobe (from Sabatier and Anthony, 2015). Red box represents area of the river-mouth bar with bathymetry shown in bottom image. Photo insert on the left shows the small sandy river-mouth bar on the Argens delta, about 120 southeast of the Rhône delta.

Mediterranean river fragmentation and loss of connectivity

Mediterranean rivers show relatively high levels of fragmentation and loss of connectivity as a result of dams and river channel regulation (Grill et al., 2019). These rivers provide eloquent examples of the reductions in sediment supply caused by the plethoric construction of dams and reservoirs (Figure 3), although environmental and other concerns saw dam construction tailing off in the 1990s, only to regain favour since the mid-2000s in the drive for 'clean' energy (Flaminio et al., 2021).

The importance of river management practices in the Mediterranean is an outgrowth of the climatic conditions which can be characterized by very dry and hot summers and variably humid winters, a clear imbalance in water availability, particularly, for agricultural needs. However, the climate is also characterized by short high-river discharge spates that can be threatening to life and damaging to the environment, as shown by the dramatic effects of Storm Alex in the Maritime Alps of France and Liguria, Italy, in October 2020. The steep hinterlands bounding parts of the Mediterranean coast and its islands are commonly a source of massive sediment release, associated with deforestation in the past, and hence the recourse to erosion check dams in many areas that have further contributed to loss of sediment connectivity, with impacts on the coast (e.g., Anthony and Julian, 1999; Bombino et al., 2022). Dams are, however, relatively recent in the history of rivers. Many deltas in the Mediterranean have been formed or have grown considerably in the wake of human interventions that liberated large amounts of sediments in the catchments (Anthony et al., 2014). The deleterious effects of river modification on Mediterranean coasts are directly linked to the diminution of sediment supply resulting from flow regulation through attenuation of the peak bedload-mobilizing flows caused by dams, but also to sediment trapping and the effects of channel and bank engineering. The regulation effect can dominate over trapping by reservoirs (e.g., Martin-Vide et al., 2020). Flaminio et al. (2021) have suggested a need for a stronger dialogue between the scientific and public domains on the impacts of dams, indicating that such knowledge transfer and exchange would be particularly beneficial regarding perceptions of 'renewable energy' and 'green energy,' and in a consideration of alternative modes of governance regarding dams.

Coastal erosion and delta subsidence

Massive engineering interventions with far-reaching consequences on coastal sediment transport and coastal stability are products of both deficits in fluvial sediment supply and rampant coastal urbanization and economic development over the last two centuries (Anthony, 2014). The expansion of coastal urban fronts, leisure ports and tourism in the course of the 20th century has, in this parallel context of sediment deficit, been the main driver of large-scale modification of the coast in various parts of the Mediterranean (e.g., Molina et al., 2018; Pranzini et al., 2018; Capucci et al., 2021; Kasmi et al., 2020; Hzami et al., 2021). Large-scale planned and unplanned development involving joint state and private capital ventures has, in many cases, exacerbated coastal instability, by leading to breakdown in alongshore sediment connectivity, while endangering coastal ecosystems. The growth of urban fronts has commonly led to drastic reductions in beach widths and to dune degradation. The construction of marinas, leisure harbours and artificial beaches has resulted in the emergence of veritable artificial shorelines that are sometimes built at the expense of the natural beaches, degraded by sediment deficits. These artificial shores generally blend with urban fronts.

Several deltas and distant coasts dependent on the rivers have become more or less severely eroded as a result of negative sediment budgets (Besset et al., 2017). By reducing river liquid discharge and sediment supply, human activities upstream have favoured accelerated subsidence of deltas (Figure 4), whereas extractive activities can exacerbate this problem in the delta environment itself (Anthony et al., 2021), invariably enhancing the potential influence of waves in washover processes and in dispersing deltaic bedload and fine-grained sediment, but also in exacerbating coastal erosion.

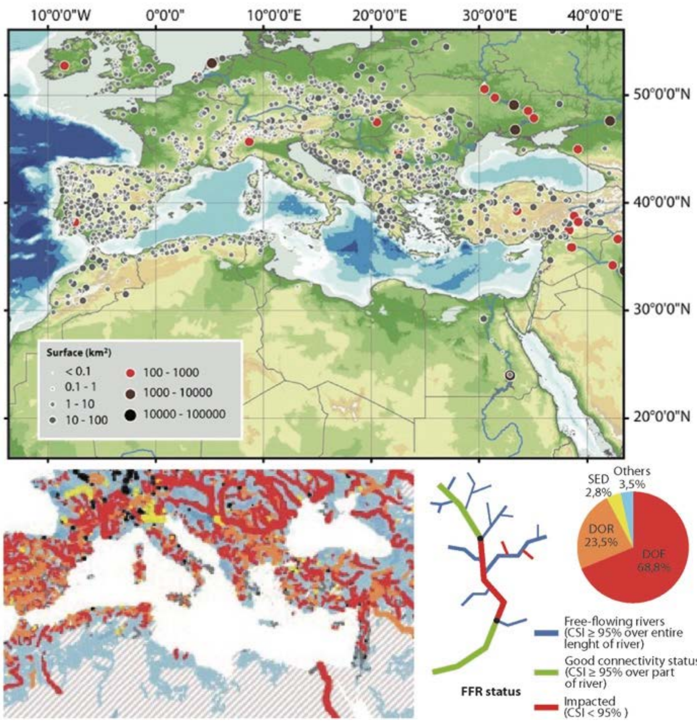

Figure 3 – Mediterranean dams and reservoirs, and river fragmentation and loss of connectivity. (a) Upper plot shows surface area of reservoirs rimming the Mediterranean and Europe (in square kilometres - adapted from the Global Reservoir and Dam Database (Lehner et al., 2011). Lower figures, all adapted from Grill et al. (2019), show highly impacted connectivity (CSI – connectivity status index <95 % and loss of free-flowing status (FFR)) in Mediterranean rivers (red). The degree of fragmentation (DOF), degree of regulation (DOR), and sediment trapping (SED) represent mean global values that are probably less than those in Mediterranean catchments.

Some of the causes of, and the responses to, shoreline destabilization have been essentially a matter of 'hard' engineering, for both historical and cultural reasons (e.g., Pranzini et al., 2018). The construction of groynes, breakwaters and sea walls in response to development pressures, and notably to cater for tourism, has perturbed the longshore transport of already dwindling sediment supply from river mouths and cliffs, leading to local-to-regional sediment budget deficits and erosion on shores downdrift of such structures (and surpluses and accretion on updrift coasts). Commonly, this has involved a vicious cycle of further construction of engineering structures, in addition to generally costly beach nourishment schemes. On many other beaches in the Mediterranean, seawalls, groynes, rip-rap revetments, detached breakwaters, and submerged structures have been constructed over the last century in order to fix sediments within a framework of declining bedload supply from rivers, thus further fragmenting longshore transport cells, creating artificial cell boundaries, and exacerbating the loss of alongshore sediment connectivity.

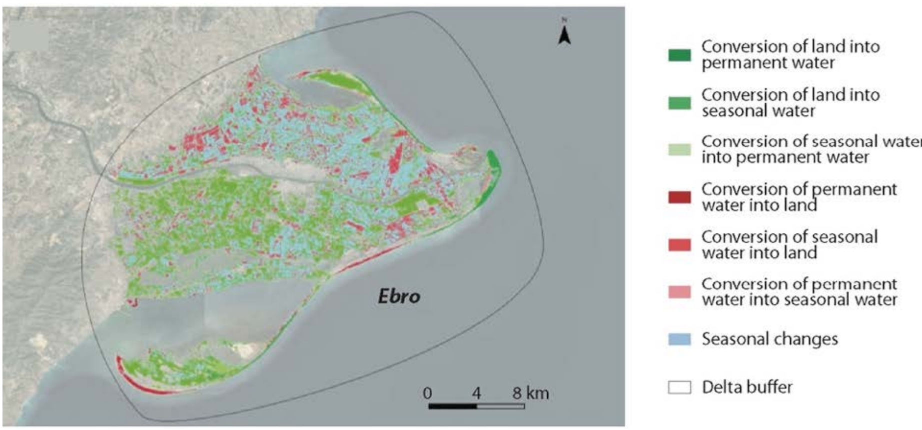

Figure 4 – Map of land→water and water→land conversions (1984-2019) for the Ebro delta culled by Anthony et al. (2021) from the Global Surface Water (GSW) database of Peket et al. (2016). The net preponderance of conversion of areas of land to water suggests prevalence of exacerbated subsidence as mapped by Rodriguez-Lloveras et al. (2020), highlighting a delta particularly vulnerable to sea-level rise.

Concluding remarks: challenges ahead

From a coastal management point of view, the vulnerability of the Mediterranean's coasts has been highlighted in thousands of publications over the last two decades. Sea-level rise will become an important future constraint on the densely developed beach and barrier shorelines and deltas of the Mediterranean. It is now clear that the dwindling of fluvial sediment supplies related to river catchment and channel modifications, and the emphasis on coastal stabilization, at whatever cost, that has been the cornerstone of coastal management practice in the Mediterranean need to be thoroughly reconsidered. Stabilization will become costlier in the future, as pressures from coastal development increase, as sea level rises and as fluvial sediment stocks continue to diminish, with further uncertainties regarding the impacts of climate change on river discharge variability. The situation calls for change, with openings coming from larger environmental awareness, the need for a connectivity approach in fluvial sediment supply to the coast, involving a balanced approach regarding the advantages and deleterious effects of river dams, recognition of the failure or poor performance of many coastal stabilization projects, and the diversification of the actors involved in coastal management and planning. These developments must necessarily debouch on a more prospective, upfront and long-term approach to coastal management.

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BEACH SEDIMENT DYNAMICS FROM NATURAL RADIONUCLIDES POINT OF VIEW

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Abstract – This study is focused on assess the use of radionuclides ^{226}Ra, ^{228}Ra, ^{40}K and $^{210}Pb_{ex,}$ as well as the ratio $^{226}Ra/^{228}Ra$, as tracers of marine sediment dynamic. For this the spatio-temporal variability of the activity concentration of these radionuclides was analysed in Las Canteras beach (Spain). This beach was selected due to its heterogenic composition and marine dynamics. A Cluster analysis and a Principal Component analysis (PCA) were performed to evaluate the spatial variability. The results grouped the samples in three zones related to the sediment distribution under the effects of the marine dynamics that are created by the different geomorphologies of the beach. In the temporal variability analysis, an ANOVA test and Tukey's Honestly Significant Difference (HSD) Test pointed out that the wave action influences the activity concentration found for the different radionuclides during erosion and accumulation periods. In addition, the results of a geochemical analysis of samples from maximum and minimum activity concentration campaigns suggested that the radionuclides studied could be used as tracers of marine sediment dynamic in beach areas.

Introduction

Natural radionuclides in the Earth's crust have different origins. Some of them come from the elements that compose it and others are generated by the interaction of the cosmogenic radiation with the elements in the atmosphere. These last ones are then deposited on the planet surface by different processes. Since all of these elements can be found in the soils of the planet that generate sediments, natural radionuclides could be used to evaluate different sediment dynamics. In the case of beaches, the morphology and sedimentary budget is mainly controlled by sand erosion and accumulation periods. Therefore, monitoring these processes closely is a key factor to a sustainable management of this high-value areas, as well as can be useful to better understand how beaches morphology can evolve with time. Different techniques can be used to evaluate sediment dynamics in beach areas, and among them, natural radionuclides have proven to be an interesting tool in coastal areas [7], [15].

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In this study the use of natural radionuclides has been assessed in Las Canteras beach, in Las Palmas de Gran Canaria, Spain. This beach is very heterogenous in sand composition and marine dynamics that affect it. In addition, the sediment dynamic as well as its sedimentary budget have been very well studied during the years. According to these studies, Las Canteras beach is divided in three arches, and it presents a natural offshore rocky bar that covers the northern and central arch (figure 1). This bar is not a complete block, but it presents fragmentations and openings that are more present in front of the central arch. The southern arch, on the contrary, does not present any bar and it is totally open to the wave action. Due to these different morphological characteristics, Las Canteras beach combines the characteristic dynamic of a closed beach protected against the wave action and that associated with a beach open to it, presenting seasonal variability in its sedimentary budget [1]. During erosion periods, sand is eroded from the southern arch and a lengthwise transport of these sediments can occur to the northern arch. During accumulation periods the sand from submerged sandbars arrive to the beach and, since the northern arch is under a constant accumulation period, some berms can appear and a lengthwise transport of sediments from the northern arch to the southern arch can occur [1].

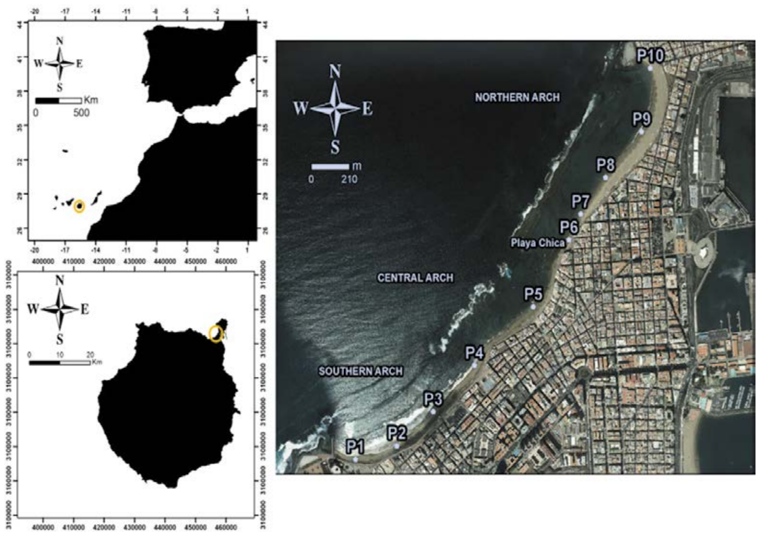

Figure 1 – Location of the study region and the sampling points in Las Canteras beach. Coordinates are in the UTM system [4].

Regarding the sand composition of Las Canteras beach, different sources can be identified: basic volcanic rocks from La Isleta, in the northeast of El Confital bay, phonolitic lava flow from the southwestern side of the bay, basic rocks and magnetite from the mouth of La Ballena ravine in the south part of the beach, submerged sandbars located between the bathymetric curve of 50 m and the beachfront and the natural offshore calcarenite rocky bar

[6], [14]. Furthermore, there are some calcimetry and petrological analyses of the beach sand and the geological composition of El Confital Bay (where Las Canteras beach is located) that identify different materials that can be found along Las Canteras beach. The sand from the northern arch has a higher content of bioclast and calcareous materials, as well as it presents a higher content in calcarenite. This calcarenite displays a higher content of feldspars in its terrigenous part and thus, feldpars seem to accumulate in the northern part of the beach. The southern part of the beach, on the contrary, tends to accumulate clinopyroxenes and other heavy minerals, such as olivine, amphiboles and Fe-Ti oxides that come from the ravine that ends in this part. The lighter lithics that can be found in this part are redistributed along the beach due to erosion and accumulation phenomena [1], [2], [12].

All these differences along Las Canteras beach enabled to evaluate the changes of natural radionuclides associated to the sediments that are transported under different marine dynamics and geological environments. On the one hand the southern arch resembles a beach open to the wave action and with sand composed mostly by heavy minerals. On the other hand, the northern arch presents the characteristics of a beach protected against the wave action and with sediments mainly composed by organic materials and calcarenite. Therefore, the results could resemble to those obtained after assessing the role of natural radionuclides in two different beaches with very different dynamic and geological characteristics. Hence, the results obtained could be expected to be applied in other parts of the world. In this framework, a spatio-temporal analysis of the activity concentrations of natural radionuclides was performed in Las Canteras beach during 2016 and 2019 [4], [5] and it is described in this work. These studies evaluated the role of gamma emitting radionuclides ^{226}Ra, ^{228}Ra, ^{40}K, $^{210}Pb_{ex}$ and the ratio $^{226}Ra/^{228}Ra$ as tracers of erosion and accumulation periods in beach areas.

Material and Methods

Samples collection took part monthly from September 2016 to April 2019, with a total of 360 samples collected. For each campaign ten samples were collected in the intertidal zone of the beach during low tide time (Figure 1). At each sampling point, a square of 1 m^2 was drawn in the sand and, after mixing in situ, samples were taken from the superficial sand (between 0 and 5 cm depth). After this, samples were taken to the laboratory, they were dried at 80 ◦C for 24 h. They were then sieved through a 1 mm mesh size to homogenise them and kept inside PVC-trunk conical containers, filled to 40 cm^3. They were sealed with aluminium strips, because they are impermeable to radon gas [4]. Finally, the samples were stored for a duration of approximately one month before measurement to allow secular equilibrium between ^{226}Ra and ^{222}Rn and its short-lived progenies (as ^{214}Pb is used for determining ^{226}Ra).

The determination of radionuclides in sand samples by gamma spectrometry analysis was carried out using a Canberra Extended Range (XtRa) Germanium spectrometer, model GX3518, with 38 % relative efficiency with respect to a 3” x 3” active area NaI (Tl) detector and nominal FWHM of 0.875 keV at 122 keV and 1.8 keV at 1.33 MeV. It works coupled to a Canberra DSA-1000 multichannel analyser with the software package Genie 2000. Efficiency calibration of the system was performed using the Canberra LabSOCS package based on the Monte Carlo method [3], [5], [10], [11]. Calibration was verified using reference standards for IAEA RGK-1 (potassium sulfate), RGU-1 (uranium ore) and RGTh-1 (thorium ore). Energy calibration was carried out using a $^{155}Eu/^{22}Na$ (Canberra ISOXSRCE, 7F06-9/10138 series) and confirmed using the 1460.8 keV line of ^{40}K (IAEA RGK-1) [3].

The radionuclides of interest were determined from different photopeaks. ^{226}Ra was determined from the ^{214}Pb using the 351.9 keV emission line. ^{210}Pb was directly measured using the emission line of 46.5 keV. The activity concentration of ^{228}Ra was calculated from ^{228}Ac by the emission line of 911.2 keV. Activity concentrations of ^{40}K and ^{137}Cs were directly measured using emission lines 1460.8 keV and 661.8 keV, respectively. The counting time for each sample was around 24 hours. With the values of ^{210}Pb and ^{226}Ra unsupported or excess ^{210}Pb ($^{210}Pb_{ex}$) [9] was calculated.

In order to better understand the role of natural radionuclides as tracers of sediment transport during erosion and accumulation periods, the variations in the chemical and mineralogy composition of 4 sand samples were evaluated. The first 2 samples selected belong to the maximum gamma activity campaign and the other 2 to the minimum one. For this, a multielement analysis using a coupled plasma optical emission spectrometry (ICP-OES), a Powder X-ray diffraction (XRPD) and a single crystal X-ray diffraction (SCXRD) analysis were performed. The X-ray diffraction analysis was selected as a technique to search the minerals that are transported during erosion and accumulations periods and could contain the radionuclides studied. With these techniques, it was expected to identify and better characterize the different sediments and minerals that mix in the sand and are responsible for the activity concentrations found [5].

A cluster analysis (CA) [13] and a principal component analysis (PCA) [16] were carried out in order to evaluate the spatial distribution of the activity concentrations of the radionuclides studied [4]. For the temporal analysis a one-way ANOVA test was performed to evaluate the presence of significant difference among the difference groups. Finally, a Tukey's Honestly Significant Difference (HSD) Test [17] was used to stablish the exact groups among which significant differences were found [5].

Results and Discussion

Figure 2 shows the dendrogram of the hierarchical cluster and the biplot correspon-ding to the PCA results. The same three groups were observed in both analyses. The first group that will be referred as zone I grouped samples from sampling points P1, P2, and P3, which are located in the open part of the beach in the southern arch. The second group that can be observed, and will be referred as zone III, includes samples from sampling points P7, P8 and P10. This sampling stations are located in the northern arch, in the part of the beach that is completed protected against the wave action by the natural offshore rocky bar. The last group that can be observed combines samples from sampling stations located in both the central arch and the northern arch. It includes samples from sampling stations P4, P5, P6 and P9, that are located in front of the openings of the natural offshore rocky bar. In addition, the biplot points out that the variance of ^{226}Ra, ^{228}Ra, and ^{40}K is mostly explained by PC1. Moreover, these radionuclides appear very close togeher in the biplot, meaning that they activity concentration variance is very well correlated. In the case of $^{210}Pb_{ex}$ it is load far from the other radionuclides, indicating that its variance is more explained by PC2 and it is badly correlated to them. These seems to suggest that the agent controling the distribution along the beach of $^{210}Pb_{ex}$ is different from that controlling the spatial distribution of ^{226}Ra, ^{228}Ra, and ^{40}K. Moreover, the presence of the distinct parts of the offshore rocky bar seems to be one of the main influences in the distribution of sediment transport and accumulation of radionuclides along the beach. Therefore, ^{226}Ra, ^{228}Ra, and ^{40}K seem to be tracing marine sediment dynamics [4].

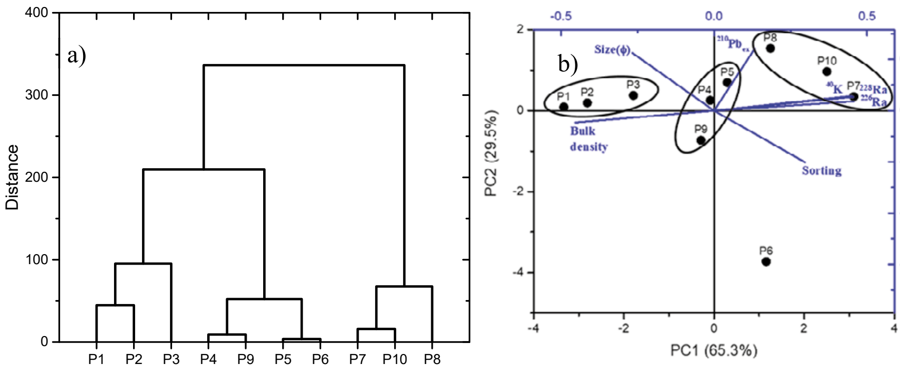

Figure 2 – a) Dendrogram showing clustering for the different sampling points based on their activity concentrations of ^{226}Ra, ^{228}Ra, and ^{40}K. b) Biplot of loading plot with the eigenvectors obtained for the grain size in the phi scale (Size φ), sorting, bulk density of the sample and activity concentrations of ^{226}Ra, ^{228}Ra, ^{40}K and $^{210}Pb_{ex}$ (blue axes) and scores of observations (black axes) Modified from [4].

Considering the zones described in the spatial analysis, the temporal series of the mean values of ^{226}Ra, ^{228}Ra, ^{40}K, $^{210}Pb_{ex}$ and the ratio $^{226}Ra/^{228}Ra$ during the whole study in each zone appear in figure 4. The ratio was also analysed since it had been proposed before as a tracer of erosion/accumulation periods [8]. This is because in the crystal framework of clay minerals both ^{226}Ra and ^{228}Ra can be found, but the carbonate and exchangeable phases contain more ^{228}Ra. Hence accretion or erosion periods could be measured by a change in the ratio between ^{226}Ra and ^{228}Ra. During accumulation periods the ratio would be below 1 due to the higher input of ^{228}Ra in this periods. On the contrary, during erosion events there would be a loss of ^{228}Ra and the ratio would increase above 1. Hence, this ratio was also analysed as tracer of erosion and accumulation periods. In the temporal series of the three zones, it can be appreciated that ^{226}Ra, ^{228}Ra and ^{40}K follow a similar pattern while $^{210}Pb_{ex}$ behaves diferently. This again suggest that the agents controlling the distribution of the first three radionuclides are different to the ones controlling the distribution of $^{210}Pb_{ex}$. Regarding the ratio $^{226}Ra/^{228}Ra$, it can be observed that for zones I and II it presents values that are above and below 1, while in zone III is always under 1. The zone III is the area protected against the wave action and thus, in this part the ratio would always be below 1 which seems to be what can be observerd in the temporal series. In addition, in zones I and, a bit lesser, in zone II, the maximum values of ^{226}Ra, ^{228}Ra and ^{40}K seem to agree with values of the ratio below 1. All of these seem to agree with what would happen during erosion periods and thus, the temporal series seem to indicate that the three radionuclides, as well as the ratio, are tracing erosion/accumulation periods in the beach.

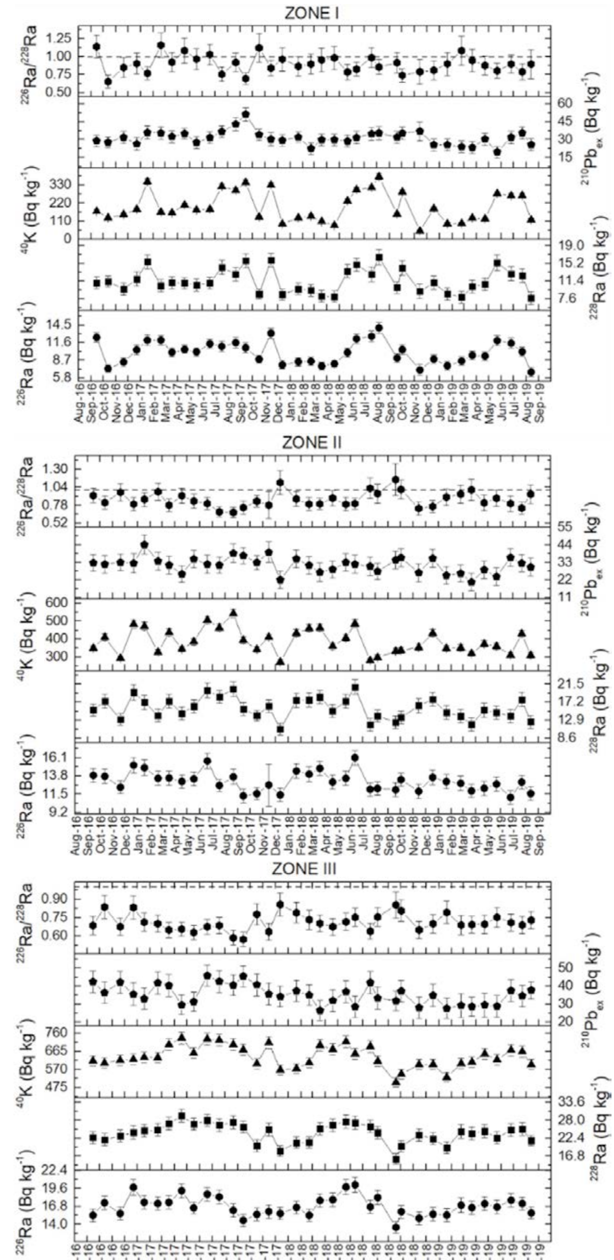

Figure 4 – Temporal series of the activity concentration of ^{226}Ra, ^{228}Ra, ^{40}K, $^{210}Pb_{ex}$ and the ratio $^{226}Ra/^{228}Ra$ during the study period for the different zones established in [4] for Las Canteras beach [5].

In order to further analyse the role of the three radionuclides and the ratio as tracers of marine sediment dynamics, the effect of different erosion and accumulation agents such as wave approach direction and significant wave height. In table 1 the results obtained for the One-way ANOVA and the Tukey's Honestly Significant Difference (HSD) Test are shown. The One-way ANOVA identified the presence of significant differences in the temporal series of ^{226}Ra, ^{228}Ra, ^{40}K and the ratio $^{226}Ra/^{228}Ra$. The HSD identified the exact groups that present significant differences in relation to the different erosion/accumulation agents studied.

Table 1 – Results of zone I for the one-way ANOVA test and Tukey's Honestly Significant Difference (HSD) Test. Modified from [5].

Area	Field	F	Prob-F	Tuckey's test
^{226}Ra	Significant wave height	9.61900	0.0005110	Low-high (0.0009) Low-medium (0.0114)
	Wave direction	6.02300	0.0194000	NW-NE (0.0194)
^{228}Ra	Significant wave height	19.14000	0.0000030	Low-High (0.0000065) Low- Medium (0.0004618)
	Wave direction	6.67200	0.0143000	NW-NE (0.0142665)
^{40}K	Significant wave height	25.34000	0.0000002	Low-High (0.0000008) Low- Medium (0.0000358)
	Wave direction	9.12100	0.0047700	NW-NE (0.0047708)
$^{226}Ra/^{228}Ra$	Significant wave height	1.98000	0.1540000	-
	Wave direction	0.21400	0.6470000	-

ANOVA prob-F 0.05
Tuckey's test p-value 0.05

In the case of the ratio, no significant differences were found for any of the zones. According to the literature [1] the area fully protected by the natural offshore rocky bar (zone III) is in a constant accumulation period. Moreover, zone II is also protected by the bar, so the lack of significant differences can be expected in these two parts of the beach. In addition, some clay minerals have been found in the northern part of the bay where the beach is located [12] so the ratio seems to work in this part of the beach. However, this could not justify the lack of significant differences in zone I and since other minerals could also contain ^{228}Ra, this ratio might not be suitable to use as marine sediment dynamic tracer worldwide, but it could be used in areas with similar characteristics to the northern part of Las Canteras beach [5].

In the case of ^{226}Ra, ^{228}Ra and ^{40}K the results relating to the significant wave height showed significant differences for zone I between the low wave height and the medium and high wave height. According to the polar plots of figure 5, the campaigns with lower values of significant wave height for zone I would present higher activity concentrations values of these three radionuclides. For zones II and III no significant differences were found [5].

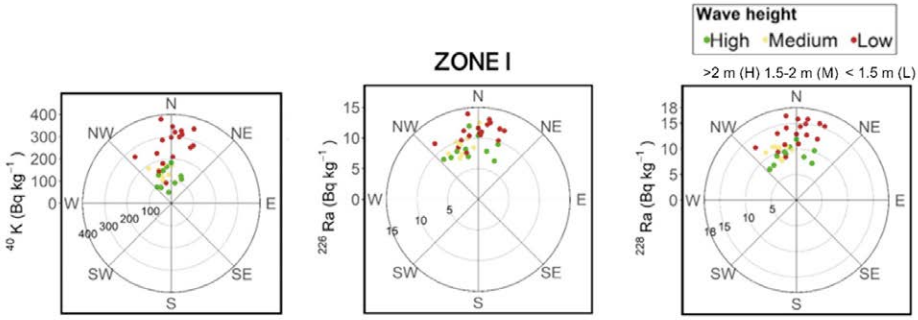

Figure 5 – Azimuth plot of wave height and direction and activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K for the different zones in Las Canteras beach. Modified from [5].

The results relating to wave approach direction also reported significant differences for zone I between the campaign when the wave approach direction was NE or NW. The boxplots of figure 6 represents the activity concentration values of ^{226}Ra (figure 6a), ^{228}Ra (figure 6b) and ^{40}K (figure 6c) for the campaigns with NE and NW wave approach directions. They shows that, in campaigns with a NE wave approach direction, the activity concentration values of these elements were higher. The NE part of the bay and the north part of the beach is where the clay minerals and feldspars were found [2], [12]. Therefore, the results point to the possible influence of the minerals located in the northern part of the beach, in the changes of activity concentration values found in zone I during the whole study period [5]. In this case, zones II and III did not show any significant differences either.

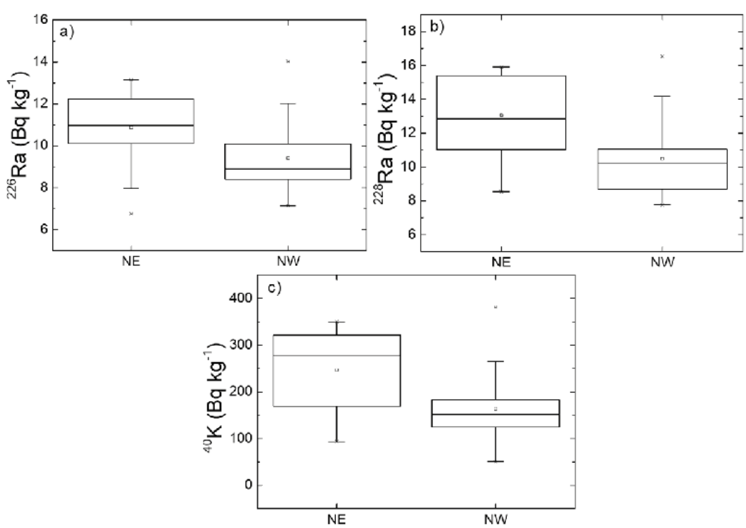

Figure 6 – Boxplot of the activity concentrations obtained for zone I in each campaign for each of the wave approach directions. a) ^{226}Ra, b) ^{228}Ra and c) ^{40}K [5].

In order to comprehend what mineral could be transporting ^{226}Ra, ^{228}Ra and ^{40}K a total of 4 samples were analysed by Powder X-ray diffraction (XRPD). The samples were chosen from two sampling stations (figure 1), one located in the open part of the beach (P2) and another located in the closed part of the beach (P8). From each sampling station a sample from a minimum activity concentration campaign (November 2018) and a sample from a maximum activity concentration value (August 2018) where analyzed. Hence, the samples from November 2018 would correspond to an erosion periods and samples from August 2018 would belong to an accumulation period. In addition, the sample from zone I was analysed by single crystal X-ray diffraction (SCXRD). The results of the X-ray diffraction analysis pointed out the increase of feldspar with potassium content in the samples from the open part of the beach during the accumulation periods. In the case of the samples from the closed part of the beach, this K-feldspar is present in both samples from erosion and accumulation campaigns. It has been described for Las Canteras beach that feldspars arrive to the southern part of the beach and are redistributed along the beach, as well as they are constantly present and accumulated in the northern part of the beach [1], [2]. Therefore, the results of the X-ray diffraction analysis seem to suggest that K-feldspar is the main K-bearing mineral. Hence, ^{40}K seems to be tracing the movement of this feldspar contained in the light fraction of the sand, making it a good tracer of the beach sedimentary dynamics [5]. The results of the multielement analysis showed that total K increases its concentration during accumulation periods and a decrease during erosion periods. In addition, Ba and Ca followed the same pattern as total K. Since it was no possible to measure Ra concentration by this method and, considering Ba has similar chemical properties to Ra, we could be assumed that total Ra follows the same pattern as total K too. Therefore, that would be why ^{226}Ra and ^{228}Ra follow a similar pattern to ^{40}K and could also trace marine sediment dynamics.

Table 2 – Multielement analysis of the total rock composition of each sand sample. Concentrations given in g kg-1 of Ba, Ca and K were analyzed. Modified from [5].

Sample	Ba	Ca	K
LOD of detector	0.0002	0.0552	0.0203
LOB	0.0113	3.1764	0.109
LOD of the method	0.0226	6.3529	0.2181
LOQ	0.0435	11.9209	0.4227
PLC18_8.2	0.3611±0.0047	172±2	16.03±0.10
PLC18_11.2	0.0519±0.0005	25±0	0.65±0.01
PLC18_8.8	0.3805±0.0023	167±1	15.48±0.09
PLC18_11.8	0.3484±0.0021	163±1	22.27±0.08

Conclusions

The assessment of the spatial and temporal variability of activity concentration of ^{226}Ra, ^{228}Ra, ^{40}K and the ratio $^{226}Ra/^{228}Ra$ in Las Canteras beach suggest that these could be used as tracers of beach sediment. Since this beach encapsulates both the dynamics of a beach protected against the wave action and that open to it, the results could be apply to areas all over the world. Therefore, the main conclusions are:

- The CA and PCA analysis used for the spatial analysis pointed out that samples are grouped in three zones related to the marine dynamics created by the natural offshore rocky bar. The biplot of the PCA also showed that ^{226}Ra, ^{228}Ra and ^{40}K are very well correlated while $^{210}Pb_{ex}$ is less correlated. Due to the atmospheric origin of $^{210}Pb_{ex}$, the results of the spatial analysis also suggest that ^{226}Ra, ^{228}Ra and ^{40}K might be tracing marine sediment dynamics.
- The statistical analysis of the temporal variability of activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K suggested that these radionuclides follow a marine sediment dynamic with higher activity concentrations values found for zone I during accumulation periods, when significant wave height was lower. In addition, activity concentrations values would increase with NE wave approach direction, which suggests these radionuclides are also tracing the origin of the sediments that arrive to the beach.
- In the case of the ratio $^{226}Ra/^{228}Ra$, no significant differences were found for any of the zones. However, zone III is the area protected by the natural offshore rocky bar and the ratio was below 1 during the whole study period, as it would be expected for a constant accumulation period. Hence, the lack of significant difference could be pointing out the lack of differences between erosion and accumulation periods. Therefore, the ratio could be applied as tracer of sediment dynamics in areas with similar characteristics to the northern arch of Las Canteras beach.
- Moreover, the mineralogical analysis suggested that the activity concentration values found for ^{40}K correspond to the movement of potassium feldspar that are transport in the light fraction of the sand into and along the beach during erosion/accumulation periods. Hence, ^{40}K seems to be the most fitting tracer for sediment dynamics in all the parts of Las Canteras beach. Nevertheless, the multi-element analysis of the composition of the total rock of the sand that can be found in the different parts of the beach in erosion and accumulation periods, indicates that Ba and Ca behave similarly to K. Since Ba has similar chemical properties to Ra, this could explain why ^{226}Ra and ^{228}Ra follow the same pattern as ^{40}K. Thus, these two elements could also be used as tracers of beach sediment dynamics.

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THE ISPRA GEODATABASE FOR MONITORING AND ANALYSIS OF THE STATE OF THE ITALIAN COASTS: AN EXAMPLE OF ITS APPLICATION TO THE ROCCHETTE - CASTIGLIONE DELLA PESCAIA COAST LINE

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Abstract – The Italian peninsula has a wide variety of coastal areas: whether natural or human-made, they should in any case be understood as interactive sea-land systems, dynamic and fragile, to be protected through the development of - often very complex - planning and management techniques. Knowledge of long-term coastal dynamics, connected to the action of the sea, to anthropic activities and to climate change, is a fundamental element in coastal areas planning and management. In the past few years, the Italian National Centre for Coastal Defence (CN COS) of the Institute for Environmental Protection and Research (ISPRA) has been carrying out environmental monitoring and characterization of the coast and coastal dynamics at national level. As of today, the CN COS has gathered a range of information on the coastal strip (from the backshore to the shoreline) by digitization and characterization from ortophotos over a period of approximately 20 years, from 2000 to 2020 (nominal survey years: 2000, 2006, 2020). In addition, a further information layer was created for year 1950 derived from historical maps of the Italian Military Geographical Institute (IGM). This activity allowed to develop a Geodatabase containing the linear information on the characterization of the natural and artificial elements shaping the Coast Line ("Linea di Costa", LC) and the Backshore Line ("Linea di Retrospiaggia", LR) as well as the areal elements representing the beaches, derived from photointerpretation of aerial and satellite images. The structure of the Geodatabase allows to perform many kinds of spatial analysis on the recorded geometrical elements, thus allowing to provide a periodic update, at national level on the evolution of the coast line.

The main objective of this work is to highlight the potential of a continuously updated geodatabase over time in monitoring and analyzing the state of the coasts at a local level, presenting one of several case studies carried out by ISPRA, following specific requests received from stakeholders.

More specifically, the temporal variations of the coastline have been analyzed, in terms of advancement, stability and erosion, of the whole Physiographic Units to which the study areas belong, in order to obtain evolutionary trends.

The methodological approach developed and tested over the case studies resulted in a "tool" that the stakeholders may use to query the LC data, thus obtaining information about the coastal dynamics in the area of interest. In this context, guidelines to the access and use of the information contained in the Geodatabase, will be compiled, in order to facilitate the user of the "Linea di Costa" ISPRA.

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Introduction

Directive 2007/2/EC of the European Parliament and Council established the INfrastructure for SPatial InfoRmation in Europe (INSPIRE[1]), with the aim of making georeferenced environmental information homogeneous and shareable within the European Union. In Italy, this directive was implemented with D. Lgs. 32/10, which addressed the Ministry for the Ecological Transition - MiTE as the competent authority for its implementation. In this context, the ministry must send to the European Commission georeferenced environmental data, and ISPRA is the technical coordination structure of the ministry for this function. This includes the role of the CN COS as the official supplier of national coastal monitoring data. The CN COS has been monitoring and characterising the coastline and coastal dynamics at a national level for over 20 years and now those data has been organized in a Geodatabase (GeoDB) containing a wide range of information on the coastal strip, from the backshore to the shoreline. Additional, very important, data which are included are polygon features describing the beaches. The main features composing the GeoDB are the digitized coastlines, relatively to four reference dates: 2020, 2006, 2000 and 1950, as described in the following section.

To date, various stakeholders at the local level (Authorities, Associations, etc.) have addressed ISPRA with explicit requests for technical-scientific advice on the morphological analysis and evolutionary trend of the coast, often related to areas of particular naturalistic-environmental value and/or tourist accommodation activities, where either maritime works or coastal defence works were planned. In the past, ISPRA satisfied such requests with the drafting of dedicated studies and technical reports.

Today, with this work, we present a procedure that may allow any interested stakeholder to perform a first monitoring of the coastal areas of interest in terms of analysis and dynamics, based on the “Linea di Costa” ISPRA. The data are distributed free of charge, updated and downloadable by accessing the Institute's "Portal of the Coast" and the procedure will soon be accessible by the same portal, together with the Guidelines for the use of the "Coastline" Geodatabase. This procedure has already been applied by ISPRA experts to four pilot cases, concerning coastal stretches located in the following locations, three in Calabria region: Zambrone (Vibo Valentia); San Lorenzo (Reggio Calabria); the coastline between Crotone and Le Castella (Crotone), and one in Tuscany: the coastline between Rocchette and Castiglione della Pescaia (Grosseto). In order to provide an example of the application of the procedure, the latter case has been chosen because that study was undertaken in response of a request from a citizens' committee, namely 'Save the Coast', based in Castiglione della Pescaia and engaged to defending the integrity of a landscape of high cultural and environmental value in the aforementioned coast stretch. The committee's request arose after the adoption by the Tuscany regional administration of the "Project for beach nourishment and rebalancing of the Castiglione della Pescaia sandy shoreline"[2]. The committee argued that the solutions announced by the project to counteract the phenomenon of coastal erosion - which envisaged to put in place rigid structures (groins, islands and barriers) made with quarry boulders - may eventually create more damage than benefits, thus negatively affecting the area both from the ecological-environmental-

[1] https://inspire.ec.europa.eu/

[2] Commissioner Ordinances no. 558/2018 -. 29/2018 -. 82/2019.

landscape and from the economic point of view. In particular, the committee addresses the landscape problems potentially introduced by the project, since it would affect the coastal territories and those immediately behind, located in the municipality of Castiglione della Pescaia, which are recognised as Tuscany's landscape assets with constraints set by law[3].

Materials and Methods

The procedure applied by ISPRA to respond to the question was based on the use of the GeoDB "Linea di Costa", which includes the digitisation and characterisation of the "historical" 1950 Coastline and the 2000, 2006, 2020 Coastlines.

The attributes of the geometrical features have been designed so as to allow an easy analysis of the shore characteristics, also in a time frame. The study activity behind the implementation of GeoDB led to the development of criteria on which to base the characterisation of the natural and artificial elements that make up the coastline, the backshore line and beach polygons, through specific attributes supporting the query-based analysis. The GeoDB is structured in such a way as to easily receive future periodic update, allowing spatial-temporal analysis of the data, at national and local level, thus providing the possibility to extract a wide range of information on coastal dynamics and shoreline evolution.

These information layers have different levels of accuracy:

- the 'historical' coastline was derived from the digitisation of 1:25 000 IGM tiles, mostly dating back to the 1950s. Due to this origin, the data obtained has a limited accuracy, due to the lower resolution of the historical data compared to more recent data obtained with more modern techniques.
- the coastlines 2000 and 2006 are the result of the digitisation and characterisation of the orthophotos IT2000 and IT2006 by the Ministry of the Environment (now Ministry for the Ecological Transition - MiTE), with ground resolution values of 1 and 0.5m, respectively. The orthophotos were almost always taken in ideal weather conditions: the few cases of rough sea were indicated and excluded from the spatial calculation. Considering that the tidal variations of the shoreline are observable only in some low-lying stretches of coastline (such as the northern Adriatic), the expected error is generally limited to a few metres, a quantity that was assessed as an acceptable trade-off between the possibility of having homogeneous and complete data with national coverage, and the need to investigate other local and temporal forcing factors.
- the 2020 coastline, which is now represented by the LC2020v1.0 version, is an update based on Google Maps images, with resolution values in the decimetre range and therefore more definite than the previously used flights.

[3] According to the Strategic Territorial Plan (containing the Landscape Plan), issued by Tuscany Regional administration and ratified by the Ministry of Cultural Heritage and Tourism in 2015, this area is of considerable public interest "because it constitutes, with its tree vegetation, a natural framework of uncommon landscape beauty that can be enjoyed from the ancient coastal road and the rocks of the Fortress of the Rocchette". As a strategic goal, the plan recommends "the maintenance of the geomorphological characteristics of the coastal dune system and the relations that it maintains with the shoreline" as well as "the preservation of the level of naturalness and the constituent characteristics of the site", which is included in the list of Sites of Community Importance.

The Historic "Linea di Costa" of 1950 and the "Linea di Costa" 2000, 2006, 2020 are divided into three different features: the Coastline (LC) both natural and artificial, complete with the digitisation and characterisation of the defence and port works; the Backshore Line (LR) both natural and artificial with the relative characterisation of the neighbouring land use; the Emerged Beaches polygons. In particular, both the LC and the LR are made up of three main groups of attributes concerning the digitisation-characterisation of the coastal objects: Natural, Artificial and Fictitious; the latter corresponds to the segments traced conventionally to isolate the artificial objects, in order to give geometrical continuity to the LC and LR. Additional attributes are included to perform the analysis of the evolution of the coastline over time. For further specifications on the elements of the GeoDB, please refer to the link of the Portal of the Coast[4], from which it is possible to download the full elements in geopackage (Gpkg) format and view the related documentation. The portal, which is a section of the ISPRA Cartographic Portal, also contains a web-GIS viewer, where one can view the Coastline information layers directly.

The coastal dynamics calculations for the case study were carried out both at the level of the Physiographic Unit (UF)[5] where the stretch of coastline in question is located and - at a more detailed level - on specific tracts, for the periods 1950-2000, 2000-2006 and 2006-2020. Recent studies conducted in the marine-coastal field, more and more often refer to Physiographic Units (e.g. [1] [2]) as the definition of "areas in which it is meaningful to extend surveys to define sedimentary movements (due to wind, waves, currents and anthropogenic actions) or the effects produced (erosion and deposition phenomena)" [1].

In order to proceed with the description of the method, it should be emphasised that the spatial analysis of coastal dynamics is applied to the low sandy/pebbly stretches of coastline included in a UF, excluding elements such as the rocky shoreline, river mouths and portions of coastline that include man-made works, which are not taken into account, or are replaced with their fictitious stretches. This is put into practice by querying over a specific binary attribute, namely, [Flag_modifica] (values yes/no) which is recorded at the moment of the update of the LC feature of the Geodatabase, so to allow the selection of only those stretches of coastline for which the calculation of changes is to be carried out.

Next, at each update of the LC information layer, the analysis of coastal variations is performed, through the identification of all coastal stretches that are at least 5 m farther than the reference coastline (e.g. for the 2020 update, the reference LC is that of 2006, and so on), applying a corresponding buffer. This analysis is recorded by a specific attribute, namely, [Modifica_ORTO#_#] (where "#" represents the LC year), which reports the observed changes in the coastline through a direct comparison of the current line with the previous one, both of them filtered as described above. The attribute allows the following values: "Advancement", "Erosion", "Stability": for each stretch of the two LC's under comparison, the 5 m buffer is applied, within which the deviation is not considered relevant. In this case, the value 'Stability' is assigned to those stretches; differently, where the corresponding coastlines exceed that distance,

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[4] https://sinacloud.isprambiente.it/portal/apps/sites/#/coste

[5] Physiographic Unit (UF): an extensive stretch of coastline, subtended by one or more hydrographic basins, in which the sediments undergo longshore movements substantially confined within the two extreme limits, constituted by natural morphological elements (e.g. headlands), through which exchanges are to be considered scarcely significant even for events with long return times. It also includes the emerged beach from the shoreline up to the dune apparatus where present, or up to the first continuous rigid structures, and the submerged beach up to the depth of closure or wave influence. [3].

the values 'Erosion' or 'Advancement' are assigned, in case the newer line is set back or advanced with respect to the older one, respectively. Only in the 1950-2000 comparison, the buffer has been set to 25 m, given the lower accuracy of the 'historic' line. As a result, the originally digitised coastline is divided into several further contiguous stretches, characterised by variation from the reference coastline. For all those stretches which were filtered-out, the [Modifica_ORTO#_#] attribute reports the value 'No information'.

With the base data organized in this way, the user - once the desired data have been downloaded - may select the physiographic unit of reference and query the GeoDB, through the LC attribute [Modifica_ORTO#_#], in relation to the "Erosion", "Advancement" or "Stability" value, depending on the information to be obtained.

Results

According to the note received by ISPRA from the 'Save the Coast' committee, the area involved in the region authority project goes from Le Rocchette to the built-up area of Castiglione della Pescaia, covering slightly less than 8 km, and falls within the UF of Castiglione della Pescaia, located between Punta Ala and Talamone (coast length of around 50km). We report, in Table 1, the values concerning the coastal dynamics, for the entire UF of reference, as obtained from the attribute tables of the 2020, 2006 and 2000 LC layers, through the following query (in the example, value "Stability" and LC of year 2006):

[Nome_UF] = ‘Castiglione della Pescaia’ AND [Modifica_Orto2006_2000] = ‘Stabilità’

Table 1 – Coastal change in the years 1950 to 2020 in the UF Castiglione della Pescaia.

UF Castiglione della Pescaia (data in km)				
Reference period	Advance	Stability	Erosion	Not Calculated *
1950-2000	16	10,6	6,2	20
2000-2006	12,6	12,5	4,6	20
2006-2020	11,7	12,8	6,8	21,5
* Uncalculated stretches include those of rocky coastline.				

From the results shown for the whole UF, we observe that stability/advancement seem to prevail with respect to erosion on stretches of natural low coast; even if we neglect the data relative to the 1950-2000 period, due to the limits of precision mentioned above, the smaller extent of the stretches in erosion compared to those in advancement and stability is still evident. Of course, the level of local detail is here lost, as the information is integrated over the wide area set by the UF.

For the stretch of coast affected by the beach nourishment and re-balancing project, a more detailed analysis has therefore been conducted, with data concerning the 2006-2020 time range; in fig.1(A), we show the analysis of the coastal dynamics in the stretch of coastline from Punta Le Rocchette to Riva del Sole: erosion stretches are highlighted in red, stable stretches in yellow and advancing stretches in green. For the beaches immediately over Punta Le Rocchette, a trend of stability and in some cases of advancement can be seen, while in the Roccamare area a trend of erosion can be seen, which reaches its maximum extent in the Riva del Sole area. Going further, in the stretch of coastline from Riva del Sole to Punta Capezzòlo and towards the town of Castiglione della Pescaia, we mainly observe stability, except for a small advancing tract and a few eroding ones close to Punta Capezzòlo (figure 1(B)).

Figure 1 – Analysis of the stretch of coastline from Punta Rocchette to Riva del Sole (A), and from Riva del Sole, through Punta Capezzòlo, to Castiglione della Pescaia (B). Boxes in part (A) of the figure correspond to the extents of figure 2 and 3.

As far as the stretches in evident erosion are concerned, it can be stated that the retreat of the coastline has shown up in the last decade. In figures 2 and 3 we show a zoom-in of the two boxes inserted in Fig. 1(A), around Riva del Sole (West) and Roccamare (East), respectively, where the detail of the LC's at different years is displayed. In the first case, it is possible to observe the evolution of this stretch, about 800 m long: even assuming a lower precision of the historical data from 1950, the first two surveys show an average advance of about 15 m until 2006, after which there is a definite average retreat of about 20 m. In the second coastline stretch (Fig. 3), a completely different evolution is noted over the years; however, in the last decade, a retreat of the coastline can be observed, albeit of little significance.

Figure 2 – Detail of the LC evolution at Riva del Sole.

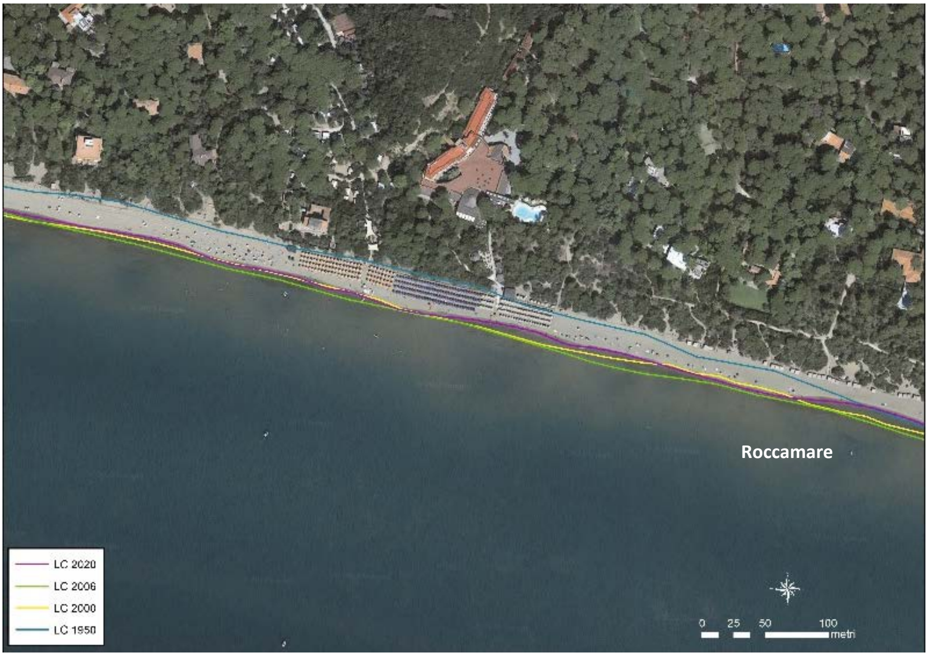

Figure 3 – Evolution in the stretch west of Roccamare.

From 1950 to 2006 there is a marked advance that in some areas reaches 30 m, but from 2006 to 2020 there is a reversal of the trend that leads to a non-uniform, but constant erosion. From the LR information layer it was possible to obtain the length of the stretches with different land use, located immediately behind the beach. A state of general naturalness of the territory emerges, underlined by the presence of coastal dunes, as summarized in Table 2:

Table 2 – Summary of data deduced from the LR.

Characterization of the Backshore Line (data in metres)						
Year	Vegetation/ bare soil	Urban scattered	Road infrastructure	Bathing facilities	Not calculated*	Total
2000	4788	2064	70	570	229	7721
2006	4784	2062	48	567	310	7771
2020	4631	1928	62	900	226	7747
* rocky coastline (e.g. Punta Capezzolo) or river mouths.						

Moreover, the data in the table show a general condition that has remained fairly constant over the decades, with one exception: in the period between 2006 and 2020, the main changes in the backshore environment concerned the transformation of natural areas or scattered urbanisation into areas occupied by bathing facilities, which increased in that period alone by about 60 %. It should be noticed that, out of the 900 m occupied by bathing facilities, about half correspond to the sites highlighted above where coastal erosion is most pronounced.

A further informative layer of the ISPRA coastal coverage concerns the beach polygons. By the standard GIS tools, we calculated the total surface area of the beaches in the study area, displayed in fig. 4. The shoreline under examination consists of a single stretch of low sandy coastline, within which the beaches are interrupted by two elements: the armed mouths of a canal and the small promontory of Punta Capezzolo. For a better characterization of the stretch under analysis, we have defined "Beach1" the shoreline between Le Rocchette and the mouth of the waterbody, "Beach2" the shoreline between the mouth and Punta Capezzòlo, "Beach3" the shoreline between Punta Capezzàlo and the canal port of Castiglione. The results are shown in Table 3, where we can notice a decrease of the 2020 data when compared to 2006, but still an increase if compared to the data from year 2000. In particular, "Beach2", which is in retreat, is the one that includes the areas most occupied by bathing facilities (Fig. 5).

Table 3 – Surface area of beaches in the analysis area.

Surface of Beaches (m²)				
Year	Beach 1	Beach 2	Beach 3	TOTAL SURFACE AREA
2000	64905	69463	31882	166251
2006	63281	82354	37587	183222
2019	63798	68183	40266	172247

Figure 4 – Subdivision of the beaches under examination.

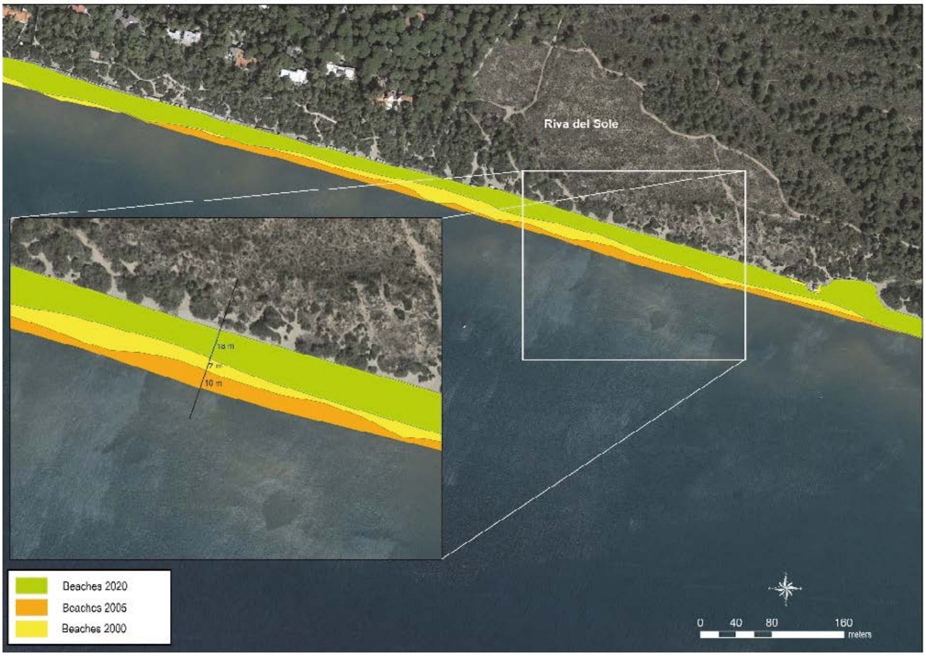

Figure 5 – "Beach2": detail at the largest recorded setback.

Discussion

The procedure described and the results reported above highlight how the "Linea di Costa" ISPRA allows the application of a simple method that can quickly give an idea not only of the current state of the coastline, but also of its evolutionary trend and can thus be used as starting information for further in-depth studies in specific areas of interest. In the pilot project that has been presented, as already mentioned, the LC2020v1.0 version that has just been published on the Portal of the Coast is being used for the year 2020, while for the analysis of the beaches the update has only been carried out for the coastal sections of the study area, as the beach information layers have not yet been updated at national level. In general, the update of the "Linea di Costa " Ispra 2020 is proceeding by successive versions, as new criteria for the photo-interpretation of the images have been defined, which have reached a higher level of quality with respect to 2006. First of all, this has entailed the modification of many elements of the Geodatabase for both digitisation and characterisation: at present, more than 10,000 elements relating to the Coastline and Backshore Line layers alone have been corrected in order to comply with the new standard. In addition, it was necessary to start the spatial analysis based on the possible co-registration issues between the LC06 and LC20 image sources and its correction, which is still ongoing and will lead to the publication of the LC2020v2 version by the end of the year.

Conclusion

In this paper we have presented a pilot case chosen to test the simple processing method based on the use of the "Linea di Costa" ISPRA and how it is possible to apply it to different scalesand different purposes. Indeed, we went from analysing coastal dynamics from the Physiographic Unit level (i.e. over approximately 50 km of coastline) to a much more detailed one (over approximately 100 m of coastline), demonstrating the excellent possibilities of using this tool to support stakeholders who need to focus on specific stretches of coastline of interest, both for management and study purposes. Clearly, this tool needs periodic updates and revisions of the standards of its structure in order to be increasingly effective and easy to use. For this reason, the ISPRA team in charge of the realisation of the information layers needs continuous feedback from the stakeholders who want to use both the procedure specifically and the Coastline data in general. This will allow the various versions of the information layers, and the documents associated with them, to be published on the Ispra Portal of the Coast over time in an increasingly effective and user-friendly manner. In the near future (by the end of the year), the LC2020.v2 version is expected to be published with the correction of image coregistration errors and some further modifications to the GeoDB that will make the procedure presented for the analysis of coastal dynamics even more user-friendly. Subsequently, the Guidelines for the use of the "Linea di Costa" ISPRA will be published.

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EVOLUTION OF THE SURFACE ROUGHNESS OF A COARSE SAND AFTER A BEACH NOURISHMENT

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Abstract – Beach nourishment with material from quarries is an increasingly common practice. These materials are usually coarse sands or fine gravels, and the particles show a very angular and rough surface. In this work, research on the evolution of the surface roughness of coarse sand particles that were dumped in January 2020 at Los Locos beach in Torrevieja (Alicante, Spain) is conducted. This sample came from a quarry and presented a high angularity and roughness on the surface of its particles. Samples were taken monthly for a year and a half (from January 2020 to June 2021), always at the same sampling point. Due to restrictions caused by the Covid-19 pandemic, samples could not be collected for 6 months. Once the samples were collected they were taken to the laboratory where the grain-size analysis of the complete sample was performed, and 108 particles of each of the most significant sieves (1.60 mm, 1.25 mm and 1.00 mm) of the coarse sand (from a quarry) were photographed. The contras, angular second moment (also known as energy), inverse difference moment, correlation and entropy were obtained (for each particle) from the photographs. Also, the swell that occurred throughout the study period was obtained from the SIMAR point 2077096 (the closest point to the study area). The significant wave height, period and direction of the waves affecting the sampling point were analyzed. The results show a decreasing trend in all the parameters studied (median sediment size, contrast, entropy, etc.). Some increases are observed due to the swell that moves the sediments from the backshore to the swash zone. These variations are first observed in the median size but are not seen until the following month in the textural parameters (contrast and entropy). When relating the parameters obtained from the photographs to the particles (contrast, entropy) with the surface texture of the particles, it is observed that they cannot be analyzed separately but must all be considered together. Thus the decrease in contrast and entropy shows a decrease in the superficial roughness of the particles, but the greater the difference between these two parameters, the greater the smoothness of the surface. After a year and a half of dumping the quarry material on the beach, a high degree of decrease in the roughness of the particles is observed; however, to reach the degree of polishing that the particles of a natural beach have, a longer period is necessary.

Introduction

When the coastline undergoes a continuous process of erosion, beach nourishment is a regular process [6]. To mitigate erosion processes, it is common to use artificial structures (breakwaters, groins, etc.) and to dump natural (dredged) or artificial (quarried) sand along the beach [7]. The incorporation of new sediments (different from the original ones) to

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beaches requires a thorough understanding of the processes to obtain the required response of the morphodynamic systems [1]. Since natural materials, mainly fine sands, are scarce, nourishment is currently conducted with coarse sands from quarries. Due to these, it is important to analyze the development of borrowed sand over time [10].

The main studies conducted on borrow sand focus on the evolution of the size and sorting of the dumped sediment [4, 5]. Most of these studies conclude that approximately one year after nourishment, both the size and sorting of the sediment is usually similar to the original material [10]. This is the case when the dumped material is relatively similar (median sediment size equal to or slightly larger) to the original. However, what happens when the median sediment size is significantly larger than the original sand? Does a quarried sand behave in the same way?

This work studies the evolution of coarse sand from a quarry dumped on an originally sandy beach. The evolution of the median size of the sediment, the surface roughness of the particles (since quarry material is usually quite rough and angular) and finally the influence of waves on this evolution will be studied.

Materials and Methods

Study area

This work is based on samples collected at Los Locos beach in Torrevieja, Alicante, in southeastern Spain (Figure 1). At the study area, the temperate climate is Mediterranean, with a semi-warm subtropical sea temperature regime (mean value of 20.5 °C). The local wave regime is strongly dependent on the seasonal nature of the area. It is a beach of 470 m length protected by the NE swells by the cape "Punta del Salaret", and in the south, it is supported by an artificial breakwater, recording 0.64 m mean significant height and 3.7 s mean period. The area is a micromareal zone, the maximum value reaches 75 cm when the astronomical tide (30 cm) is affected by meteorological factors. A small rocky step causes undertow currents that cause a loss of sand that cannot be recovered due to the characteristics of the bathymetry. This originally sandy beach (median sediment size of 0.193 mm and 22 m average width) was nourished (35 m average width) in January 2020 with material from a quarry with a median sediment size of 1.19 mm (Figure 2).

Maritime climate

Puertos del Estado (http://www.puertos.es) provided the data from SIMAR point 2077096 (-0.583 E; 38.000 N; Figure 1c), which was used to obtain the swell. The SIMAR series is the most complete database for the Mediterranean with data since 1958.

The wave height, period and direction of the waves produced during the study period were analysed. The swell data refer only to the swells that impact directly on the study point, from N111ºE to N204ºE (Figure 1d). The rest of the swells are considered calm at this point of the beach.

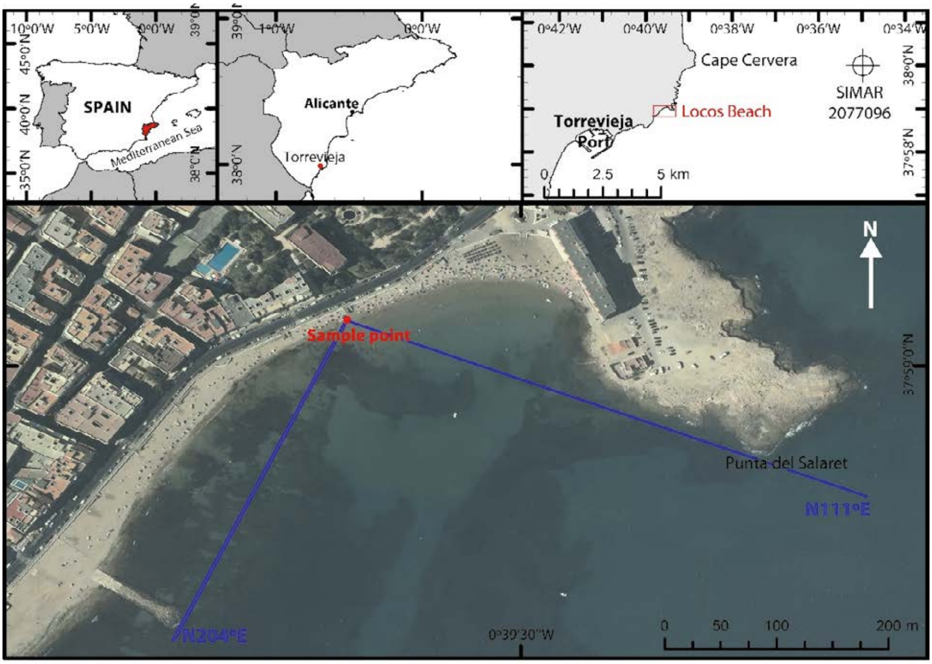

Figure 1 – a) Study area located in Spain, b) in the province of Alicante and (c) in Torrevieja town, with the location of the SIMAR node used for wave data. d) Location of sample point at Los Locos beach.

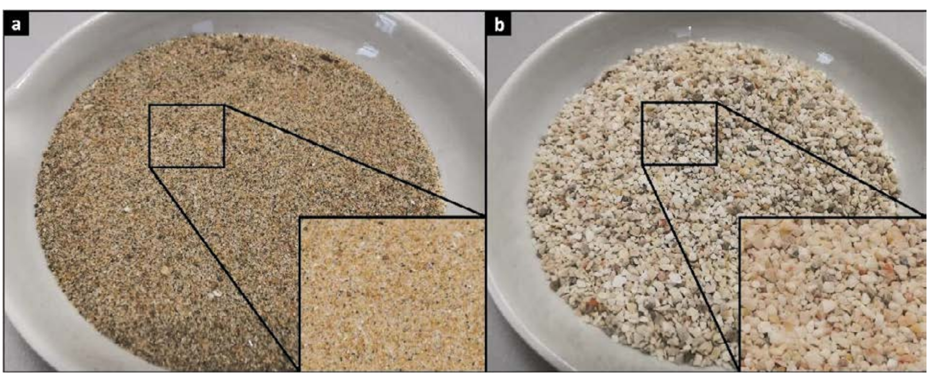

Figure 2 – a) Sample of the original beach (median sediment size of 0.193 mm). b) Sample of the material of the nourished beach (median sediment size of 1.19 mm).

Sediment analysis

Sampling was performed always at the same point (705536.22; 4206585.76;30) of the swash zone (Figure 1d) from January 2020 to June 2021 between the 15th and 20th of each month. Due to the Covid-19 pandemic and the mobility restrictions it caused, samples could not be collected between March and August 2020.

Once the samples were collected, they were taken to the laboratory where they were washed and grain-size analysis was performed. Then from each sample and sieve (1.60 mm, 1.25 mm and 1.00 mm as they retained the highest percentage of the sample), 108 particles were photographed with a microscope with a wide resolution and a magnification of at least 50x.

The subsequent image processing (texture measures) and statistical treatment were performed using ImageJ. In ImageJ, this is accomplished using Julio Cabrera's plugin GLCM (grey level cooccurrence matrix) Texture Analyzer [3]. The distance – offset – between two pixels was established on 1 (size of the step) and their spatial relationship was calculated for direction of the step of 0, 90, 180 and 270 degree angle). The outputs were: contrast, angular second moment (also known as energy), inverse difference moment, correlation and entropy were obtained. Finally, the average for 0, 90, 180 and 270 was conducted.

Results

First, the results concerning the evolution of the median sediment size are shown (Figure 3). The median sediment size (D_{50}) of quarry material originally (18/01/2020 describes filling sediment parameters during the nourishment) had a value of 1.19 mm, but due to waves it is mixed with the original beach material (D_{50} = 0.193 mm) and in April 2021 the D_{50} was 0.344 mm with only 43 % of the sample being quarry material (> 0.4 mm). The sediment size at the sampling point and the percentage of quarry material varies throughout the study period, the increases in both parameters are mainly due to waves (Figure 4). After events with wave heights greater than 1.5 m, these parameters increase, because the swell picks up material from the backshore and deposits it on the shoreline.

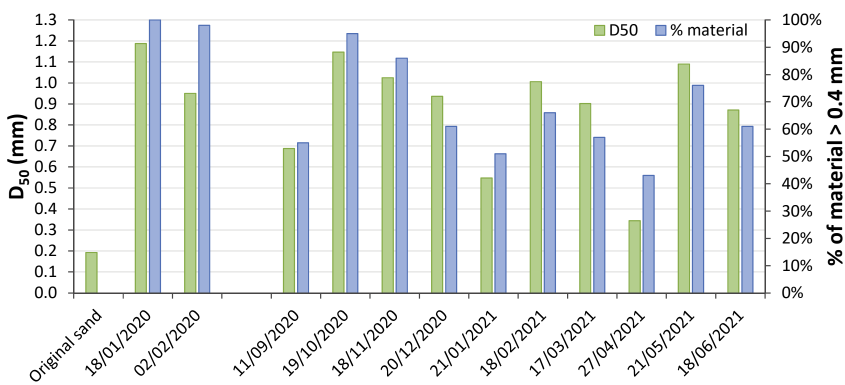

Figure 3 – Evolution of the median sediment size (D_{50}) and the percentage of material larger than 0.4 mm.

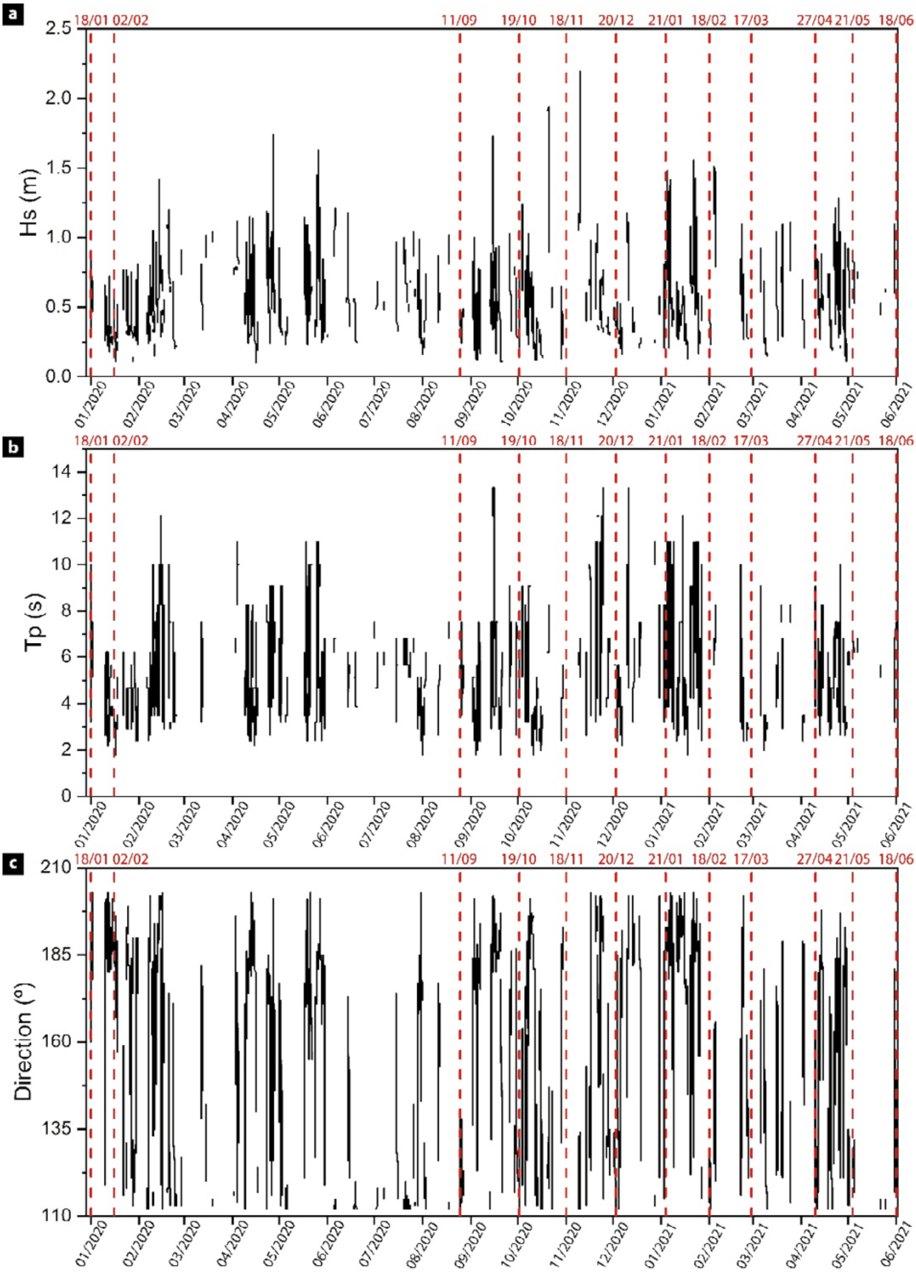

Figure 4 – Wave data that impact the study point during the monitoring time and sampling dates (marked vertically). a) Significant wave height (in meters). b) Wave period (in seconds). c) Wave direction (in degrees, 0 is north, 90 is east, 180 is south, and 270 is west).

Secondly, the results of the evolution of contrast (C), entropy (E), and the difference between contrast and entropy are shown (Figure 5 and Figure 6). Of the five parameters studied on the particle photographs, only these parameters are shown since they show the greatest relationship with particle surface roughness. As with D_{50}, it is observed that all parameters tend to decrease during the study period. However, when D_{50} increases this is not represented in the textural parameters until the following month, for example, the increase in D_{50} that occurs in February 2021 is not represented in the entropy until March 2021. This could be because the increase in median size in February was due to a loss of the finer material and did not affect the coarse material of the nourishment. Whereas the increase in entropy the following month may be due to a storm that moved material from the foreshore to the swash zone a few weeks before the sample was collected.

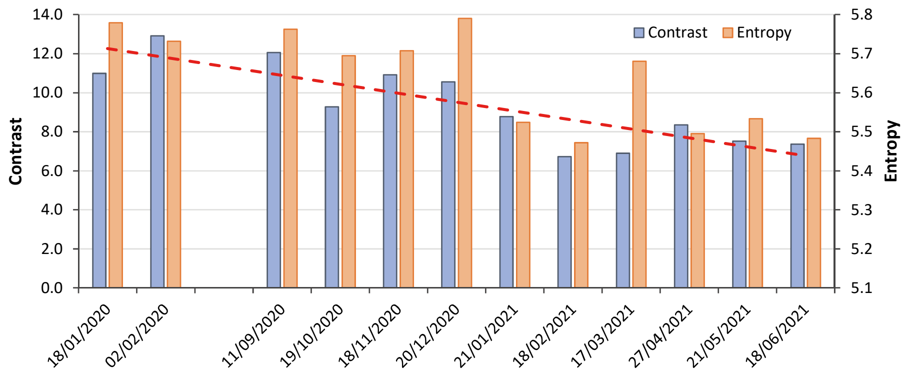

Figure 5 – Evolution of contrast and entropy of analyzed particles from beach nourishment.

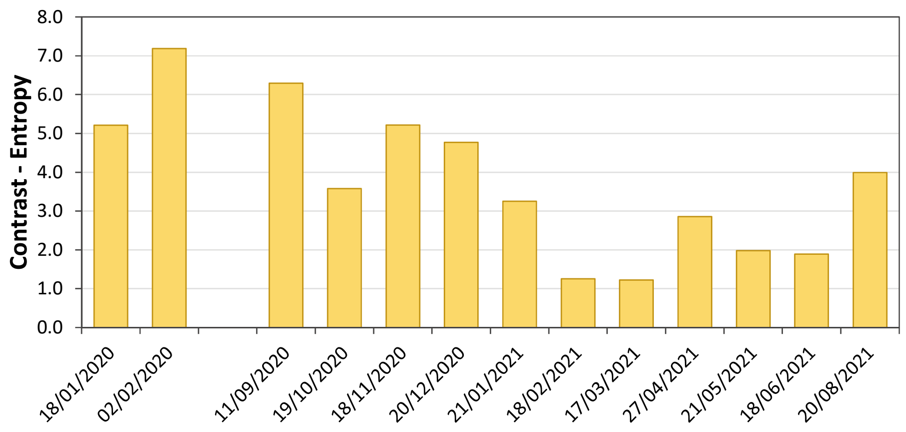

Figure 6 – Evolution of the difference between contrast and entropy (contrast minus entropy) since beach nourishment.

Nevertheless, although the textural parameters (contrast and entropy) show a decrease over time, when these values are related to the image of the particles (Figure 7) it is observed that to determine the evolution of the surface roughness of the particles, the textural parameters cannot be considered individually, but must all be considered together. Thus it is observed that the lower the contrast and entropy the less rough the surface is, but the higher the ratio between contrast and entropy (C-E) the higher the smoothness of the particle.

Finally, it is observed that after a year and a half of wave action on the particles they reach a level of surface roughness similar to those of a natural beach. Although a longer period is still necessary to reach the level of polishing that natural particles have (Figure 7b), the quarry particles reach a high degree of rounding and surface smoothness (Figure 7e,f) concerning their original state (dumping time, Figure 7a).

Figure 7 – a) Particles dumped on the beach in January 2020. b) Particles of a natural beach (Playa del Triador, Castellón, Spain). c-f) Particles with the maximum and minimum values of contrast (C), entropy (E) and contrast-entropy (C-E).

Discussion

According to different authors, approximately one year after sandy beach nourishment with borrow material, the median sediment size is very similar to the size of the original beach sediment [4, 5, 10]. However, in this case, where the size of the dumped material is 6.17 times larger than the original beach sediment this does not occur (Figure 3). The closest size to the original sand size occurs in the April 2021 sample (16 months after the dumping) with a value of 0.344 mm (1.8 times larger than the original) and 43% of new material (> 0.4 mm). However, due to the swell, which incorporates new material from the backshore, this size increases considerably in the following months. Therefore, to reach a size similar to that of the original beach, much more time must pass, so that the quarry material decreases its volume on the beach and wears out [8].

Regarding the surface roughness of the particles, few studies have been conducted [2, 9]. One of them concerns the abrasion rate on pebbles on a beach in Italy, in which the volume loss was measured and reached 61% after 13 months of dumping the material. [2]. And although in this study only the degree of rounding of the particles was measured (by weight loss and visually), whose size was much larger than those of our research (> 50 mm), the period to reach a good surface roughness agrees with that demonstrated in this work (18 months).

Conclusion

A significant increase in surface roughness is observed over time. It is observed that in a year and a half the particles found in the swash zone reach a significant surface smoothness. It should be taken into account that there is an important period of absence of samples due to Covid, during which important storms occurred, so perhaps the fact that during the first year no significant variability in surface roughness is observed may be due to the movement of the sediment by the waves. However, it can be assured that in approximately 1.5 years the quarry particles are smoothed reaching values similar to those that can be found in a natural beach, although more time is required to achieve the same level of surface polish.

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A METHOD BASED ON BEACH PROFILE ANALYSIS FOR SHORELINE IDENTIFICATION

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Abstract – Coastal erosion coupled with human-induced pressure has severely affected the coastal areas of the Mediterranean region in the past and continues to do so with increasing intensity today. In this context, the Pisa coastal plain shows a long history of erosion, which started at the beginning of the nineteenth century. The work aims to provide a method and a software to extract the shoreline position. We apply the Structure from Motion (SfM) techniques to reconstruct a high-resolution Digital Elevation Model using a drone for image acquisition. The algorithm is based on the variation of the topographic beach profile caused by the transition from water to sand. The SfM technique is not efficient when applied to reflecting surfaces like sea water resulting in a very irregular profile over the sea. Taking advantage of this fact, the algorithm searches for the point in the space where a beach profile changes from irregular to regular, causing a transition from water to land. The algorithm is promoted by the release of a QGIS v3.x plugin uploaded on the official repository of the software, which allows the easy application and extraction of other shorelines.

Introduction

In the last years coastal erosion has become one of the main environmental threats worldwide [1]–[4]. About 28 000 km^2 of the global coastline was eroded between 1984 and 2015 and about twofold as many as those formed by accumulation processes [5]. According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) [6] the predicted future scenario for coastal zones will deteriorate as a result of the gradual rise in sea level and of the possible surge of extreme events due to current global warming [6]. Specifically, the Mediterranean region is severely affected by the impact of extreme climatic events (e.g., storm surges) joined with human activities (e.g., poorly planned buildings on the coast, dam construction, land use changes inland), resulting in rising vulnerability of the coastal areas [7]. The number of coexisting socio-economic activities (urbanization, tourism, natural protected areas) makes it imperative to understand and further

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monitor coastal dynamics [8]–[11]. Land cover change is considered one of the most important variables of global change affecting the littoral systems, particularly for the effects on river sediment supply [12]–[14]. A reduction in solid load documented for several river-systems of the Mediterranean basin (e.g., Nile, Ebro, Rhône), in particular after the 1970s [8], [13], [15], [16], has been considered one of the main causes of coastal erosion, together with subsidence and sea level rise [9], [17]–[19].

Despite the importance of a correct valuation of solid load, for many Mediterranean rivers solid load measurements are insufficient, probably because they are cost- and time-consuming. For these reasons, the input of solid load in countering coast erosion is largely approximative. Even less data is available about the dynamics of long-shore and off-shore dispersion of sediments carried by rivers.

Currently, the more advanced techniques for littoral monitoring start with the sample of the shoreline, which is the dynamic interface between water and land [20] and, according to Boak and Turner [21], there are two main groups of shoreline indicators: those based on the detection or identification of visible features (e.g., instantaneous water lines, vegetation lines), and those based on the intersection of the coastal profile with a specific elevation datum like the 0m Above Mean Sea Level (AMSL). Different procedures exist for coastal monitoring, which are based on direct and remote acquisition systems. Shoreline acquisitions is normally made by the use of DGPS technique of post-processing or of real-time methodology [22], [23]. The main disadvantage of this technique lies in the time required to cover large coastline stretches. Remote sensing can be distinguished by observation of satellite images [24]–[28] , Unmanned Aerial Vehicles (UAV) [29]–[32], video monitoring [33], [34], historic aerial photos, and cartography [35], [36] .

Several methods capable of discriminating between sea and land have been proposed to extract shorelines from images. Plant and Holman [37] used a method initially developed for grey-scale cameras, called Shoreline Intensity Maximum (SLIM). Recently, with the adoption of colour cameras, spectral information has also been exploited to identify the shoreline, using the water property to absorb the red signal and the sand property to absorb the green and blue signals [38].

The work aims to propose a new method to recognize the shoreline position based on the beach profile using high resolution Digital Elevation Model (DEM) derived by Structure from Motion (SfM) technique. The algorithm is applicable with the use of a QGIS v 3.x plugin which is composed by a user-friendly interface.

Study area

To investigate the role of different methods in the reconstruction of shorelines, we chose to acquire UAV images and Differential GPS (DGPS) in the littoral area located in the hydrographic right of the Arno River. The stretch of coast studied is about 4.5 km and is located on the right bank of the Arno River.

The Pisa coastal plain has been gradually shaped by the Arno River since the Late Holocene [39]–[42] (Figure 1). In the littoral area located in the hydrographic left of the Arno River the littoral drift is mainly oriented towards the south, with the exception of the area between Calambrone and the Scolmatore Channel, where the littoral drift is oriented towards the north. Conversely, in the littoral sector located in the hydrographic right, the littoral drift is oriented towards the north [11], [40] (Figure 1).

Several previous studies showed that this area is currently affected by erosion. Following a period of progradation due to the phases of Arno delta building beginning at about 3000 ka BP [43]–[47], different parts of the Pisa plain experienced marked coastal erosion, which started at the end of the 19th century and amplified after the construction of the river mouth jetty, especially on the hydrographic right [36], [48]–[51].

The area northward of the Arno River Mouth is particularly affected by erosion, but overall value of erosion remained low until the 1950s when there was a rapid documented increase of the process [51]. Erosion was particularly severe at the end of the 1980s, maybe caused by the effects of dredging/damming [52], [53]. The following period was characterized by an increase in erosion around 2010, while a reduction in the erosion rate has been documented in the last eight years (since 2012). The period most affected by erosion was around the 1980s, while the areas that most experienced this phenomenon are the area northwards of the Morto Nuovo River [49], [51], [54].

The role of solid load in countering the coastal erosion of this territory is recognised by the qualitative anticorrelation between fluvial discharge and erosion rate [51]. In particular, the lower fluvial discharge values occurred in the years 1954, 1978, 2012 corresponding to a peak of erosion, while in the years 1928–1944, 1954–1975, and after 2012 the erosion rate tends to decrease, and the river discharge increased. In the period 1960–2012 the river discharge was significantly low. This was particularly true when the Arno River can transport a significant amount of sediments and this is verified with a discharge >700 m^3/s (referred to the station of San Giovanni alla Vena) [51] .

Figure 1 – Location map of the study area.

Materials and Methods

We have acquired 224 points with a R8s Trimble real-time kinematic (RTK) DGPS. The 224 points were divided into pairs, so that the shoreline was sampled by taking a first point in the water and second one on the land where the waves ended [56]. Positioning of the shoreline depends on the elevation of the two investigated DGPS points. In the case that one among the points has a negative elevation and the other one has a positive value; the algorithm makes a linear interpolation between the two acquired points. It selects the point with 0 m of elevation among the interpolate points and it derives the x and y coordinates of the shoreline from this point. In case both points have positive (or negative) elevations, the only difference is that the algorithm selects along the topography profile the point (latitude and longitude) with the coordinate z equal to the mean altimetry of two DGPS points investigated from this point. With this algorithm, we assume AMSL basing on the elevation of the DGPS points. When the 0 m AMSL is included in the topography profile, we consider this altimetry as the most representative of the margin between water and land basing on the definition provided by [21]. When the 0m AMSL is not included in the topography profile, we must choose another AMSL altimetry. In such case, we believe that the best representative altimetry is the mean elevation between the two extremes of the profile (one towards land and the other towards sea).

After the identification of all the 112 points of shoreline, we draw the polyline representing the margin between water and land.

SfM photogrammetry is a technique that allows to reconstruct 3D models starting from a collection of photos of the same elements obtained from different viewpoints [57]–[59]. The frames are sampled by means of an Unmanned Aerial Vehicle (UAV) equipped with a consumer-grade camera.

In particular, we used DJI Phantom 4 Pro V2, which is a quadcopter with a flight autonomy of 30 minutes even if, for safety reasons, we did not exceed 20 minutes of flight. The FC6310S camera was able to take photos of 5472 × 3648 pixels (in a 3:2 aspect ratio setting).

All acquisitions were obtained with a 24 mm focal length and camera oriented in orthogonal mode with respect to the ground.

The flights were in automatic mode and reached a maximum distance of 500 m from the pilot (as required by the Italian regulatory system), making it possible to perform 1 km sections for each flight.

All flight plans were created using the Desktop UgCS (Universal Ground Control Station) software and were performed using the UgCS application for Android OS. The "Area scan" function allowed us to set the parameters so as to obtain a flight height of 50 m above ground level (AGL) and an overlap of the acquired photos equal to 75 % for each side. By using this flight height, we were able to scan a 75 × 50-meter area for each photo. Image acquisition was directly controlled by the flight execution software, UgCS for DJI (Android version); the shooting interval was set to 2 seconds, the manual focus to infinity, while disabling the autoexposure, and storage format was JPG. Four parallel transects were performed for each flight, to obtain a mapping of 1000 × 70 m with the yaw of the drone constantly set at the same angle with respect to the Earth's North.

The UAV and DPGS samplings were carried out simultaneously; moreover, the area is subject to a small tidal excursion [60]. For this reason, we can consider that the two samples represent the same situation of the sea and that the results are not affected by a significant change in weather and sea conditions. The results derived by the two methods are comparable to each other.

Georeferencing of the 3D model obtained through SfM requires the identification of the ground control points (GCPs) of already known coordinates. We processed the photos and GCPs by using Metashape Professional software (Agisoft LLC, St. Petersburg, Russia), which implements SfM and multi-view stereo matching algorithms.

GCPs are typically used as control points to optimize camera position and orientation data, making it possible to obtain better model reference results.

To extract the shoreline from DEMs and orthomosaics, we identified a new semi-automatic method based on the beach profile. The method is based on the principle that SfM performs poorly on uniform or reflecting surfaces like the sea [61]. The beach profiles obtained with SfM are more irregular and unrealistic on sea, becoming regular and realistic when the points are referred to the land. The algorithm is based on the use of transects along the beach. The orientation of the transects must have from the water to the land. The profile of the transect, which includes the surface of the sea, will be characterized by a low coefficient of determination (R^2), moving from the sea towards the beach and gradually discarding part of the transect profile, which will be regularized until it includes only and exclusively the beach profile.

When the profile has an R^2 greater than or equal to a determined threshold, the algorithm stops and associates the point of coordinates closest to the sea (for example the shoreline point; Figure 2).

We developed a QGIS v3.x plugin in Python 3 to make the algorithm available to the scientific community working in the field. The plugin can be downloaded with the official repository of QGIS. After installation of the plugin a new icon is visible on the QGIS toolbar: when clicked, an interface is opened (Figure 3). The interface is composed by three tabs: "Run algorithm", "Information" and "Log". The first tab allows to set the input used by the algorithm:

- DEM raster requires the topography of the beach;
- Transects layer requires the vector layer of the transects used to calculate the shoreline. The transepts must be designed with a sea-land orientation, and they must have an order field;
- Order field is the field of a transect layer that can be both numeric and alphabetic. It is used to process the transects with a specific order by which the shoreline will then be constructed;
- Delta X is the dimension of the step used to analyze the beach profile;
- R2 limit is the limit of R2 above which you pass from a sea profile to an exclusively beach profile;
- Output Shoreline allows to save the Shapefile result.

By clicking on the "OK" push button, the plugin executes the algorithm. Every error and information on execution of the algorithm are recorded in the "Log" tab.

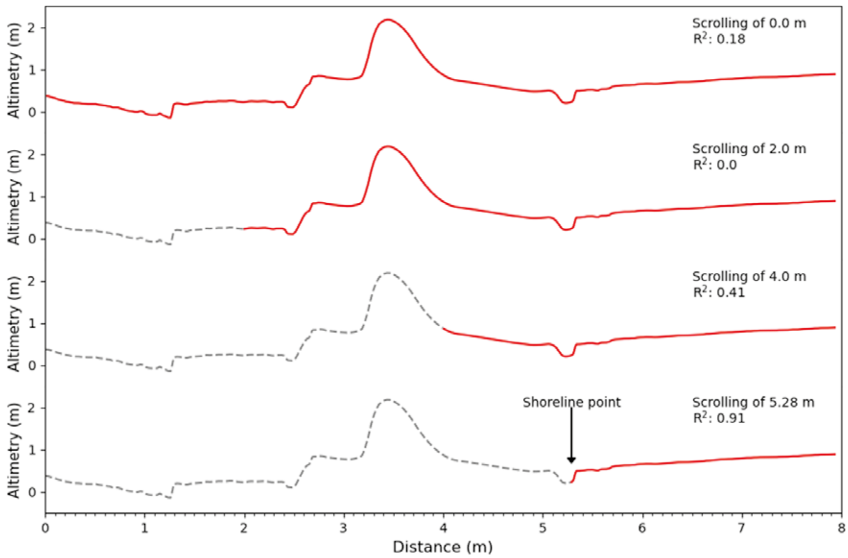

Figure 2 – Description of shoreline identification algorithm. Four illustrative steps of the algorithm to find the shoreline point (from the top to the bottom). R^2 is calculated only on the part of the profile coloured in red. The grey dashed line represents the progressive part of the profile discarded by the algorithm (modified by [62]).

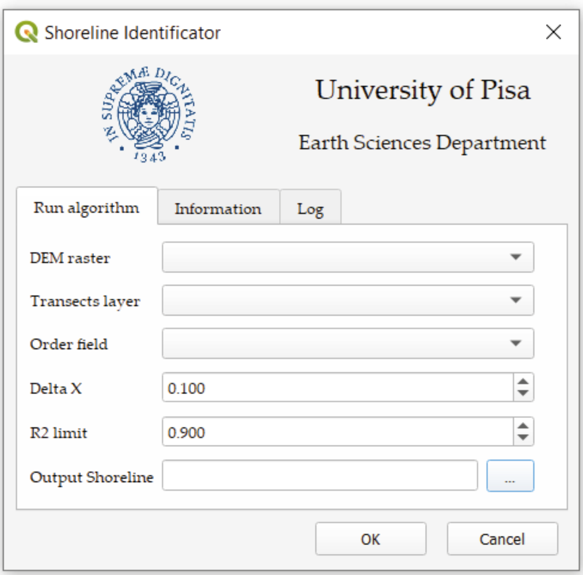

Figure 3 – "Shoreline Identifier" Plugin interface.

Results

The investigated shoreline of about 4.2 km was divided into four flights of UAV. The DEMs have a mean resolution of 2.22 cm/pixel and the entire covered area is 0.44 km^2.

Figure 4 shows three frames of the shorelines obtained with DGPS points and UAV image processing. The two shorelines are different, but it is difficult to claim whether one is better than the other. The DGPS-derived shoreline in Figure 4a approximates the real shoreline better than the UAV-derived shoreline. However, in Figure 4c, the behaviour is opposite, and in Figure 4b, the two shorelines approximate the real shoreline better alternating.

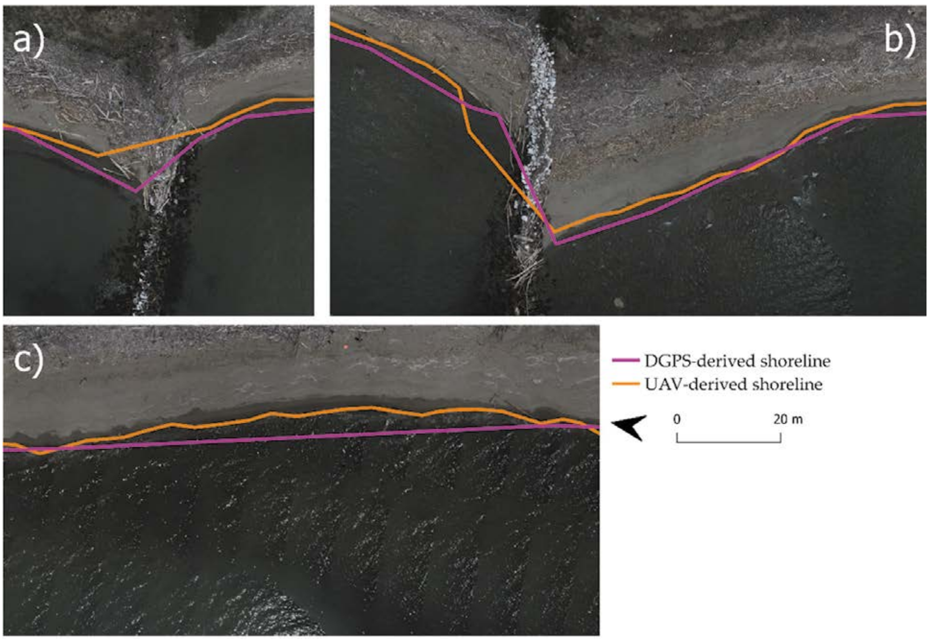

Figure 4 – Shorelines derived from DGPS points (pink line) and from UAV image processing (orange line). a) The DGPS-derived shoreline (pink line) approximates the real shoreline better than the UAV-derived shoreline (orange line); b) the two shorelines approximate the real shoreline better alternating; c) the UAV-derived shoreline (orange line) approximates the real shoreline better than the DGPS-derived shoreline (pink line) (modified by [62]).

Discussion

We evaluated shoreline extracted by the method proposed in this work comparing with a shoreline derived by DGPS. Figure 4 displays the distances between the relative points of shoreline derived from DGPS and those derived from UAV images. We needed about 8 transects every 100 meters to obtain a minimal error between the two types of shorelines

(Figure 5). The minimal mean error with more than 12 transects/100 m is 1.58 m. The number of transects necessary to obtain a precise shoreline is also influenced by the coastline profile; for example, a more irregular coastline needs a greater number of transects. The advantage of this method is that we can decide the number and position of transects after the survey during the elaboration and this is not possible when we sample the shoreline with a DGPS survey.

Figure 6 shows the differences in terms of areas by comparing the DGPS-derived with the UAV-derived shoreline. The blue areas represent the total area when the DGPS-derived shoreline is less seaward than the other shoreline. The orange areas show the total area, when the DGPS-derived shoreline is more seaward than the other shoreline. The shoreline derived from the UAV images is closer to the beach than the shoreline derived from the DGPS points (Figure 6). The UAV-derived shorelines overestimate the mainland compared to the DGPS-derived shorelines. In some cases, equal to about 30 % of the total investigated area, the UAV-derived shorelines underestimate the mainland compared to the shoreline derived from DGPS (Figure 6).

The Root Mean Square Error (RMSE) between the DGPS shoreline and the UAV-derived shoreline using 12.8 transects/100 m is 1.69 m, much lower than the methods involving the analysis of satellite images, whose order fluctuates between 6 and 12 m depending on the techniques and images used [63]–[65].

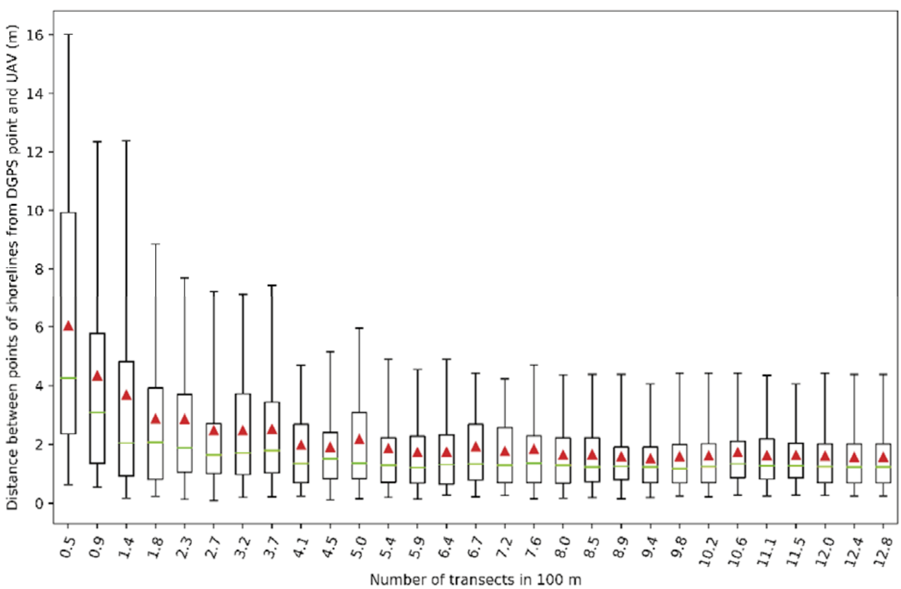

Figure 5 – Analysis of errors between shoreline points derived from DGPS points and those derived from DEM by Structure from Motion (SfM) processing. The box represents the 25th and 95th percentiles, the green line the median, the red triangle the mean, and the whiskers the 5th and 95th percentiles (modified by [62]).

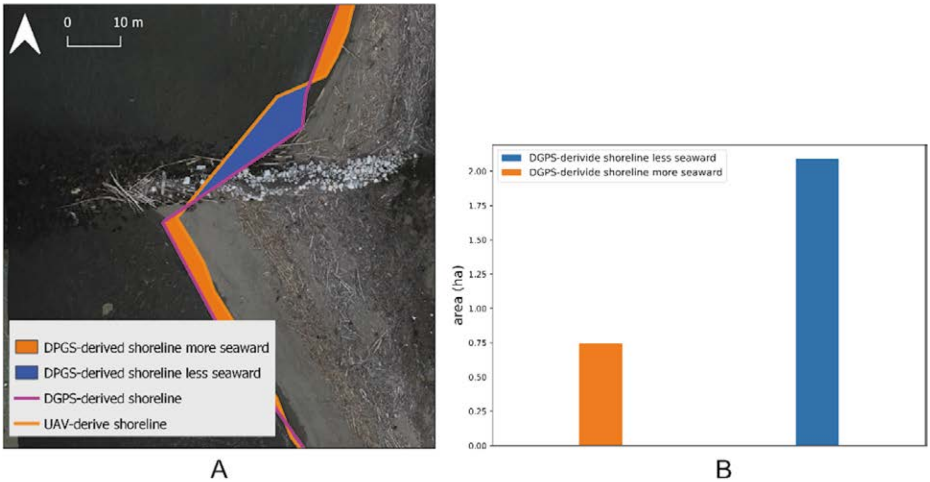

Figure 6 – Analysis of the differences between DGPS-derived shorelines and UAV-derived shorelines. (a) Example of the differences in the areas between DGPS-derived shorelines and UAV-derived shorelines; (b) bar plot of the different areas of the beach comparing the two types of shorelines. The orange and the blue rectangles show the total area when the DGPS-derived shoreline is more or less seaward compared to the other shoreline obtained from UAV images (modified by [62]).

Conclusions

The method proposed in this study is a valid alternative to the classical methods of shoreline identification based on topography. This method makes it possible to obtain shorelines using the topography obtained from UAV images; it is a novelty compared to other uses of DEMs obtained from UAV images present in the literature.

This approach is innovative, and it could also be a valid alternative to the methods based on manual identification or on remote-sensing image colours. In this respect, it is very hard to compare differently-derived shorelines when the errors are about 1–2 m. When we compare the use of satellite images and of DGPS, identification of the error between the two methods is simpler than when we compare the DGPS-derived shoreline with UAV-derived images. This happens because the error of DGPS points to extract the shoreline is negligible compared to the errors that occur when using satellite images with a pixel size of about 10 meters. However, when we compare DGPS-derived shorelines with UAV-derived images, all the errors are of the same order of magnitude. This work has shown that in some cases the DGPS-derived shoreline is better than the UAV-derived shoreline, but in the same number of cases, the roles are reversed. In summary, this new method has two main advantages regarding the use of DGPS points: I) the first advantage is the amount of time it takes to obtain a stretch of coast; ii) the second advantage is that the position of the transects used to reconstruct the shoreline can be decided after sampling and not during acquisition of the DGPS points.

The main disadvantage of this method compared with the DGPS technique is that the second one allows, for time unit, to sample a longer stretch of beach, but, as discussed, with fewer points and consequently with a lower resolution. The use of DGPS allows for a massive sample of the shoreline position.

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USE OF RPAS TO MONITOR COASTAL DUNE SYSTEMS AND BEACH EROSION IN GUARDAMAR DEL SEGURA, SPAIN

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Abstract – Coastal dune ecosystems had a crucial role in coastal dynamics, so it is essential to measure their movements precisely and monitor their changes over time. The natural interactions can be altered by anthropic pressure, modifying the coastal dynamics, causing alterations in beaches and dunes and affecting their stability. In recent years, the appearance of affordable low take-off weight Remotely Piloted Aircraft Systems (RPAS), together with the development of image-based computing techniques such as Structure-from-Motion (SfM), has increased the use of RPAS-based photogrammetry to produce high-resolution digital elevation models (DEMs) for the study of different surface processes, and specifically, for surveying dune ecosystems. This study aims to evaluate the applicability of RPAS to conduct periodic accurate studies at an affordable cost, to monitor the evolution of the coastal system of beaches and dunes, as well as the erosion caused by coastal regression. The study is focused on Guardamar del Segura, Alicante (Spain), an area strongly affected by anthropogenic pressure and coastal erosion. The methodology applied used a DJI Phantom 4 quadcopter, a device with a high ratio of sensor quality and performance at a very reasonable cost. The flights were planned so that the study area, with a length of 3.2 km long and 150 m wide (0.51km^2), was covered in 4 passes. A series of targets distributed throughout the study area were used as ground control points (GCP) for the photogrammetric georeferencing process. Its coordinates were surveyed by a Leica Zeno FLX100 GNSS, which provides an accuracy of its measurements of 2 cm horizontal and 3 cm vertical. The SfM algorithm enables the reconstruction of a 3D scene by resolving the geometry of the images, the camera positions and their orientation simultaneously using Agisoft Methashape software. The Digital Surface Models (DSM) obtained from the RPAS with the SfM-MVS algorithm have a high density (450 pts/m^2) and high accuracy, with RMSE in both the GCPS and check points < 3 cm in horizontal and < 1 cm in vertical measurements. The orthophotos and DSM generated have a spatial resolution of 2.5 cm/pixel. This very high resolution enables to accurately detect the shoreline, the dune limits and anthropogenic actions, as well as the shape of the dune and beach. Also, to monitor changes and the effects of storms precisely. Significant erosion has been detected along the entire length of the coastal area, as well as a movement towards the interior of the dune ridge was detected. In conclusion, the complex dune ecosystem and beaches of Guardamar del Segura has proven to be an excellent test site for monitoring coastal processes using a small, lightweight, easily deployable and affordable commercial RPAS. The possibility of quickly obtaining orthophotos and Digital Surface Models of very high resolution, covering large extensions at a low cost, enables us to model and monitor these rapid-changing environments with regularity and accuracy.

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Introduction

Coastal dune ecosystems had a crucial role in coastal dynamics, so it is essential to measure their movements precisely and monitor their changes over time. In addition, anthropic actions, modifying the coastal dynamics may cause alterations in beaches and dunes and affect their stability [8]. Dunes in coastal environments are challenging landforms to analyse, due to the complex interaction among topography, vegetation, aeolian and marine processes that affect them [14]. Traditional surveying methods frequently require a large amount of time and labour for obtaining accurate data, even using technologies such as global navigation satellite system (GNSS) using real-time kinematic (RTK) for surveying [7]. Although the use of transects might be adequate for modelling a beach, in a dune area the likelihood of correctly representing the behaviour of a wider zone using transects decreases [1]. Additionally, the reduced resolution of the field data often makes it difficult to obtain precise volumetric measurements of the dune system and thus to accurately monitor the changes.

In recent years, the appearance of affordable low take-off weight Remotely Piloted Aircraft System (RPAS), together with the development of image-based computing techniques such as Structure-from-Motion (SfM), has increased the use of RPAS-based photogrammetry to produce high-resolution digital elevation models (DEMs) for the study of different surface processes [6], and particularly, for surveying dune ecosystems [3]. It enables the study of the coastal strip with fast and high-performance surveys, at the desired sample frequency and with accurate results [13].

This study is focused on Guardamar del Segura, Alicante (Spain), an area strongly affected by anthropogenic pressure and coastal erosion [11]. The aim is to evaluate the applicability of RPAS to conduct periodic accurate studies at an affordable cost, to monitor the evolution of the coastal system of beaches and dunes, as well as the erosion caused by coastal regression.

Materials and Methods

The area of study encompasses the coastal area that extends from the north of the town of Guardamar del Segura, Alicante, located on the southeast Mediterranean coast of Spain. It covers two beaches, one southward of the mouth of the Segura River, Los Viveros Beach, and the other one to the north, Los Tusales beach (Figure 1). Its main characteristics are described in Table 1. Both are open sandy beaches in the natural coastal dune park named Dunes and Pine Forest of Guardamar del Segura, declared a Site of Community Interest (SCI) due to their unique landscape and ecosystems. The breakwaters located at the mouth of the Segura River had affected these nearby beaches, causing the North-to-South longitudinal transport to be cut and thus an erosive process in Los Viveros Beach [2].

The total surface area covered in this research was 0.51 km^2, forming a rectangular region with a length of 3.2 km and a width of 150 m (Figure 1c). The predominant wind directions are ENE and NE, both with a frequency of 15 % with maximum speeds not exceeding 10 m/s. The tidal range is only influenced by weather conditions, giving values of approximately 0.30 m [4]. The study area is subject to tremendous anthropogenic stress. A marina was built in 1998 and restoration to recover the foredune from the different aggressions it was suffering was planned in 2002 and finally completed in 2011 [11].

Table 1 – Main characteristics of the beaches studied.

	Los Viveros beach	Los Tusales beach
Length (m)	1620	1780
Average width (m)	14	25
Sediment type	Fine golden sand	Fine golden sand
D_{50} (mm)	0.228	0.220
Urban development	No	No
Dune ridge	Yes	Yes

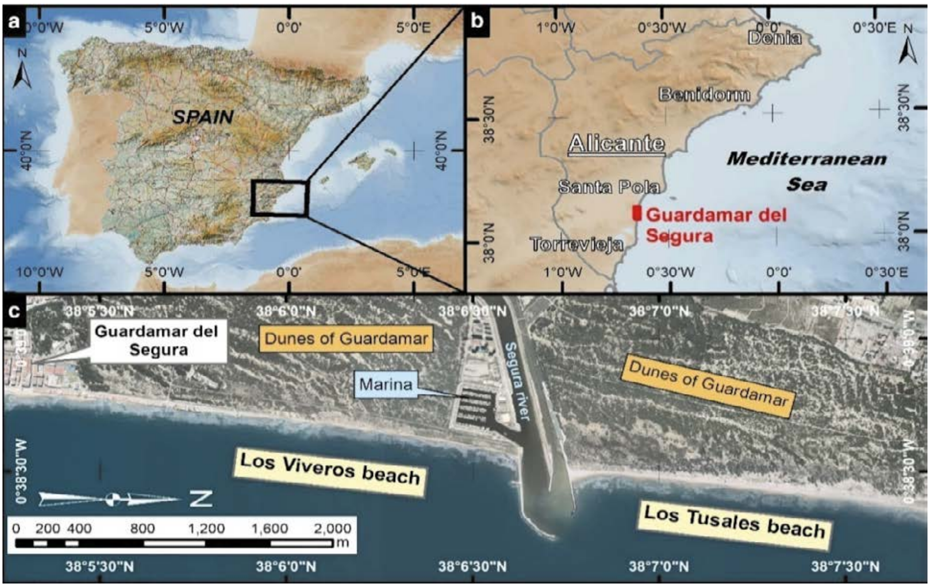

Figure 1 – Area of study located on the Mediterranean coast of Spain (a), in the south of the province of Alicante (b) northward of the town of Guardamar del Segura (c).

The RPAS used was a DJI Phantom 4 quadcopter, a device with a high ratio of sensor quality and performance at a very affordable cost (valued at 1500€). It was equipped with an FC330 built-in camera and a 1/2.3” CMOS sensor with a resolution of 12.4 Mpix. A Leica Zeno FLX100 GNSS antenna was used for surveying, enabling professional data capture in an ultra-portable housing at a very reasonable cost (3500€). The accuracy obtained using RTK with the NTRIP-based network solution linked to the GNSS ERVA reference station network via GPRS/3G connection was 2 cm horizontal and 3 cm vertical. Data processing was carried out using a Dell WorkStation with an Intel Xeon W2123 at 3.6 GHz, 16GB of RAM and a GPU Nvidia Quadro P2000. The general workflow followed is shown in Figure 2.

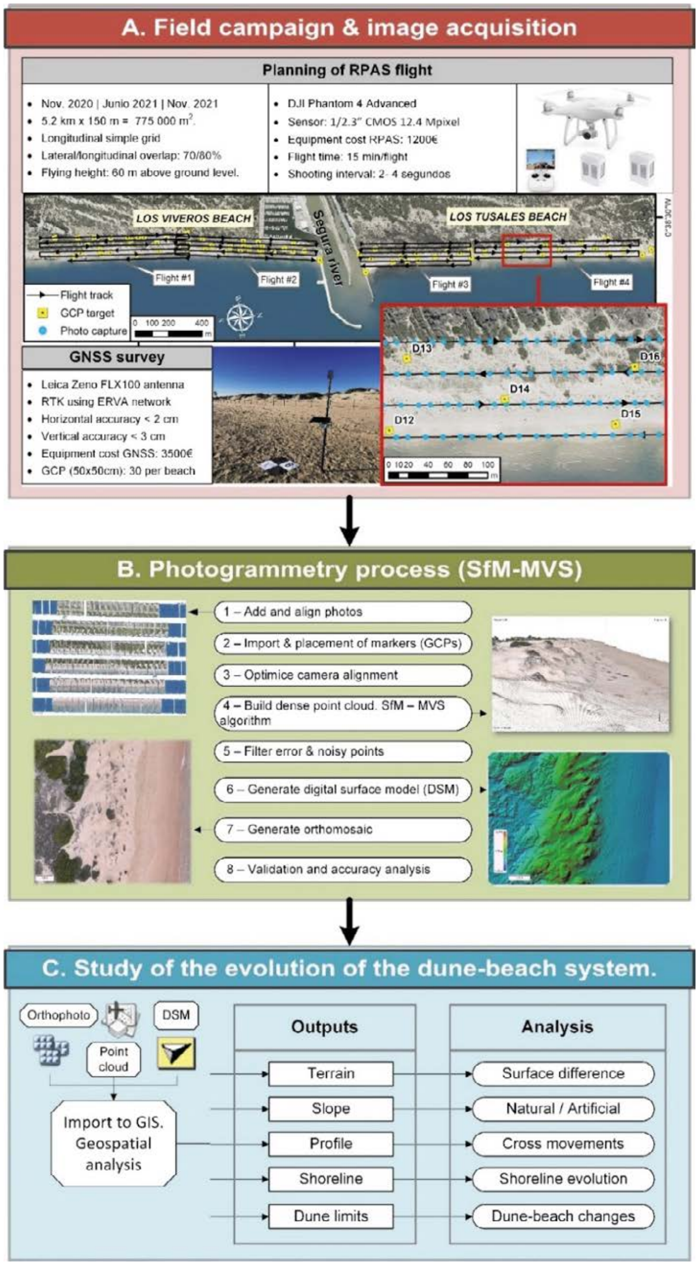

Figure 2 – General workflow followed, (A) field campaign and image acquisition, (B) the photogrammetry process using SfM-MVS algorithm and (C) study of the evolution of the dune-beach system using geospatial GIS techniques.

Three flight campaigns were carried out in November 2020, May 2021 and November 2021. The flight altitude was set at 60 m above ground level, taking a picture every 2–4 s. The latitudinal overlap was set to 70 %, and the longitudinal overlap was fixed to 80 %. The flights were planned so that each beach was covered in 2 passes, with approximately 600 images per campaign captured. At the same time, a series of 50x50 cm targets distributed throughout the study area (30 per beach) were used as Ground Control Points (GCP) for the photogrammetric georeferencing process.

The photogrammetry process using the Structure-from-Motion MultiView Stereo algorithm enables the reconstruction of a 3D scene by resolving the geometry of the images, the camera positions and their orientation simultaneously using Agisoft Methashape software (Figure 2B). The GCP surveyed by GNSS improves the model reconstruction results. Once the accuracy is satisfactory, a reconstruction processing algorithm is applied to generate the dense point cloud with RGB colours (Figure 3C). Through the calculus of the confidence parameter, the noisy areas of the dense cloud (e.g. the sea) can be deleted prior to generating a full Digital Surface Model (DSM) (Figure 3B). This DSM was used to create an orthomosaic of the entire monitored area (Figure 3A).

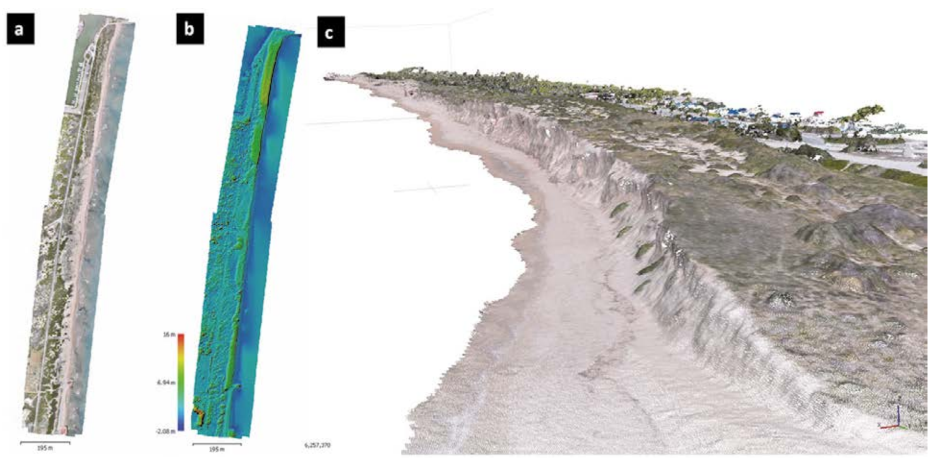

Figure 3 – Orthomosaic (a) DSM (b) and detail of the dense point cloud in Los Viveros beach.

The last phase was the study of the evolution of the dune-beach system (Figure 2C). The datasets created for each surveyed period (orthomosaics, cloud points and DSM) were imported into a GIS environment to perform geospatial analysis. A terrain dataset is a multi-resolution TIN-based surface created from measurements stored as entities in a geodatabase. The slope of the surface is generated from the DSM, enabling the analysis of the stability of the dune slopes and whether they correspond to a natural slope (when the value is below the friction angle of sand, 35°) or if is higher and may represent an artificial material or instability risk. An advantage of using DSMs is that it is possible to interactively generate cross-shore transects anywhere in the study area for each date studied. The position of the shoreline and the dune foot is also identified. The shoreline for the RPAS survey had been manually delineated using the orthophoto generated. The criteria to identify the shoreline were marking the high-water mark on the beach [9]. Also, for the dune foot, the line was delineated by the combination of visual identification on orthoimages and changes in the slope of the DSM. Finally, changes were detected between the available periods (25 November 2020 – 31 May 2021, 31 May 2021 – 30 November 2021) as well as within the total study period (25 November 2020 – 30 November 2021) to see interannual changes.

Results

The DSMs obtained from the RPAS with the SfM-MVS algorithm have a high density (450 pts/m^2) and high accuracy, with RMSE in both the GCPS and check points < 3 cm in horizontal and < 1 cm in vertical measurements. The orthophotos and DSM generated have a spatial resolution of 2.5 cm/pixel. This very high resolution enables to accurately detect the shoreline, the dune limits and anthropogenic actions, as well as the shape of the dune and beach. Also, to monitor changes and the effects of storms precisely (Figure 4).

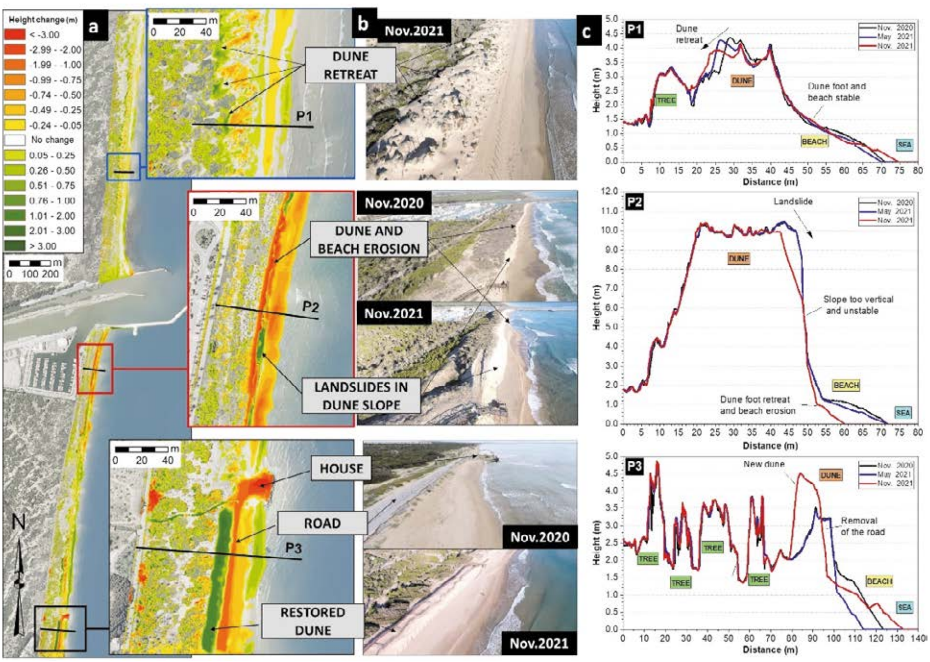

Figure 4 – Height changes obtained from DSM difference between November 2020-November 2021, with areas of interest showing changes in dune and beach (a). Aerial views obtained from videos recorded during the RPAS surveys (b) and cross-shore profiles with changes marked (c).

At Los Tusales beach, stability in the sedimentary budget is observed, although there is a movement towards the interior of the dune ridge. Shoreline also remains stable. However, in Los Viveros beach, southern of the breakwaters of the mouth of the Segura River, significant erosion has been detected along its entire length. The shoreline has retreated up to 10 m whereas the dune foot recedes 3 m. The dune slope in this strip of the coast is almost vertical (>75º) due to the erosion of the storms that hit this beach during the year studied. A volume of 11 520 m^3 of sand has been lost in one year.

Restoration actions were also detected and monitored in the south part of Los Viveros beach, an area extremely affected by erosion at the point that the existing road and houses had to be demolished. 150 m of new dune at a height of +4.5 m.a.s.l. were created and beach width was recovered.

Discussion

This study validates the use of aerial photogrammetry techniques using low take-off weight RPAS and their subsequent treatment with SfM-MVS algorithms for the generation of low-cost and high-quality DSMs. The outcomes in terms of accuracy are comparable to those obtained by diverse researchers [5, 12] and improve the first attempt made by the authors in 2017 [10]. Overall processing time using a new workstation (less than 3 hours for the whole photogrammetry workflow) has led to an enhancement in the spatial resolution of the outputs, obtaining points cloud with more than 265 million points that enable to modelling of the dune-beach system very accurately. The surveying time is also dramatically reduced from classic topography survey methods, covering the two beaches with only 4 flights of 15 minutes each, permitting to cover an area of 0.51 km^2 in one morning. That is an important factor, especially for extensive and inaccessible zones such as beaches or dune fields [3].

However, there are some drawbacks to this approach. Firstly, flight regulations can be restrictive on the areas to survey, especially near populated areas [10]. Secondly, the SfM-MVS technique generates a dense point cloud of the surface that can be converted in a DSM, but height can come from the top of buildings, tree canopy, powerlines and other features, so it is necessary post-processing to mask the areas with this undesired data [12].

The results obtained in the period of study show that the erosive trend detected in previous research in Los Viveros beach [2, 10] has continued, whereas Los Tusales Beach is stable. The lack of enough backshore width could have led to the increase in the erosion detected in the last period. Wave attack may also create a notch at the dune foot leading to mass failure: the collapse of a dune slab. That could also explain the steeper slope observed on the seaward side of the coastal dune on the north strip of this beach. Apart from the erosive coastal dynamics mentioned above, the effect of anthropogenic actions must be added. For instance, the continuous process of regrading the seaside slope of the dune, detected during the monitoring, increases the retreat of the foot dune.

The novelty of this research is the extensive field survey conducted using RPAS, outlining the significant reduction in time and costs instead of classical surveys, providing regular and detailed analysis of the evolution of these rapidly changing systems based on quality data and enabling coastal managers to adopt appropriate maintenance decisions.

Conclusion

The complex dune ecosystem and beaches of Guardamar del Segura has proven to be an excellent test site for monitoring coastal processes using a small, lightweight, easily deployable and affordable commercial RPAS. Despite the existing minor drawbacks, the advantages of RPAS surveys combined with SfM-MVS methodology make this method suitable for coastal dunes and beach surveys. The possibility of quickly obtaining orthophotos and Digital Surface Models of very high resolution, covering large extensions at a low cost, enables to model and monitor these rapid-changing environments with regularity and accuracy.

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USE OF MIXED STUDY TECHNIQUES IN THE EVALUATION OF COASTLINE DYNAMICS - THE "PORTO CESAREO" MPA CASE OF STUDY

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Abstract – In recent decades, the much-discussed climate changes with the consequent variations in sea and weather conditions and the rise of the mean sea level are causing an indisputable set of negative actions on the entire coastal system mainly due to the increase of the erosive phenomenon along the shorelines. These critical scenarios have a major impact even on a local scale, and because of that, we decided to study a well knows tract of rocky/sandy mixed coast, in a highly anthropized area, even if located inside the "Porto Cesareo" Marine Protected Area (MPA) (Ionian Sea, Gulf of Taranto, Puglia Region, Italy). The high naturalistic and archaeological value of this area calls for a greater institutional effort in the study of erosional phenomena. Several historical documents from other studies point out that this coastal area is an ideal place for this kind of research. The effects of coastal erosion and anthropic pressures along this tract of coast require adequate efforts for a consistent and rapid evaluation of the coastal dynamics. The methodologies proposed in this work are based on mixed techniques from different fields of study, integrating recent aero photogrammetry surveys with drones, aerial images acquired by the Italian Military Geographic Institute (IGM), elaboration of paleoshorelines related by underwater archaeological markers and their dating, and finally on the elaboration of satellite products useful for the study of vast areas. The monitoring of coastal areas and the evaluation of shoreline dynamics are core topics in the implementation of managing actions of decision-makers on a local, regional, national, and international scale, above all in places like the chosen one, inside an MPA. Remote sensing through the use of RPAS (Remotely Piloted Aircraft Systems or Drones) has proved to be very useful for identifying phenomena that act on a small spatial scale and in supporting and implementing protective measures according to the adaptive management approach, through multi-year surveys on habitats of conservation interest [18]. For the implementation of fine-scale monitoring actions, we have chosen products from the Sentinel satellite of the Copernicus constellation (European Space Agency - ESA). In this context, the use of satellite products provides a recurrent view of the ground, useful in the short and long-term monitoring of changes in wide coastal areas, and in particular, offers a coastline positioning evaluation in near real-time. Local monitoring actions performed in recent years have already shown an erosive trend in the past decades, and even, negative forecasts for the next decade, so further surveys with mixed methodologies could be crucial in the evaluation of the evolution of this particular coastal area by local authorities.

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Introduction

In recent decades, the much-discussed climate changes with the consequent variations in sea and weather conditions and the rise of the mean sea level are causing an indisputable set of negative effects on the entire coastal system mainly due to the increase of the erosive phenomena. This is particularly true along the Apulian region coastline, as assessed by various studies, one for all the *Piano Regionale delle Coste Puglia* [18], that reports positive erosional dynamics along the Ionian coastal areas. More specifically, between the Torre Lapillo (40.280979° N 17.840503° E) site and the Porto Cesareo town (40.261868° N 17.887420°E), particularly in the last ten years, many environmental emergencies took place, causing a high number of erosional events and pushing the regional authorities to implement a series of intervention in emergency status [1, 2, 3]. The sandy beaches of Porto Cesareo are among the more touristic attractions, with an annual average of at least 300 000 seasonal touristic presences [6], creating an entire economic system. This implies that public concern about the coastal area dynamics on the different types of impacts and risks that affect different matrices is present among the local stakeholders. So, the conservation of these landscapes must be pursued considering the preservation of all the economic assets, such as the sandy beaches, for touristic purposes, and for their intrinsic environmental and ecological value. In addition, the land-sea contact areas are well-known resting sites for archaeological evidence of the past, threatened even after a single extreme event [14, 15]. So, the point is to preserve a comprehensive good environmental status for the local community as a whole, and as an attractor for visitors.

This new wave should be rooted in a more capillary and systematic monitoring action for the definition of management actions to reduce the consequences of extreme events. So, the local governments (Coastal Municipalities and MPAs management bodies) must be more involved in the monitoring actions of the coastal areas, repeated over time, sometimes on vast areas. To cope with these needs, in collaboration with the Porto Cesareo MPA management body, we proposed a reliable and easily implementable methodology for the local operators, easy to use recurrently. We decided to study a well-known tract of rocky/sandy mixed coast in a highly anthropized area, even if located inside the “Porto Cesareo” Marine Protected Area (MPA) (Ionian Sea, Gulf of Taranto, Apulia Region, Italy). The coast of Porto Cesareo municipality falls within a well-identified landscape morpho unit whose limits are represented by the tip of Torre Squillace (40.235144° N 17.909999° E), immediately south of Porto Cesareo and Punta Rondinella (40.464297° N 17.247009° E), near Taranto, sharing the same morphological characters. The stretch of coast, from Porto Cesareo to Marina di Pulsano (40.349174° N 17.374957° E), is characterized by a substantial alternation between a flat, sloping rocky coast and pocket beaches bordered by low rocky promontories. In this morpho landscape unit falls the inflection zone that marks the change of direction of elongation of the Ionian coast of the Salento Peninsula which passes from E - W to NW - SE. The morphological characteristics of this stretch of coast, are classified as pocket beaches, as they do not have large longitudinal extensions and are limited by promontories that break up the various physiographic units, making each sector exclusive with its characteristics mainly linked to the local exposure to wave motion. According to the classification of the beaches of Puglia these beaches individually identify 6 coastal systems of the "stationary barrier" type.

This coastal system consisting of sandy deposits, in some cases extended for kilometres, located in sedimentary traps defined by the particular configuration of the rocky coast and almost totally devoid of sedimentary contribution from the hinterland The main sediment sources can only be indigenous and therefore come from dismantling calcarenite or generally calcareous promontories located in the immediate vicinity without the possibility of replacement or fluvial inputs given the local absence of waterways. The sediment recycling takes place mainly between the emerged beach and the dune, where present, and the submerged beach [10, 11, 13]. The seabed overlooking the stretch of coast of interest degrades with a succession of submerged terraces to a depth of about 30 m and then slowly increasing to a depth of 40 m at about 8 km from the coast. These natural environments have been undergoing severe erosion for some decades as a result of a combination of factors operating on different scales, both natural and human-induced. Natural factors that most affect the erosion phenomena are winds, storms, currents near the beaches, sea-level rise, and soil subsidence.

Man induced factors include the massive use of the coastal strip with wild and rapid urbanization consequent the construction of infrastructures and works for residential and recreational settlements, the use of the soil, the alteration of vegetation, and the works for the regulation of the hydrographic network. Indicatively, it can be assumed that these erosive phenomena, in Porto Cesareo, as in many other Italian areas, have begun to manifest themselves plainly since the sixties of the last century both for natural factors and as a phenomenon induced by the pressures of use on the coastal areas. In the examined area, starting from the 1940s and 1950s, reclamation interventions began in the areas behind the dunes, which allowed the creation of collection basins and a network of connecting canals, which determined the conditions for the beginning of the first coastal erosional phenomena, albeit with a very low intensity. Unfortunately, the Porto Cesareo coastal area has never been a site for monitoring aimed at quantifying the erosive phenomenon.

Therefore, today it is only possible to qualitatively observe the effects of this phenomena that manifest themselves in the progressive and general erosion and dismantling of the dune cords and the progressive and general depletion of sediment from the submerged beach to the retreat of the shoreline in particular in the south-east part of the Torre Lapillo bay. In January 2010, a series of storm surges which triggered serious erosion of the stretch of sandy coast throughout occurred the Salento peninsula. The coastal municipalities that have suffered the most from the negative effects of this phenomenon, including Porto Cesareo, have encouraged the competent offices of the Puglia Region to implement urgent actions to mitigate the damage. In May 2010, the Apulia Region authority responded to the coastal municipalities by launching the first phase of recognition for the erosive phenomenon. The first results of this study showed that the erosive phenomenon resulting from the storms of January 2010 also affected stretches of the coast previously classified as stable [4, 5]. While, as is obvious, in the stretches of sandy coast, already with a historical tendency to erosion, the storm surges of January 2010 further aggravated the stability of the coast and endangered the infrastructures, the natural habitats, and the archaeological heritage. In the Porto Cesareo area, several nowadays submerged archaeological contexts – settlements, shipwrecks, cargos – were investigated in the framework of the UnderwaterMuse project[1] (Programme Italia-Croatia), and seem to be significant markers of sea-level changes and seascapes evolution along centuries. The large

[1] https://www.italy-croatia.eu/web/underwatermuse

submerged area in front of the Bronze Age site of Scalo di Furno (40.275725° N 17.874066° E) represents the lower terrace of the settlement, showing structures and materials. Between the Torre Chianca (40.271722° N 17.870762° E) and the tip of Belvedere (40.280250° N 17.878912° E), there are other remains of structures and alignments of pole holes with pottery from the Middle Bronze Age, together with portions, partially submerged, of a Roman settlement and necropolis attested by funerary steles and tombs.

The underwater research conducted between the promontory on which the settlement stands and the islet in front has provided an important contribution to the reconstruction of the ancient landscape; in fact, they allowed to recognize a submerged part of the protohistoric village itself: two wall alignments, probably remains of the fortification work and a paved area referable to an open area, very rich in ceramic fragments and animal bones; this sector of the village is today between 2.20 and 3.55 m deep, but in the Bronze Age, as indeed, the entire area between the mainland and the island of Malva must have been completely emerged [7, 8]. In the same area, the wreck of a Roman *navis lapidaria* lays, with a cargo of monumental cipollino marble columns, probably beached when the sea level was lower than the current one of 1.5 m. Other two beached wrecks of the medieval age, in the sites of Bacino Grande (40.280625° N 17.866034° E) and La Strea (40.250065° N 17.898074° E), testify significant coastal seascapes changes, as well as the presence of archaeological material and anthropic deposits on the islets of the Porto Cesareo archipelago, dating from the Archaic to the Roman Age, and the structures partially under the sea level on the Strea peninsula (Medieval age). Also, the quarry of Torre Castiglione (40.289319° N 17.817496° E), brought to the light by the powerful storms of 2019, is a precious testimony of a different ancient coastal landscape. This could make it possible to create a spatially and temporally explicit database that allows rapid consultation of erosion parameters (such as beach depth) and a rapid institutional planning and intervention [19].

Materials and Methods

The proposed monitoring plan provides for the integrated use of different types of data, harmonized through accurate georeferencing. Some of these data already natively contain georeferencing, as in the case of satellite data. Others, such as the historical aerial photogrammetry of the Military Geographical Institute (IGM), and the drone surveys have been corrected with the use of the Global Navigation Satellite System (GNSS), model Topcon HiPer SR. Remote sensing through the use of RPAS (Remotely Piloted Aircraft Systems or Drones) is proving to be very useful for identifying phenomena that act on a small scale and supporting and implementing protective measures according to an adaptive management approach, favouring the creation of a long-term investigation model, through multi-year surveys on habitats of conservation interest and coastal dynamics [12]. Photographic data and their photogrammetric elaboration allow to find a specific “point”, thanks to its georeferencing, which allows evaluating the evolution of certain phenomena being able to extract a large amount of data from the same product, this thanks to the capability of choosing different scales of analysis [16]. In recent years this technique has proved to be extremely effective and interesting in the environmental analysis of a multitude of matrices.

The data georeferencing process, essential for this type of analysis, requires the use of dedicated software for the correction and determination of the positions. Common points were identified between the IGM images and the current territory, such as the vertices of coastal towers, islets, reefs, which have not changed in the past 100 years. Finally, as regards the archaeological surveys, the onboard GPS of the support boats for underwater research was used.

The working group used an RPAS DJI model Phantom 4 Pro, that allows to cover areas from 25 to 35 hectares in a day and to return a multitude of outputs within a short time, like high-resolution orthomosaic, Digital Elevation Models (DEM), contour lines, habitat mapping (habitat identification is based on broad classes that are easily recognized based on ground truth and image analysis by trained operators. In this case, we focused on discriminating the area covered by beaches, which are easily isolated given the large difference with the urban environment behind.), 3D models and, sections and profiles of the beach. The survey sites were identified in the three pocket beaches located in the central area of the protected marine area "Porto Cesareo", the work area falls within the ideal polygon having vertices with coordinates 40.275400° N 17.868497° E, 40.271928° N 17.882110° E, 40.268685° N 17.880147° E, 40.272608° N 17.866113° E (fig. 1).

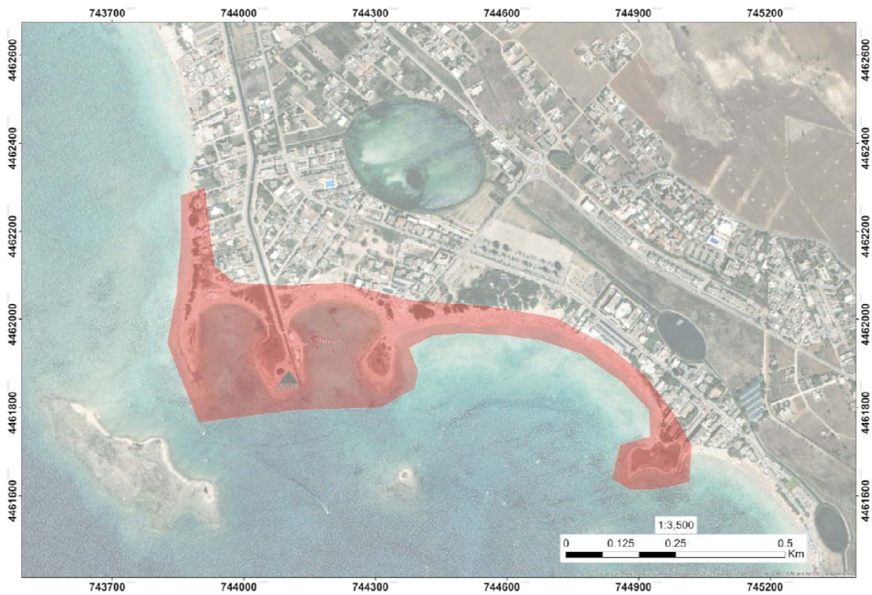

Figure 1 – Area of work.

The investigated beaches have an extension of about 1528 m within a system that is spread over about 4 km. These beaches have been selected as an elective place for summer tourist visits and installation sites of beach resorts that contribute to the local economy. Furthermore, are areas subject to numerous archaeological finds both on land and in the facing stretches of water that have made it possible to extract a paleoshoreline [7, 8]. Once a geodatabase is created, all aerophotogrammetric images, both historical and recent from drone, are georeferenced with the same reference system in order to compare data.

Finally, as already reported, for the archaeological surveys, vessel-installed GPS were used to support the underwater research activities. The assessment of the coastline dynamics was carried out through the use of the Digital Shoreline Analysis System (DSAS) Version 5.1 tool, distributed for the ESRI ArcGIS platform by the United States Geological Survey (UNGS) Woods Hole Coastal and Marine Science Centre[2].

This tool allows the calculation of statistics relating to the rate of change of coastlines starting from historical data relating to their positioning. For the use of this tool, it is necessary to create a shapefile in correspondence with non-dynamic structures (in this specific case it was decided to use a road infrastructure already present in the 40s) called baseline, and a single shapefile containing all the coastlines for each survey year, by each type of used methodology. These shapefiles represent the necessary inputs to the DSAS tool for the construction of transects that intersect perpendicularly to the baseline and allow the calculation of distance measurements (Shoreline Change Envelope and Net Shoreline Movement) and statistics (End Point Rate, Linear Regression Rate, and Weighted Linear Regression). Once these two shapefiles have been generated and their attribute tables have been appropriately populated, they have been inserted into the project database. Once populated the attribute table of the "Shorelines", the "Cast Transect" key generates the transect, perpendicular to the "Baseline", which intercepts the "Shorelines". Finally, the "Calculate Rates" key generates the output statistics.

This standardized procedure allows processing the outputs from different acquisition methodologies of the same portion of the coast, using the same parameters, to monitor the evolution of the coastal strip. The use of information from different acquisition technologies, as already specified, requires corrections and additions; in our case, the presence of human artifacts dating back to the 16th century made it possible to use these structures, along with other geomorphological features of the area, as an additional tool for calibration and correction in positioning. We used IGM digitized stereoscopic aerial photos, acquired in the years 1943, 1954, 1977, and 1997. These are specifically nadiral frames with photogrammetric characteristics, of variable format, on panchromatic material (B/W), at the approximate scale of 1: 33 000 (variable with the detection altitude). These historical photos cover 79 years, with discontinuous intervals, and have the disadvantage of showing a point-like image of reality, but as a counterpoint, they are also the only validated, objective, and easily available source of information on a now past reality. The images were suitably georeferenced through the GNSS in the EPSG 32633 - WGS 1984 - UTM Zone 33N coordinate format. Specifically, 11 control points scattered in the area of interest were acquired, and the spatially explicit images thus obtained were processed to generate the contour lines necessary for identifying the discontinuity lines in a cross-comparison with other processing of the raster dataset, such as hillshade models, capable of emphasizing elevated structures about the height of the sun (Painted Relief). This algorithm was employed using the acquisition date and time information for every single frame, both for the IGM images and for the aerial photogrammetric images from the drone. This information was included in the freeware SunEarth Tools which allows you to calculate the Solar Azimuth and the Elevation of the Sun for each location by year and time of acquisition.

[2] https://www.usgs.gov/centers/whcmsc/science/digital-shoreline-analysis-system-dsas

The processing of raster files was carried out through the geospatial processing software ERDAS IMAGINE and ArcGIS (ArcMap), these steps allowed for the extraction, comparison, and validation of all the shorelines. Among the various definitions of this structure, we decided to adopt the one reported by the Coastal Engineering Research Centre [9] which defines the shoreline as the "line of contact between the earth and a body of water". The shorelines thus extracted were then exported as a shapefile and loaded into the GIS environment for subsequent processing. The images that made it possible to create the orthomosaics and DEMs relating to the year 2022 were acquired using RPAS, produced by DJI, model Phantom 4 Pro. The acquisition using RPAS took place at a constant altitude of 100 meters, in optimal light conditions calculated based on the absence of cloud cover and at an appropriate time with an appropriate height of the Sun above the horizon, fundamental factors to consider since they can create artefacts in the photogrammetric processing phase. The overlapping of the single images was 80 % to improve the software's matching capacity and, in this case, it was not necessary to create a clip excluding the edges of the area, notoriously areas where important deformations occur, as these areas did not negatively affect the extraction of data of interest.

Using the Agisoft Metashape photogrammetric software, the acquired images were mosaiced and an orthomosaic of the study area was processed. Although the images acquired employing RPAS are natively georeferenced, it has been found that the quality of this positioning does not respect a congruous standard with the use presented here, both for the X, Y, and Z coordinates. For this reason, it was decided to correct the georeferencing and the elevation based on points acquired in the field through GNSS with which the orthomosaic and the final DEM have been correctly calibrated. The images thus corrected were then processed, as the IGM images, for the extraction of the contour lines and the hillshade model, from these two outputs were thus extracted the shorelines for every single survey as shapefiles then loaded into the project database for the final processing. Satellite remote sensing can provide low-cost long-term shoreline data capable of resolving the temporal scales of interest to coastal scientists and engineers at sites where no in-situ field measurements are available. The use of satellite data in the context of this work mainly served to fill the significant information gap that previous data sources intrinsically have in their acquisition protocol. Satellite images fill this gap thanks to their revisit time and the implementation of algorithms for extracting information from easily usable databases.

Initially, the focus was on the use of the "Coastal Erosion Monitoring with Sentinel-1" Training Kit-COAS02 protocol produced by Copernicus Research and User Support (RUS), with data from Sentinel-1 satellites, C-band synthetic aperture radar (SAR) imaging. Unfortunately, this information turned out to be too coarse for our scale of interest, but certainly of undeniable usefulness for larger areas and where information on the field is scarce. For this reason, and also in order not to deny one of the main objectives of this work, namely the use of this "manual", especially for MPA personnel and coastal municipalities, it was decided to use data from Sentinel-2 satellites (Multi-Spectral Imager (MSI) with a resolution from 10 m to 60 m, depending on the bands[3], which allow the extraction of more useful information on our scale of interest. To make the most of the potential of this data and maintain ease of use for each level of expertise, we decided to use the open-source software toolkit, in Python language, CoastSat [20] which allows the user

[3] https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2-msi/resolutions/spatial

to obtain time-series of shoreline position of any sandy coastline, worldwide from 30+ years (and growing) of publicly available satellite imagery.

The toolkit exploits the capabilities of Google Earth Engine to efficiently retrieve Landsat and Sentinel-2 images cropped to any user-defined region of interest (ROI). The resulting images are pre-processed to remove cloudy pixels and enhance spatial resolution, before applying a robust and generic shoreline detection algorithm. This shoreline detection technique combines a supervised image classification and a sub-pixel resolution border segmentation to map the position of the shoreline with an accuracy of ~10 m. The purpose of CoastSat is to provide coastal managers, engineers, and scientists with a user-friendly and practical toolkit to monitor and explore their coastlines. CoastSat enables the non-expert user to extract shorelines from numerous Landsat platforms and Sentinel-2 images. The shoreline detection algorithm implemented in CoastSat is optimized for sandy beach coastlines, it combines a sub-pixel border segmentation and an image classification component, which refines the segmentation into four distinct categories such that the shoreline detection is specific to the sand/water interface.

The ease of use is also evident from the input data requested from the user, which are restricted to the Region Of Interest (ROI), the time frame to be monitored and the satellite platform to be exploited. As mentioned above, there are some additional parameters that can be modified to optimize the shoreline detection but for more technical details we refer to the GitHub project page[4]. The algorithm uses an image classification scheme to label each pixel into 4 classes: sand, water, white-water, and other land features. As stressed by the developers, this classifier has been trained using a wide range of different beaches, but it may be that it does not perform very well at specific sites that it has never seen before.

To test if this was the case for our survey site, we crossed the information coming from the processing of the lines coming from RPAS surveys and IGM images, as well as the overlap with the orthomosaics and DEMs generated by the same RPAS surveys and the collimation of the related shorelines. The results of this test confirmed the compatibility of this approach and the correct calibration of the tool. Before running the batch shoreline detection, the tool gives the option to manually digitize a reference shoreline on one cloud-free image. This reference shoreline helps to reject outliers and false detections when mapping shorelines as it only considers as valid shorelines the points that are within a defined distance from this reference shoreline. Employing the CoastSat toolkit, 34 lines were extracted for the year 2019, 32 lines for 2020, and 26 for 2021.

The processing of the extracted coastlines provided, once the shapefiles were imported into GIS, the separation of data by year and by month, to create an annual average line through the DSAS tool itself. The annual mean line was calculated from the transects generated by the DSAS tool, specifically through the layer of the points of intersection between the transects, perpendicular to the "Baseline", and the shorelines through the "Mean centre" tool, the midpoints for every single transect, were generated. The use of the Point to line tool then made it possible to generate the relative average coastline, subsequently smoothed through the "Smooth line" tool with "Bezier interpolation" (fits Bezier curves between vertices.

[4] https://github.com/kvos/CoastSat

The resulting line passes through the vertices of the input line. This algorithm does not require a tolerance. Instead of the Polynomial Approximation with Exponential Kernel that calculates a smoothed line that will not pass through the input line vertices). These mean lines were eventually loaded into the database for subsequent final processing.

Results

The proposed monitoring plan provides for the integrated use of different types of data, harmonized through accurate georeferencing. Remote sensing through the use of RPAS (Remotely Piloted Aircraft Systems or Drones) is proving to be very useful for identifying phenomena that act on a small scale and supporting and implementing protective measures according to an adaptive management approach, favouring the creation of a long-term investigation model, through multi-year surveys on habitats of conservation interest and coastal dynamics [12].

Photographic data and their photogrammetric elaboration allow to find a specific "point", thanks to its georeferencing, which allows evaluating the evolution of certain phenomena being able to extract a large amount of data from the same product, this thanks to the capability of choosing different scales of analysis [16]. To display the results, among the various outputs generated by the DSAS tool, it was decided to use the "Net Shoreline Movement" (NSM) which expresses the distance expressed in meters between the oldest and most recent coastline for each transect.

This choice is always to pursue of the main purpose of the project, which is to provide a simple interpretation system for both the operators and the stakeholders of the areas affected by erosion (e.g., coastal municipalities and state-owned concessionaries who each year attend to the effects of the erosive phenomenon tangibly).

Discussion

From the results reported in Figure 2 and Table 1, it is possible to infer that in the 79 years between 1943 and 2022, out of 67 transects with an intermediate distance of 20 meters built in the DSAS tool, 85.0 7% are in an erosive state with an average negative distance of 17.84 meters. On the other hand, 14.93 % of transects result in accretion with an average positive distance of 7.49 meters. The accretional area is localized in the Torre Chianca bay, due to its peculiar morphologic structure working as a sediment trap. The other beaches, instead, are subjected to constant erosion due to their exposure.

Thanks to the underwater archaeological evidence it was also possible to determine the long-term evolution of the same trait of coastline. As reported in Figure 3 and Table 2, the useful information from this elaboration is quite tricky to interpret, so a good compromise could be to rely on the average distance of change reported in 507.36 meters seawards the actual coastline.

Table 1 – Net Shoreline Movement (m), 1943-2022.

Total number of transects	67
Average distance	-14.06
Number of transects with negative distance	57
Percent of transects that have a negative distance	85.07 %
Maximum negative distance	-53.19
Maximum negative distance transect ID	19
Average of all negative distance	-17.84
Number of transects with positive distance	10
Percent of transects that have a positive distance	14.93 %
Maximum positive distance	10.83
Maximum positive distance transect ID	37
Average of all positive distances	7.49

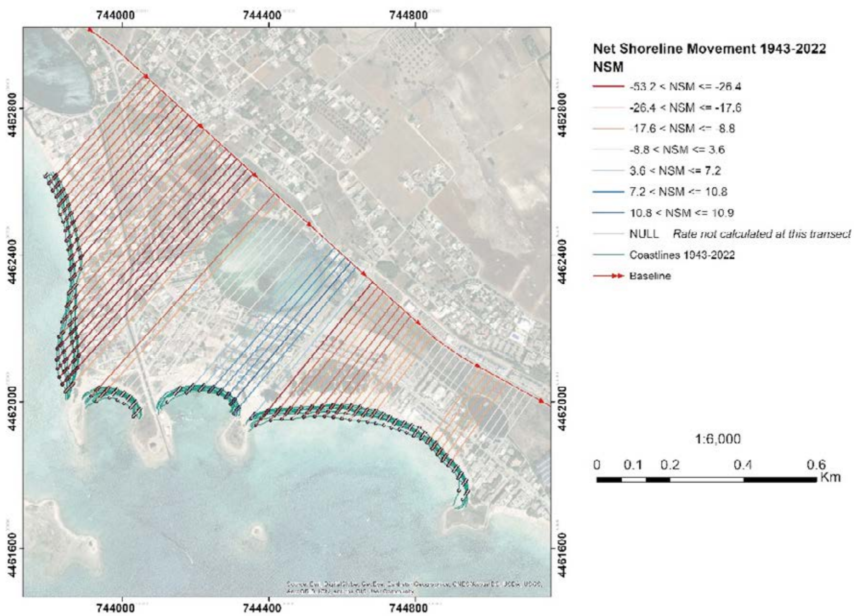

Figure 2 – NSM inferred from 1943-2022 lines DSAS processing.

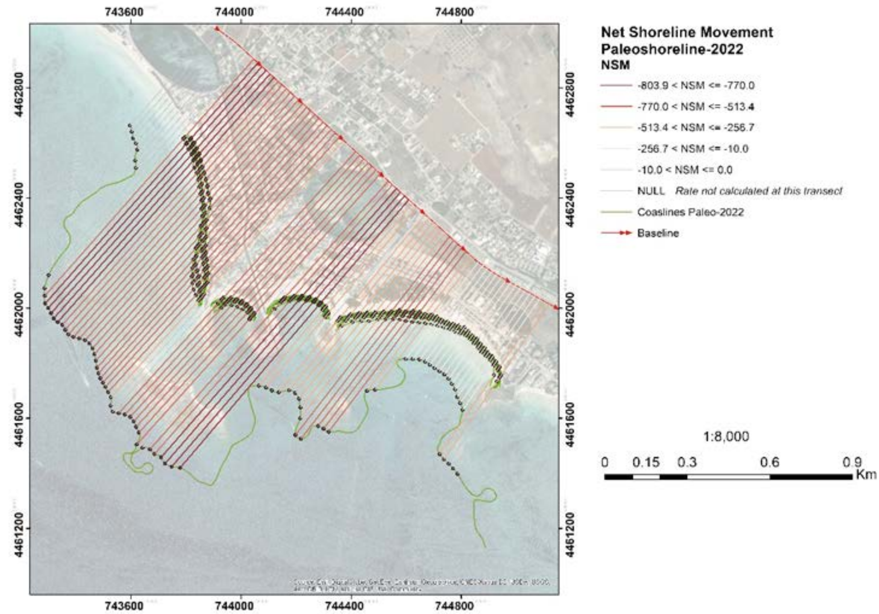

Figure 3 – NSM inferred from Paleoshoreline-2022 lines DSAS processing.

Table 2 – Net Shoreline Movement (m), Paleoshoreline-2022.

Total number of transects	67
Average distance	-507.36
Number of transects with negative distance	67
Percent of transects that have a negative distance	100 %
Maximum negative distance	-803.82
Maximum negative distance transect ID	11
Average of all negative distance	-507.36
Number of transects with positive distance	0

Conclusion

Coastal spaces can be defined as "living organisms”, Due to the various factors that influence the dynamics of the coastal environment, this is certainly one of the most complex and fragile habitats, strongly affected by any variation that can be generated even several kilometres away from the place under examination [17]. The purpose of this work wants to highlight the possibility to integrate widely used means, cheap and reliable, freely and easily accessible data, together with the necessary expertise of the personnel of the coastal community authorities, in areas affected by erosional phenomena. The aim is to implement a monitoring system for the acquisition, processing and integration of results in an adaptive management perspective, aiming at a quick and concrete protection and management of the coastal environment. In this specific case, in a marine protected area, in which a large percentage of the local wealth is attributable to the tourist exploitation of coastal areas, the implementation of a constant, reliable, and integrated monitoring system of interactions and criticalities is even more important. Only an in-depth knowledge, at a local level and widespread throughout the territory, of the critical issues of the coastal environment and the ever-increasing threats it faces, could effectively help to prevent and quickly inform the local stakeholders on the actions to be implemented for counteract the risks, such as better design in the use and installation of erosion protection structures, or a more informed assessment in the investment of capital in certain areas rather than others. The methodology presented here, strengthened by a simple approach based on validated tools, is proposed as a further small step for the dissemination of those tools and expertise increasingly necessary at every administrative and management level to address those challenges, once considered future but now contingent if not overwhelming.

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SEDIMENTOLOGICAL CONSEQUENCES OF POSIDONIA OCEANICA BANQUETTE REMOVAL: SAKARUN BEACH CASE STUDY (DUGI OTOK, CROATIA)

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Abstract – Removal of *Posidonia oceanica* banquettes from Sakarun beach (Dugi otok Island, Croatia) was a common practice to increase recreational use during the summer tourist season. The sandy part of the beach showed gradual erosion and has partially disappeared. Geological and geomorphological investigations (including bedrock characterization, analysis of sediment grain size and carbonate content, beach profiling, and digital surface modelling) were conducted over nine-month period to investigate the relationship between the banquette removal and sediment loss. The results indicate that the continuous removal of sediment-laden posidonia banquette may cause a deficit in the beach sediment budget, the effects of which may not become apparent until several-year delay.

Introduction

Seagrass meadows are ubiquitous habitats in the coastal areas of the Mediterranean. One of them, *Posidonia oceanica* (hereinafter posidonia), a legally protected species in most Mediterranean countries [1], is one of the most important taxa of this group. It is the basis of primary production in the sea [2], increases the oxygen concentration in the water column [3] and provides a habitat for numerous marine organisms. In addition to their biological importance, posidonia meadows influence water currents, sedimentological and geomorphological characteristics of the seafloor [4], and the coasts where its detritus is deposited [5]. Seabed sediment is more stable in the dense network of plant rhizomes, and the meadows reduce sediment resuspension and promote sedimentation [3,4,6]. Deposits of plant detritus, called banquette, usually form on the beaches off which posidonia meadows grow [7,8]. Banquettes are massive and more or less firm structures that make the beach more resistant to the action of waves: by covering the beach sediment, they protect it from erosion, while the banquettes themselves may contain considerable amounts of sediment. Although posidonia banquettes are known to have an effect on reducing beach erosion [2], there is far too little published research detailing this effect.

The occurrence of posidonia banquettes on the Croatian coast is known in several places, but according to the available literature, they are more common in other Mediterranean countries (e.g., Italy, France, Spain). To date, there are few data and research results on posidonia banquettes on the Croatian coast. Considering the orientation of the Croatian coast (NW-SE) and the prevailing wind waves that last long enough to form banquettes (south-east waves), posidonia detritus it expected to accumulate on coastal sections and beaches that are most exposed to south-eastern waves. One of tthese is Sakarun

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beach on the of Dugi otok Island (Figure 1). This beach can be characterized as a pocket beach, although it exceeds the average dimensions of this type of beach on the Croatian coast: they are usually smaller, located within bays, composed of loose gravel and different from the rocky headlands by which they are they are bordered. Pocket beaches are a popular geomorphological coastal form on the Croatian coast [9]. They have an attractive landscape and are therefore a valuable resource for the Croatian tourist industry. A deeply indented spacious Sakarun Bay with a sandy bottom and a long pebbly-sandy Sakarun beach deviates from the above description and attracts numerous beach goers and boaters.

Deposits of posidonia detritus, which settle on the Sakarun beach every year, were regularly removed in order to achieve a more representative and attractive appearance of the beach, which would increase its popularity and thus strengthen the overall tourist activity on the Dugi otok Island. Due to the observed increased erosion on the beach, i.e. in particular the decrease in the amount of sandy sediment, the complete removal of posidonia banquettes was stopped in 2020.

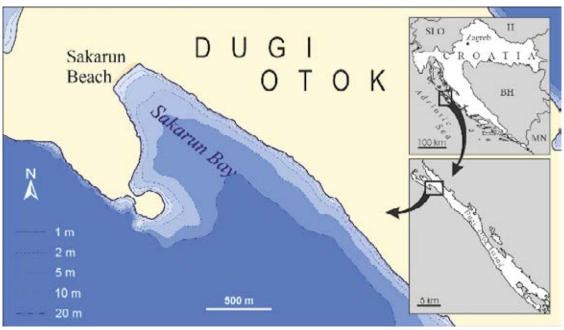

Figure 1 – Up: Location map of the Island of Dugi otok. Right: Sakarun beach within the Sakarun Bay containing posidonia detritus in the shallow sea.

Study site

Sakarun Beach is 300 meters long and up to 36 meters wide. The beach is known as a popular tourist destination. It is accessible from two sides by road, but it is also a destination for many sailors who use the buoy field in the wide bay. The bay is cut about 800 meters deep, while its average width is about 500 meters. The sea depth in the bay does not exceed 20 meters. Along its edge and in the open sea in front of it there are posidonia meadows. The biogenic detritus accumulates and settles in the bay (Figure 1), while up to 2 m thick banquettes are formed on the beach itself. Preliminary field investigation revealed that the beach sediment is primarily gravel, combined with a thin strip of sandy sediment in the intertidal. The beach is surrounded by the carbonate bedrock and oriented toward southeast (Figure 1), directly to Sirocco wind waves of shore-normal incidence. Previous results of beach morphodynamics are lacking, as well as description of beach sediment characteristics. Monitoring period of the beach banquettes began in the fall of 2020 through the summer of 2021 and lasted a total of 9 months. During the monitoring period 4 Sirocco episodes occurred (one in October, two in December, one in February) with wind speed in 8-10.7 m/s range.

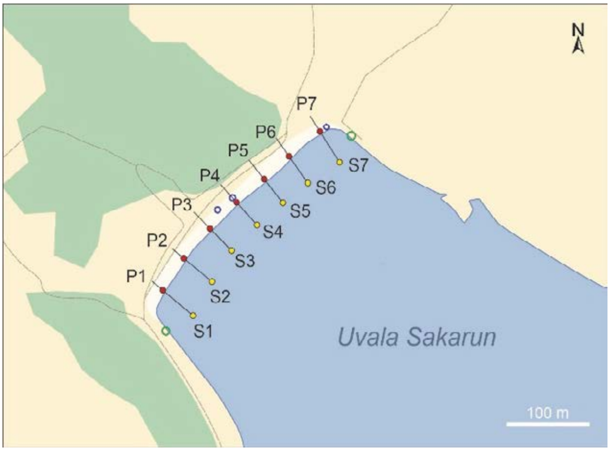

Figure 2 – Sakarun Beach with sediment sampling locations. Sampling locations P1-P7 refer to upper intertidal beach sediment, while sampling location S1-S2 refer to shallow subtidal sediment.

Materials and methods

Gravel beach sediment and bedrock were collected once for thin sections preparations to determine the origin, composition, and age of the underlying bedrock and the origin of the gravel material.

Sandy sediment samples were collected once along the sandy strip of sediment cover, in the intertidal (P1-P7) and in the shallow subtidal zone (S1-S7) along 7 profiles. A total of 14 sediment samples were collected. All sandy samples were subjected to grain size analysis by wet sieving and sediment classification was done according to [10]. Carbonate content was calculated from volumetric measurement of CO_2 produced after treatment with 1:1 dilute HCl acid in the Scheibler apparatus. All sediment fractions of each sediment sample were examined with a stereomicroscope to identify the origin of the sediment grains.

The mineral composition of the sandy sediment was determined by powder X-ray diffraction (XRPD technique) using a Philips PW 3040/60 X'Pert Pro diffractometer.

During the 9-month monitoring period, samples of posidonia banquettes were collected 9 times. Sediment was extracted from each banquette sample by rinsing in freshwater and subjected to the sediment analyses described above. The weight of each banquette sediment sample was determined as weight per 1 m^3 of posidonia banquette. Average sediment weight was calculated as a mean of all obtained weights.

Surveys of Sakarun beach were conducted each month along the 7 profiles (Figure 2) using a high-precision DGPS (Trimble R8 GNSS receiver) and the real-time kinematic positioning service CROPOS VPPS (virtual reference station). Aerial photographs were taken by drone each month during the monitoring period and then used to create DEM using Agisoft Photoscan (Metashape). DEMS of the differences were created using Golden Software Surfer.

Results

Both, the beach bedrock and the gravel beach sediment are highly erodible and thin-bedded bioclastic pelagic packstones and bioclastic floutstones of Cretaceous age, generally characterized as carbonate flysch.

The main characteristics of the sandy sediments are listed in Table 1. Intertidal beach sediment is mostly very well sorted slightly gravelly sand or sand with the mean size of ~0.2. mm. Subtidal sediment is mostly characterized as sand with a similar mean size. Both sand sample groups are highly carbonaceous and usually contain over 94% of carbonates. The sediment extracted from the posidonia banquettes had very similar characteristics to the intertidal and subtidal sands. The weight of sediment extracted from the posidonia banquette varied from 0.5 to 220 kg of sediment in 1 m^3 of banquette, with a mean (average) of 64 kg/1 m^3. Microscopic examination revealed that almost all grains in all sediment samples were skeletal grains, composed of marine skeletal material, including molluscs, foraminifera, bryozoans, serpulids, echinoids etc. (Figure 3). Most of skeletal grains exhibit a high degree of fracturing.

The mineral composition of selected sand samples showed that calcite, aragonite and Mg-calcite are the dominant mineral phases in all sand sample groups studied (Table 1).

The analysis of all beach profiles and the detected processes were explained using representative profile P1-S1. The beach profiles showed that the maximum changes occurred along profile 1 during the monitoring period (Figure 4). The maximum dynamics of posidonia banquette destruction and build-up occurred during and after Sirocco episodes, respectively, while the maximum elevation changes of posidonia banquettes occurred in the intertidal and the lowermost supratidal. Profiles along the entire beach indicated the presence of sandbar that moved along the shallow subtidal during the observation period.

3D models of the beach confirmed the beach profiling results and showed the maximum changes between two sucessive fieldworks up to 1 m in the intertidal and the lowermost supratidal (Figure 5).

Table 1 – Intertidal and subtidal sandy sediment characteristics. Description: (g)S – slightly gravelly sand, S – sand.

Sample:	Mean (mm):	Median (mm):	Sorting ():	Sediment type (after Folk, 1954):	Carbonate content (%):	Dominant minerals:
Intertidal beach sediment						
P1	0.208	0.196	0.564	(g)S	94	calcite, Mg-calcite, aragonite
P2	0.211	0.198	0.566	(g)S	99	/
P3	0.258	0,252	0.763	(g)S	99	/
P4	0.235	0.225	0.628	S	94	calcite, Mg-calcite, aragonite
P5	0.218	0.205	0.596	(g)S	98	/
P6	0.192	0.189	0.486	S	96	/
P7	0.241	0.235	0.625	S	94	Mg-calcite, calcite, aragonite
Subtidal beach sediment						
S1	0.187	0.186	0.475	S	94	Mg-calcite, calcite, aragonite
S2	0.183	0.183	0.460	S	93	/
S3	0.199	0.191	0.556	S	94	/
S4	0.183	0.183	0.455	S	94	Mg-calcite, calcite, aragonite
S5	0.187	0.187	0.466	S	95	/
S6	0.209	0.197	0.579	(g)S	95	/
S7	0.176	0.176	0.524	S	94	calcite, Mg-calcite, aragonite

Table 2 – Posidonia banquette sediment characteristics. Description: (g)S – slightly gravelly sand, S – sand.

Sample:	Mean (mm):	Median (mm):	Sorting ():	Sediment type (after Folk, 1954):	Carbonate content (%):	Dominant minerals:
Posidonia banquette sediment						
POS1	0.221	0.207	0.598	(g)S	99	Mg-calcite, calcite, aragonite
POS2	0.214	0.199	0.669	(g)S	95	Mg-calcite, calcite, aragonite
POS3	0.211	0.197	0.629	(g)S	95	Mg-calcite, calcite, aragonite
POS4	0.233	0.223	0.704	(g)S	99	Mg-calcite, calcite, aragonite
POS5	48	/	/	limestone gravel*	96-98*	/
POS6	0.217	0.201	0.650	(g)S	97	/
POS7	0.207	0.193	0.722	(g)S	98	/
POS8	0.228	0.211	0.771	(g)S	96	/
POS9	0.221	0.206	0.682	(g)S	95	/

*according to carbonate content of basement rock after [13]

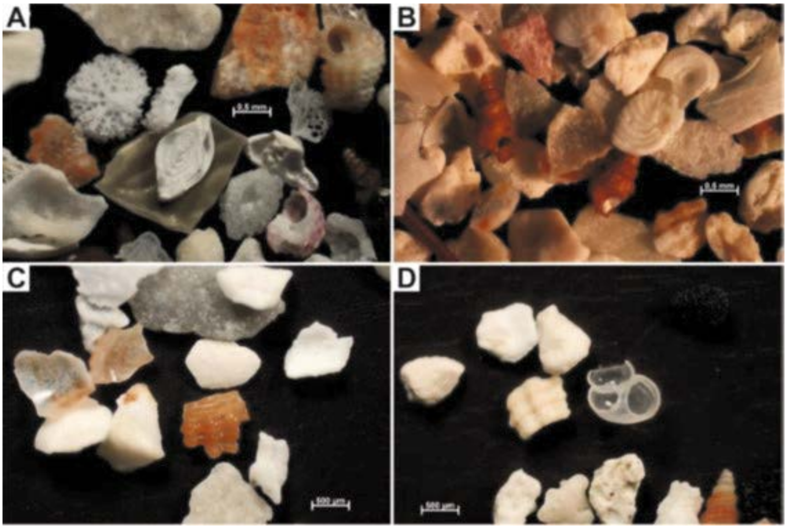

Figure 3 – Biogenous skeletal grains in fraction 0.5-1 mm of various samples. A) Sample P1 – foraminifera test with mollusc and bryozoan fragments. B) Sample P4 – mollusc and foraminifera tests with echinoid spine and mollusc fragments. C) Sample S4 – mollusc fragments. D) Sample S7 – mollusc fragments.

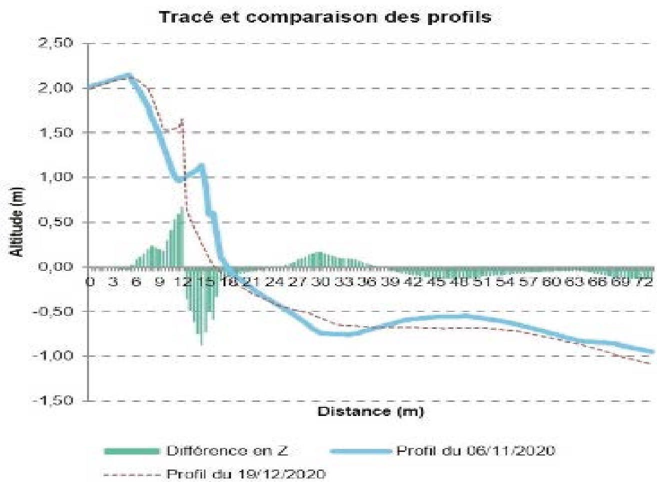

Figure 4 – Difference of profile 1 between November (blue line) and December (dotted line) 2020.

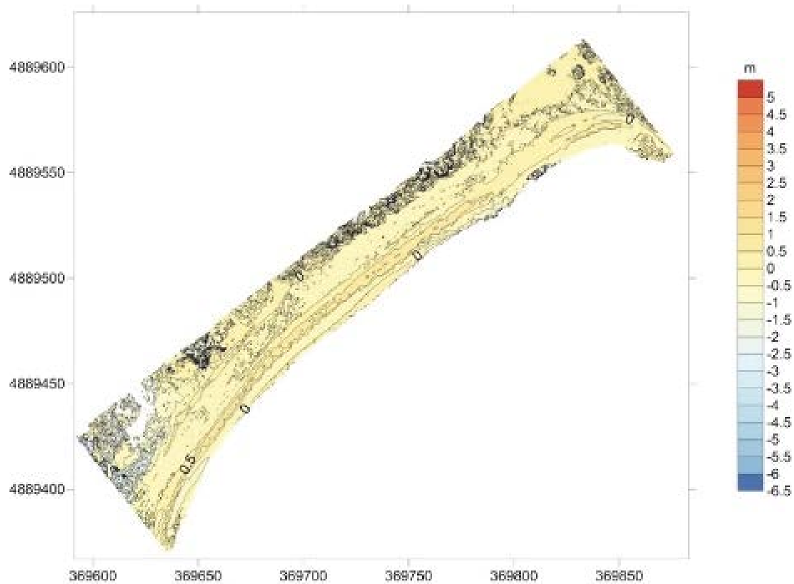

Figure 5 – DEM of difference for the November/December 2020 with postition of the profile 1.

Discussion

The Sakarun beach and the Sakarun Bay are the result of the erosion of erodible carbonate bedrock by the action of the prevailing Sirocco waves to which is the Bay oriented. The erodible nature of the bedrock resulted in the accumulation and rounding of carbonate gravel, which makes up most of the beach. The presence of posidonia meadows in the coastal area of the Dugi otok island leads to a massive accumulation of posidonia detritus and the formation of banquette (Figure 6). This accumulation is largely favoured by the prevailing Sirocco waves of SE incidence. Banquette are composed of posidonia leaves, rhizomes and aegagropilae. Banquettes are generally formed in the intertidal zone and cover sand deposited in the lower (intertidal and subtidal) part of the beach. All banquettes contain sediment, mostly sand, and to a lesser extent gravel. Because of the sediment they contain, banquettes are considered biogeomorphological structures. All sand samples collected from the beach and extracted from banquettes are pure marine biogenic sands and slightly gravelly sands, composed of carbonaceous skeletal remains. Such sediments are ubiquitous along the eastern Adriatic coast [11,12]. A high high degree of fracturing, indicating that original biogenic material was brought to the coast and further crushed by wave action.

Figure 6 – Banquette formed on the Sakarun beach.

Banquette dimensions usually change during and after Sirocco storms. During the storm, all the banquettes and the sand can be removed from the beach, as noted by the locals between the two fieldworks. When the storm subsides, both sand and banquettes are re-accumulated on the beach, indicating that sand and posidonia leaves have accumulated for a short time in shallow Sakarun Bay, awaiting re-accumulation on the beach. During the monitoring period the largest variations in banquette height were observed on the SW section of the beach (profile 1; Figure 4), while the largest changes occurred in the intertidal area. DEMs of differences between fieldwork during the monitoring period supported the results obtained from the beach profiles. In addition, all beach profiles showed that the sandbar exists in the shallow subtidal area of the Bay. It is hypothesised that its movement pattern may be explained by wave climate, which should be investigated during further monitoring.

Based on the average amount of sediment (mainly sand) in the banquettes of 64 kg/1 m^3 and the estimated volume of 1560 m^3 of banquettes on the beach during the monitoring period, it is calculated that the complete removal of banquettes from the beach removes 37 m^3 of sediment. According to [14,15], the accumulation rate of biogenic carbonate sediment in the temperate region is usually 1-2 cm in 1000 years. Assuming that all the sand on Sakarun beach is made in the Sakarun Bay, a rough estimation indicates that the total annual sediment production is 14 m^3. The result of the amount of sediment removed and produced clearly showes that erosion occurs at the Sakarun beach. The erosion results became visible after several years of banquette removal, indicating that further erosionall impacts on the beach can be expected in the coming years.

Conclusions

Sediment and posidonia banquettes form biogeomorphological structures on Sakarun beach. Removal of the banquettes for the tourist purposes leads to erosion of the sand, the most valuable part of the beach for tourism. The processes observed on Sakarun beach indicate the need for a development plan for posidonia management, in which permanent removal of the banquettes should be avoided.

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GEOMORPHOLOGICAL APPROACHES TO STUDY POSIDONIA BANQUETTES AND THEIR EFFECTS ON THE COASTAL FRONT OF SCHINIAS - MARATHON NATIONAL PARK

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Abstract – In this study UAV technology with RTK-GPS is used in order to map in detail, the beach morphological characteristics in conjunction with shoreline change investigation with remote sensing techniques, aiming to the impact of the presence of *Posidonia oceanica* beach-cast seagrass litter in the area of Schinias national Park, Marathon, Greece. The principal aim of this research is to evaluate the relation between the banquettes and the sediments, as well as the banquette's significance concerning the beach protection. Field data were collected by performing 4 UAV Missions during one year with a view to: a) identifying spatiotemporal changes in volume, shape and area covered by the banquettes, and b) analysing relations between banquette deposition and sedimentary budget components and changes. Also, remote sensing data covering a period of 76 years was realized at the coastal front of Schinias-Marathon National Park, in order to identify current trends of the shoreline and the reasons for the intense erosion that has been caused. The total area covered by *Posidonia oceanica* beach-cast deposits was 11468.49 m^2 (maximum covered area in this research) and the volume of the two different banquettes was approximately 2492m^3. Concerning the granulometry analysis the dominant sediment class was the class of fine sand in all seasons. Shoreline differences between 1945 and 2021 in the study site, reveal a loss of land surface mainly due to the operation of the Marathon Dam (1929) causing high coastal erosion rates for the next 40 years. The setback rate is not constant for the entire dataset while also part of sedimentary equilibrium of this coast has probably been gradually restored within the last twenty years. Across the study site, a rather remarkable shoreline accretion is observed for the latest period (2018 - 2021). This, is a rather interesting finding, possibly related with the extensive Posidonia banquettes that have accumulated here, following the no removal strategy adopted by the Management Body of Schinias - Marathon Protected Area, since 2018. Thus, the presence of the banquette on a beach and the fine grained sediment enclosed in the banquettes, mitigates the erosion processes, can contribute to the sediment budget and affect positively the shoreline displacement. Therefore, the decisions of the extraction or not of such a formation must be taken under serious consideration.

Introduction

Coastal environments and, in particular, beaches are rapidly evolving systems, driven by the continuous interaction of the topography and transport processes with wind,

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wave and tidal forcing. In order to understand and quantify coastal morphodynamics, it is necessary to acquire high-resolution data on beach topographic changes [3]. In the present study the UAV (*Unmanned Aerial Vehicle*) was used in order to map with great detail the beach morphological characteristics, in combination with the study of the shoreline displacement over time with a view to assessing the impact of the presence of *Posidonia oceanica* beach-cast organic material [10] on the coastal front. When in large accumulations, these deposits may develop characteristic formations on the lower shore known as banquettes [2]. Shoreline stability and the recession of the erosional processes, due to the presence of the banquettes on the beach have been studied. The principal aim is to evaluate the relation between the banquettes, their different expansion-volume on the beach, and their significance as a natural protection of the beach against dominant wave dynamics [4].

The study area is the coastal plain of Schinias Bay and it is located in the northeast region of the Attica Prefecture, approximately 50 km from the centre of Athens (Fig. 1). The broader area of Schinias and Marathon is an area of special ecological and socio-economic importance due to the presence of several historical monuments, sports and military facilities, while also of intense agricultural and touristic activities in Attica. Additionally, SMNP is part of the Natura 2000 European Network of protected areas (GR3000016 - Schinias Wetland and GR 3000003 – Schinias-Marathon National Park). The area is part of the southern Euboean Gulf, with an orientation of NE to SW. In particular our test site is located in the northern tip of Schinias Bay. This region is limited by the Kynosoura peninsula to the east and comprises a channel mouth draining a small lagoon. The marine counterpart of the area has been mainly designated for the presence of extensive *Posidonia oceanica* meadows of variable extend form along the beach almost annually at least for the past 4 decades.

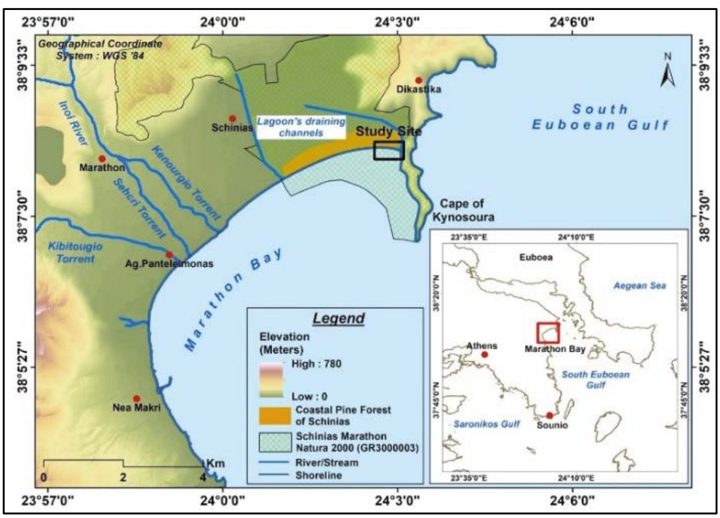


Figure 1 – The location of the study area in Marathon Bay, the physiographic setting of the coastal plain of Marathon, the torrents of the coastal plain and the lagoon's draining channel and also the limits of the Schinias - Marathon National Park. The lower right map also depicts the location of marathon bay in the wider area of Attica peninsula [6].

Materials and Methods

UAV data collection and field survey

DJI Matrice 210 RTK was used for data acquisition. For this survey the sensor Zenmuse X5S was selected. This sensor is CMOS, 4/3", it can collect RGB images with 20.8MP of effective Pixels. The photo resolutions are in 4:3, 5280×3956 and in 16:9, 5280×2970. It is also equipped with RTK technology, which expands its capabilities as it is extremely steady on flight (±10 cm on air) even with strong winds. Due to the smoothness of the terrain (almost flat as it is a beach front) the flights were horizontal parallel to the ground at a certain height AGL (Above Ground Level) [11]. The sensor of the UAV is pointed in 80 degrees (nadir). The images were taken in a specific overlap, in order to achieve 3D reconstruction of the relief, which led to the volume measurement of the different concentrations of the banquettes onshore. The software used to make the flight plans is the Pix4D capture (v.4.12.1). We use Ground Control Points (GCPs) to increase the accuracy of the UAV imagery to centimeter level [5]. At least 5 GCPs were used for each Mission of his study. They also improve the results from the Structure from Motion (SfM) interpretation of the photogrammetry process [13]. Prior to the flight the GCPs were surveyed with RTK GPS. The results from the RTK GPS survey along with the images collected from the drone flights were interpretated through Pix4D mapper v.4.5.6. in order to produce the orthomosaics, the Digital Surface Models (DSM) and the Digital Terrain Models (DTM), in order to calculate accurately the fluctuations of the volume of the banquettes during different seasons.

Sediment sampling

Sediment samples were collected during the photogrammetry missions (July 2020, September 2020, February 2021, June 2021). The sites where the sediments were acquired are in general, on the shoreline and on the shoreline area of the banquettes, forming transects, spaced approximately 50 m apart each other, in order to have a better image of the relation between the presence of the banquettes and the granulometry of the sediments. A GPS device was used to have the exact coordinates of the sampling sites with accuracy of ±3 m. The sampling sites varied during each mission because of the beach morphology and the movement of the banquettes.

The granulometric analyses conducted at the Bio-Geo-Chemical Laboratory (ISO 17025) of HCMR. Firstly, some of the samples taken from the banquettes were wet sieved with Calgon (Sodium Hexaphosphate -(NaPO3)6) (sieve diameter 4mm) to withdraw any grain from the leaves, in order to calculate the total amount/volume of sediments entrapped in the banquette. Then the rest of the samples, along with the sand which had been withdraw from Posidonia leaves, were dried in the oven in 45 °C for two days and they were sieved (sieves from 4 mm to <63 μm). Additionally, the results were interpretated statistically through the Gradistat v. 8.0 [1], in order to define the quality and the quantity of the distinctive sediment classes.

Shoreline Displacement Analysis

The survey of long-term shoreline displacements was carried out by comparing historical and contemporary aerial photographs (1945, 1960, 1969, 1988, 1996, 2001, 2010) along with satellite imagery (2012, 2014, 2018) and orthophotomosaic from photographs obtained using Unmanned Aerial Vehicle (2021) covering a period of 76 years (1945 - 2021). The shoreline uncertainty variable for each shoreline was defined as the spatial resolution (cell size) of the corresponding mosaic or image whose shoreline was digitized. Based on this approach regarding the shoreline uncertainty and consequently the error of the results, the accuracy of each shoreline from the available data, with the series mentioned above, was 1 m, 1 m, 0.64 m, 0.67 m, 1 m, 0.49 m, 0.25 m, 0.49 m, 5 m, 3 m and 0.027 m respectively. The satellite images (with a resolution of 3 and 5 m respectively) raise the error of the results. Nevertheless, because the rest of the data is of high accuracy, we can say that the accuracy of the results is of the order of +/- 1 m since we know in each result which shorelines interacted more and we have a fairly good knowledge of the study area. The quantification of long-term shoreline displacements was made with the use of the add-on application of Digital Shoreline Analysis System (DSAS) within the GIS platform ArcMap 10.6 [7]. This was accomplished by assessing 68 transects (every 10 meters), placed perpendicular relatively to the historical shorelines from a stable baseline [12]. At each transect the Net Shoreline Movement (NSM), the Shoreline Change Envelope (SCE), the End Point Rate (EPR) and Linear Regression Rate (LRR) was calculated and analyzed. All distances were calculated in meters, while the rate of change in meters per year (m / y). For a comprehensive overview regarding the trend of the shoreline and the interpretation of the results, the analysis was also applied along the wider area of the Schinias pine forest, i.e., along 3 200 m of shoreline (or hereafter study area).

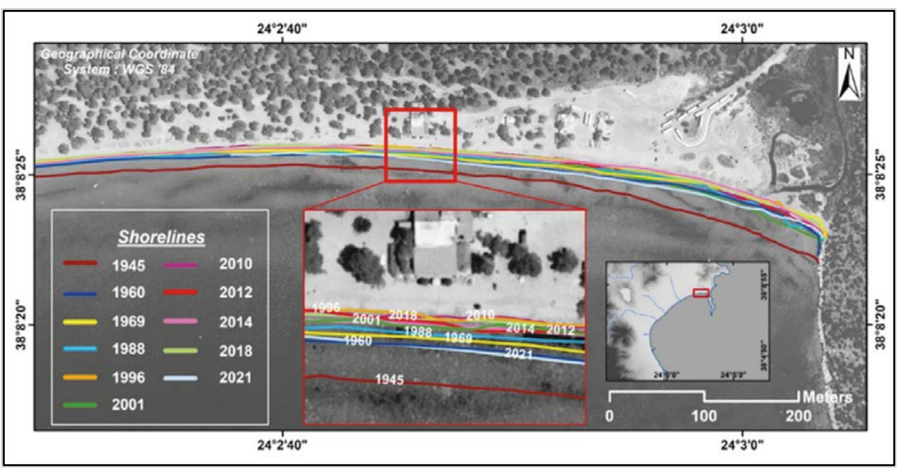
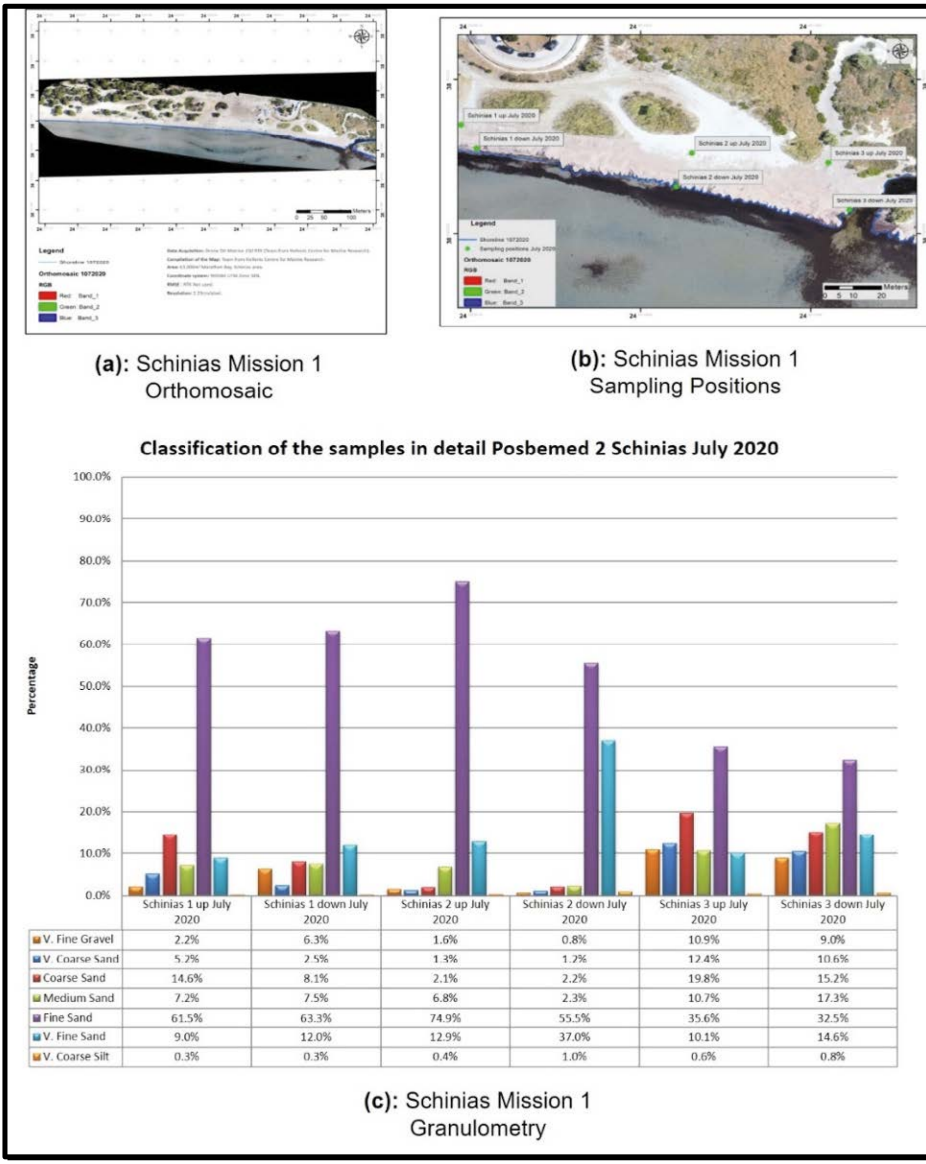


Figure 2 – All the digitized historical shorelines at the study site.

Results

According to UAV photogrammetry data processing the maximum banquette deposition is encountered during Mission 3 (February 2021). This fact can be explained by



	Schinias 1 up July 2020	Schinias 1 down July 2020	Schinias 2 up July 2020	Schinias 2 down July 2020	Schinias 3 up July 2020	Schinias 3 down July 2020
V. Fine Gravel	2.2%	6.3%	1.6%	0.8%	10.9%	9.0%
V. Coarse Sand	5.2%	2.5%	1.3%	1.2%	12.4%	10.6%
Coarse Sand	14.6%	8.1%	2.1%	2.2%	19.8%	15.2%
Medium Sand	7.2%	7.5%	6.8%	2.3%	10.7%	17.3%
Fine Sand	61.5%	63.3%	74.9%	55.5%	35.6%	32.5%
V. Fine Sand	9.0%	12.0%	12.9%	37.0%	10.1%	14.6%
V. Coarse Silt	0.3%	0.3%	0.4%	1.0%	0.6%	0.8%

Figure 3 – Mission 1.

the dead leaves deposition mechanism which is very active during winter. Therefore, this observation enhances this study's results showing that the largest deposition of Posidonia dead leaves occurred between September 2020 (Mission 2 – Fig.4) and February 2021 (Mission 3 - Fig.5). In that period also the maximum volume of the sediment entrapped in the banquette calculated in this study (~161.17 ±2.76 m^3 minimum-2 large trucks transporting solid materials and ~1692.26 ±312.52 m^3 maximum-16 large trucks transporting solid materials). Both calculations-scenarios (minimum-maximum) indicating the obligation of the proper management (rationally remove or not remove at all the banquettes) in order not to lose all this amount of sediments, that is very difficult to accumulate to the beach since no physical nourishment mechanisms exist. Another significant factor explaining banquette deposition dynamics is their height. It is obvious that the maximum height of the banquette ranging from 1 m Profile A-A’ Mission 2 (September 2020), to 0.20 m Profile C-C’ Mission 4 (June 2021). Summarizing the banquette’s main deposition mostly occurs after autumn, during the final phases of a storm event, when wave energy decreases. During Mission 3 the banquette shows its maximum extension. Other significant results originated from the granulometric analysis of each sample and then in all classes of each Mission separately (Fig. 3, 4, 5 and 6). In all Missions it is observed that the dominant class is fine sand, a fact that clearly reveals the protective role of the banquette. In general, the larger percentage of sediments can be characterized as sand (over 90 %). Deposition of coarser sediments is observed during Mission 1 (July 2020) and Mission 4 (June 2021).

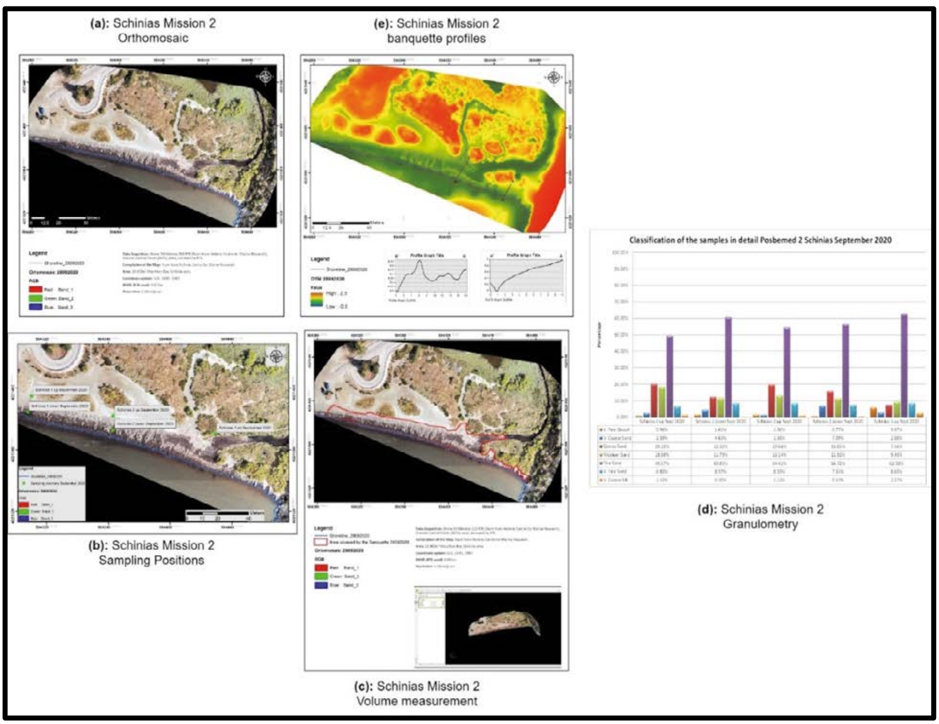


Figure 4 – Mission 2.

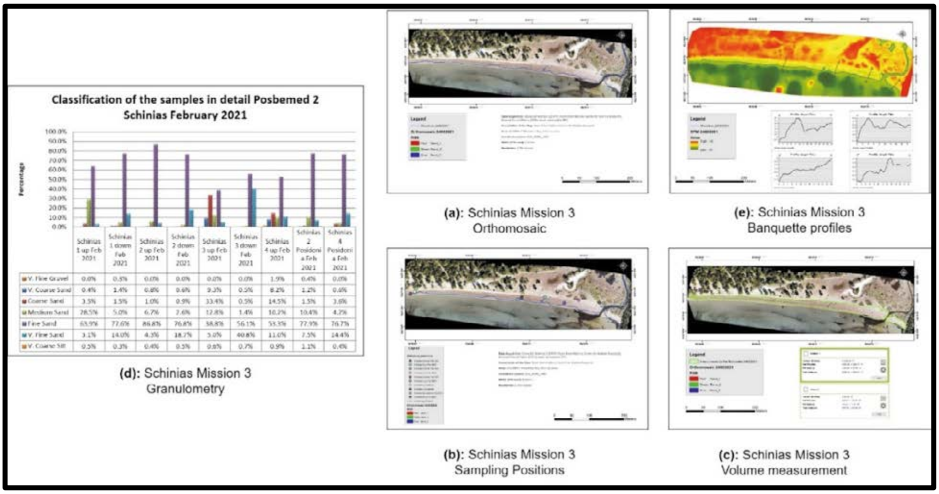


Figure 5 – Mission 3.

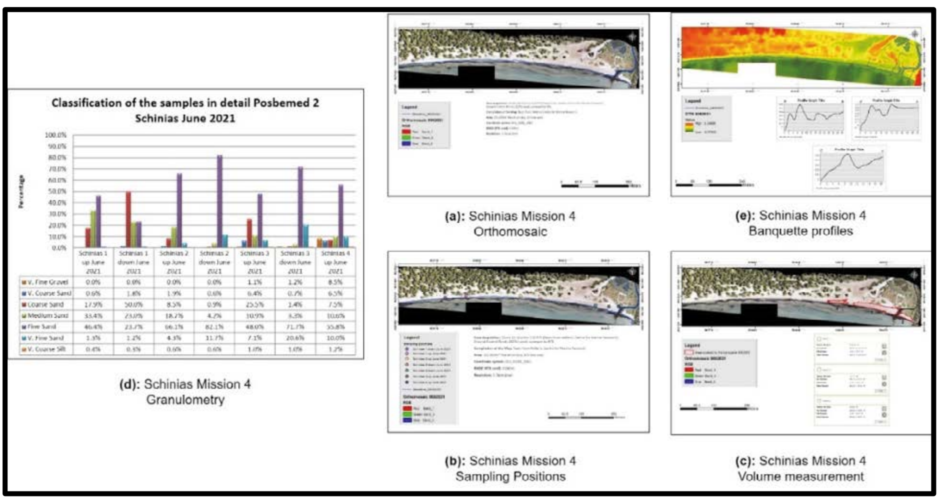


Figure 6 – Mission 4.

The results of NSM shown that the shoreline has undergone retreat in the last 76 years. The largest changes (25 - 30 m) are observed at the eastern part, with the maximum value (-30 m) at transect 3 at the eastern end of the beach. From east to west, values gradually decrease (from transect 30 to 68 values range from -10 to -12.5 meters). The average change of the shoreline across the study site is –15.3 m. The SCE values range from 20 m (transect 61) to 40 m (transect 6). Based on the EPR, the average displacement rate in the study area shows only negative values (shoreline retreat) for the period 1945 – 2021 (Figure 7a). The maximum setback value is found in transect 3 (-0.39 m / yr.) and the minimum in transect 43 (-0.14 m / yr.). The overall average shoreline retreat rate for the study site is 0.2 m / yr. The study of the Linear Regression Rate (LRR) shown that the setback rate has been estimated not to have been constant (Figure 7b, c, d and e): changes from the period 1945 – 1969, where the shoreline is constantly eroding with the higher rates, to the period 1969 – 1996, where erosion rates decreased significantly. Within 1996 advance of the shoreline is first observed, then alternating with periods of setback until 2010. Within 2010 - 2018, shoreline advance becomes more frequent (while again alternating with periods of retreat). Also 2014–2018, milder setback (and even advance) values are generally observed along the study area, particularly pronounced at the easternmost part of beach where the greatest setbacks had been previously detected. Finally, a rather remarkable shoreline accretion is observed for the latest period (2018 - 2021).

Discussion

The key novelty of this study is not only that static information on the shore of the study area is shown on the different products, but also the accurate estimation of the sedimentary volume entrapped in the banquette is also calculated due to the use and combination of state-of-the-art methods and techniques for the study of the Schinias beachfront. The banquette affects directly the sediment deposition, and consequently the granulometry of the beach sediments, providing a low energy environment as indicated by fine sand accumulated therein. Indeed, fine-grained sediments are more likely to be eroded and transported to the sea during strong winds-waves. Thus, the amount of such sediments entrapped in banquettes in our study area, can contribute to the sediment budget of this coastal zone, highlighting the key role of the banquettes in microtidal embayed Mediterranean beaches. The volume of the banquette varies significantly between seasons and is affected by local weather conditions, especially strong eastern-southeastern winds for the case of Schinias.

Based on the shoreline displacement data, the study area seems to be subjected to coastal erosion since 1945, resulting to a loss of land surface of the order of 10,189 m^2. The operation of the Marathon Dam in 1929 severely disturbed the sedimentological balance of the wider coast resulting high rates of shoreline retreat for the period 1945 – 1969. Part of the coastal sedimentological balance was rather restored from the 80's onwards, based on the shoreline analysis which indicated decrease of the retreat rates and periods of shoreline advance began to appear since then. Although the study area appears more sheltered due to Kynosoura cape, it presents higher changes and retreat rates as compared to the western part of Schinias beach. Regarding the correlation of the shoreline with the Posidonia banquettes, noteworthy is the position of the shoreline on 2018, when a non-removal strategy for Posidonia banquettes was set forth by the Management Body of SMNP, presenting lower setback values and even mild advance at the study area, where indeed the greatest setbacks had been previously detected. Moreover, this finding stands out against the general situation characterizing the wider beach of Schinias (beyond the study area), where setback values remain constant for the same period [8]. Also, a rather remarkable shoreline accretion is observed for the latest period (2018 - 2021) across the study area, which could be likely directly related with the extensive Posidonia banquettes that have undisturbed accumulated here this last couple of years.

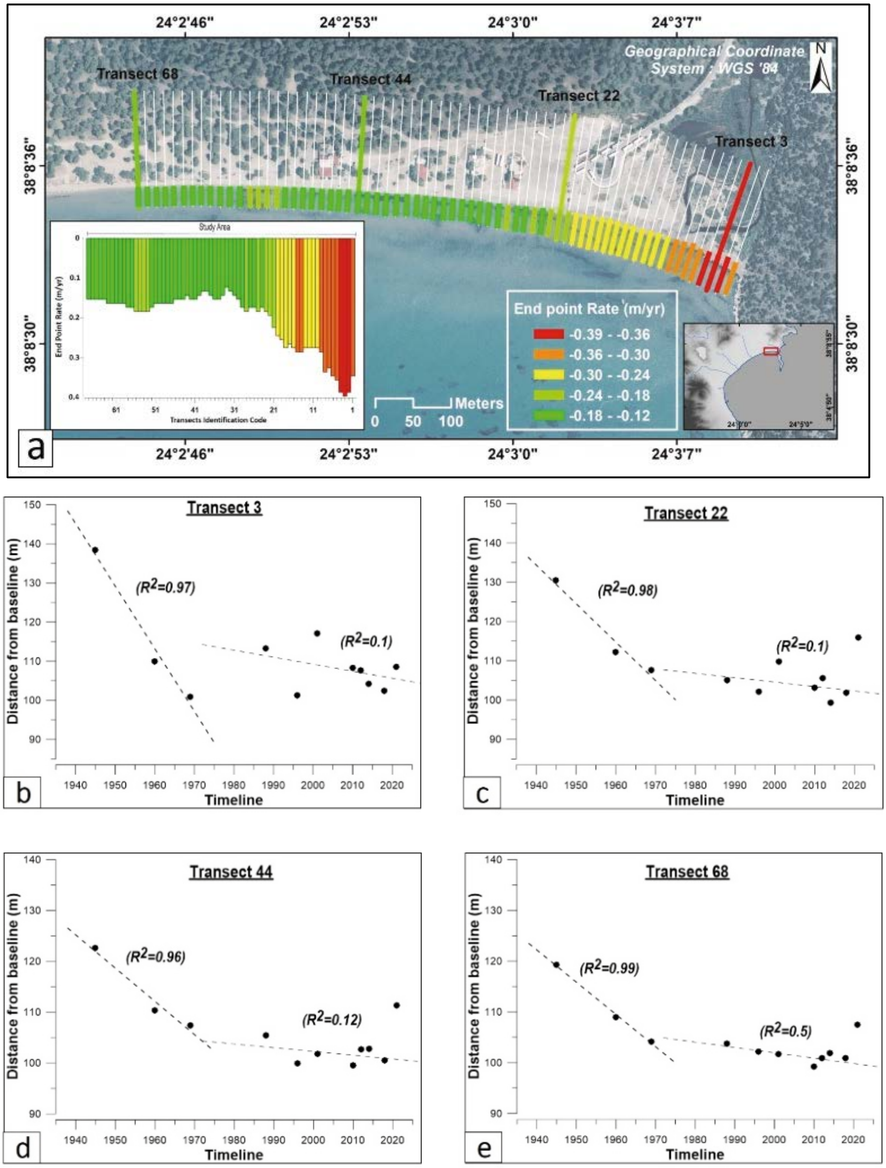


Figure 7 – Representation of the shoreline displacement rate (EPR) at each transect (in meters per year) across the study area, for the period 1945 – 2021(a) and the positions where the representative transect 3 (b), 22 (c), 44 (d) and 68 (e) intersects the shorelines as well as the linear correlation of the points at each transect.

Conclusion

The fluctuations of the area covered by the banquette, the shoreline displacement and the sediment deposition on shore, along with the geomorphologically sheltered environment, make the role of the banquette particularly significant for our study area. Coastal displacement has been estimated approximately 20 m (erosion) since 1945 [9] and it would only be higher but for Posidonia banquettes accumulation, since the main sediment supply comes from marine and aeolian processes. The draining channel doesn't provide significant amount of sediment since it has not an extensive drainage network. Against the general erosion trend characterizing the wider study area [9], banquette accretion contributed to shoreline advance (~1 m maximum) within the time frame of this study, further indicating the protective role of these natural features; more long-term monitoring is however necessary to better understand long-term trends in this process. High-resolution photos taken from the drone along with the centimetre accuracy performed by the GNSS-RTK (DGPS) provide exquisite data for such surveys. More extensive monitoring, considering both long-term and seasonal changes is required. In this way, coastal trends and spatiotemporal sedimentological changes in direct relation with key environmental factors will be better comprehended, providing valuable input to management planning and decision-making processes for this area of high ecological interest.

Acknowledgements

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SESSION

COASTLINE GEOGRAPHY AND COASTAL LANDSCAPES: TERRITORIAL DYNAMICS AND INTEGRATED PROTECTION

Chairperson: Donatella Privitera
Department of Educational Sciences
University of Catania

COASTLINE GEOGRAPHY AND COASTAL LANDSCAPES: TERRITORIAL DYNAMICS AND INTEGRATED PROTECTION

Coastal areas are strategically important in the Mediterranean, one of the most important centers of biodiversity in the world, as they perform natural, residential, recreational and commercial functions of particular relevance and ancient tradition. The protection and development of coastal areas must therefore take into consideration the physical, environmental, landscape and cultural characteristics of the reference territory and of the society involved.

The Session focused on the potential and criticality of the geographic, landscape, economic, legislative, and socio-cultural aspects, as well as the various forms of anthropization and environmental restoration, which affect the Mediterranean coastal territories and waterfronts.

The Session included, moreover, a total of 23 articles coming from different countries. Specially the thematic area dedicated to the geography coastal strip, to the dynamics of landscapes and anthropized areas; to the history, description and classification of the landscape, to its design, planning, legislation and integrated management. Other topics of the session were the relationship between economic activities, urbanization and sustainable development; the importance of protected areas in participatory and shared territorial governance.

All papers here published provide relevant insights about important aspects of coastline geography and coastal landscapes in several districts and also countries. Since it is impossible to describe all contents of the articles in this short introduction, the focus is only on a few main insights from each paper.

Dhiab Rym et al. in *Beach macro-litter monitoring on Monastir coastal sea (Tunisia): First Findings* investigated the macrolitter on three beaches on Monastir coastal (Palmier, Marina, Karaia) and on Kuriat Island during four seasons.

Farris et al. present an integrated approach to the marine litter hot spots identification with the contribution *An integrated approach for marine litter hot spots identification*, where the results come from a coordinate activity of filed campaigns, satellite monitoring and numerical model simulations.

Also, Buoninsegni et al. in *Marine litter surveys on Boccasette beach (Rovigo, Italy)* examine the abundance and accumulation of the beach marine litter in relation to the main human activities and during some different meteorological conditions. The study area is the Veneto Regional Park of Po Delta (northern Adriatic Sea).

FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Laura Bonora, Donatella Carboni, Matteo De Vincenzi, Giorgio Matteucci (edited by), *Ninth International Symposium "Monitoring of Mediterranean Coastal Areas: Problems and Measurement Techniques". Livorno (Italy) 14th-16th June 2022*, © 2022 Author(s), CC BY-NC-SA 4.0, published by Firenze University Press, ISBN 979-12-215-0030-1, DOI 10.36253/979-12-215-0030-1

In *Trieste, back to the sea. Designing sustainability and development of logistics and industrial port areas after the pandemic* Bisiani traces the stages of a long process of safety and industrial reconvention of an industrial polluted area, a typical "brownfiled", within the port of Trieste.

D'Ascola et al. in *Monitoring of the evolution of "barene" borders and the safeguard of the Venice Lagoon morphology: a contribution from the Coastal Change from Space project results* study the acquisition of a time series from optical satellites to observe changes in the Venice lagoon.

Candura et al. in *The economic and environmental impact of large ships on the territory, on the coast and on the sea: the MSC cruises case study* aims to participate in the reflection on the theme of sustainability, which is also abused lexically, to look at the possibility of directing cruise tourism towards a new way of introducing man into the landscape.

Sopina et al. with the research *Spatial Planning Influence on Changeability Process of Urban and Natural (Land)scape Relation: Understanding the dynamics of Ancona on the West and Rijeka on the East Adriatic Coast* aim to investigate how spatial planning guides the changeability process of landscape relations in the Adriatic cities of Ancona and Rijeka settled between two strong natural elements of the sea and the mountains. The study interconnects the heritage urbanism approach and the urbanscape emanation concept in establishing identity factors, evaluation criteria, and enhancement models.

Ivona et al. in *Old landscapes and new functions. Coastal architectures redesign the geography of the coastal belts* focus their attention on one of the most symbolic maritime cultural assets: lighthouses, of how they could become resources for sustainable development on the social, economic, touristic and cultural levels.

Ladu and Marras in *Nature protection and local development: A study concerning a natural park located in Sardinia (Italy)*, after a first introduction on the state of planning of natural parks in the Sardinian Region, analyze the case study and proposes a planning methodology that supports plan-making processes concerning natural parks.

In *Water, heritage, and city. Urbanized deltas on the line between nature and culture*, Luciani show the complex conflictual that emerges when urbanized water lines are addressed through planning and design, providing an overview of some key themes in urban and spatial regeneration theory and practice.

In *Coastal dunes along the Marche littoral (Adriatic side of Central Italy)* of Bisci et al. are synthetically reported the results of a critical analysis of the main features of both relict dunal coastal areas and scarcely anthropized zones located along the littoral of the Marche Region (Adriatic side of Central Italy).

The contribution of Carboni et al. - *Fishing and territory. Status and Perspectives of Sardinia artisanal Fischeries* - intends to suggest a survey on the dynamics related to fishing activity in Sardinia. The study outlines small-scale fishing in the Marine Protected Area of Asinara Island and fosters knowledge and evolution of artisanal fishing activities in the study area.

Cazzani et al. in *Analysis and survey of Lake Garda lemon houses: A tool to understand and manage a Mediterranean landscape in Lombardy study* tell Lake Garda mild microclimate allowed the settlement and flourishing of a peculiar cultivation, that of the *limonaie* (lemon houses).

While the aim of Dorigatti et al. in *Marine protected areas and the problem of paper parks* is to briefly overview paper parks problem regarding Marine Protected Areas (MPAs).

Simeone et al. in *Development of a sustainable accessibility model for the Marine Protected Area Gaiola Underwater Park, in Naples, Italy* aim to show and discuss the results obtained from the application of the new fruition model of accessibility of MPA Gaiola that allowed to keep a safe environment, a more respectful preservation of the environmental and cultural heritage of the Park and, at the same time, a safer and more enjoyable experience for bathers and visitors.

Giordano et al. in *The environmental function analysis: a promising tool to evaluate the coastal zone conservation potential* examines reports and compares the application and usefulness of the Environmental Function Analysis (EFA) tool to discover the potential for conservation of two very different coastal areas located along the Campania Region (Southern Italy).

Pombo et al. in *Protecting Vagueira (Portugal) waterfront: preserving natural, recreational, residential, and commercial functions* determine if the deployment of a detached breakwater in front of Vagueira beach (Portugal) would help protect the coastal community and safeguard its natural services and general assets.

In the same direction, is the article of Russo - *The territorial organization of the Amalfi Coast: nature and man's intervention* - with aim to analyze the natural and anthropogenic components of the coast Amalfi, today threatened by geological instability and by the growing demands related to traffic and mass tourism.

In *Land use analysis and coastal structures: Adriatic coast as a case study*, Montaldi et al. focus on the territory, that extends from Monte Conero (municipality of Ancona) to the municipality of San Salvo in Chieti province showing how the dynamics of coastal settlement, albeit with reduced intensity compared to the recent past, continue to erode soils of ecologically fragile environments.

Altavilla et al. in *The development of "sustainable" surveillance and monitoring activities carried out by the italian coast guard for the safeguard of the marine protected areas* highlight the responsibility of the Italian Coast Guard (ITCG), according to the current regulatory framework, of the surveillance of the Marine Protected Areas (MPAs) and also fulfills essential maritime environmental police tasks in order to protect the maritime and coastal environment.

Saragosa and Chiti analyze in *Atmospheric agents and spatial planning. Case study of the Municipality of Rosignano Marittimo in Tuscany* the physical definition of the coastal system and the management of same, that sets the goal of defining a possible methodological approach through the presentation of the case study Rosignano Marittimo for territorial planning in coastal areas, able to define a flexible cognitive framework, by means of which to distinguish strategies in the short and long term, for planning and managing of maritime state property assets.

Savino et al. present in *A new proposal for a strategic and resilient regeneration plan for seaside waterfronts. An Adriatic case: Riccione* a proposal for a planning strategy to ensure a sustainable and resilient development for large urban seaside resorts. In fact, the paper is intended to present an innovative focus on the coastline topic, moving from the analysis of the seaside waterfront's peculiar features but refusing the current separation of border areas (seashore, beach, promenade, and buildings overlooking the seaside) from the rest of the urban organization.

Finally, Spagnoli and Piferi carry out in *Regeneration of historic centers in Mediterranean cities: the case study of the Venice district in Livorno* an experience of design research, aimed at the regeneration of a portion of the waterfront of the city of Livorno, which is now fragmented and in a state of decay. The research proposes a new spatial arrangement through the re-functionalization of the building and the design of all the access systems to the area, driveways, pedestrian and cycle paths, which can allow its proper use by citizens and tourists.

Concluding this short introduction, I'd like to thank all the authors for their valuable articles, also the scientific and organizing committee for all the help during the Symposium. I wish all of you together to scientific committee of this session a pleasure and interesting read of the articles published.

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THE DEVELOPMENT OF "SUSTAINABLE" SURVEILLANCE AND MONITORING ACTIVITIES CARRIED OUT BY THE ITALIAN COAST GUARD FOR THE SAFEGUARD OF THE MARINE PROTECTED AREAS

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Abstract – The Mediterranean Sea represents one of the richest sites in terms of biodiversity on our planet, however, considering the nature of a semi-closed basin, it is subject to limited water exchanges with other seas, thus making it sensible to risk of pollution due to either intense ship traffic, building speculation and high number of inhabitants living along the coastal areas. The peculiar bio-geomorphological formations, which characterize the Italian peninsula, makes it a region of significant natural and environmental value, whose integrity, however, is strongly affected by the high anthropic impact that persists along the 8,000 km of coastline. The need of safeguarding this natural heritage, has led the Ministry of Ecological Transition (MiTE) to implement a strong policy of protection, regarding the national Marine Protected Areas - up to now 29, to which are to be added two submerged parks (Baia and Gaiola) and the Pelagos Sanctuary for Marine Mammals - which have gain great scientific, ecological, cultural and economic importance. Those areas are subject to environmental protection and specific regulations.

The Italian Coast Guard (ITCG), according to the current regulatory framework, is responsible of the surveillance of the Marine Protected Areas (MPAs) and also fulfils essential maritime environmental police tasks in order to protect the maritime and coastal environment. Over the years, specific environmental maritime police campaigns and complex operational activities have been planned and carried out with the aim of combining the protection of the maritime environment, the safeguard of coasts and biological resources, which are closely connected with each other, through the use of the aero-naval assets and ITCG specialized units able to discover, analyse and repress illegal phenomena that may harm the environment. This methodological approach has allowed to increase the effectiveness of deterrence and prevention of harmful behaviours.

The ITCG also carries out environmental monitoring activities through implementation of recent electrical powered vehicles and instruments which are best suitable for temperature anomalies detection of sea water, granting an observation of impacts related to climate change, especially in those protected mentioned areas. All the information acquired over time will be integrated in a database and will provide useful information to define projections on the evolution of climate change which would be essential for the decision-making process aimed to prevent harmful impacts on natural ecosystems.

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Introduction

The protection of the marine and coastal environment represents one of the main institutional tasks of the Coast Guard [2], let alone one of the priority objectives to pursue, is for the wealth of the national naturalistic patrimony, both for the relevant social, economic and cultural interests involved in the enhancement and use of the relevant resources. The safeguard activity that the Coast Guard is able to guarantee through the employment of the operating members is constant and detailed, despite the remarkable extension of the coastline of our Country witch pairs to approximately 8000 km and is due to the ability to express specific skills on the national territory, as well as in international scenarios.

The Coast Guard, also considering its vocation for natural environmental, functionally depends by the Ministry of Ecological Transition and, within the powers established by the current legislative framework, carries out numerous activities to protect the marine and coastal environment not only in the MM.PP.AA. but also, in all the other sea areas under the jurisdiction of the State and subject to particular constraints of environmental protection (Ecological Protection Zones, Natura 2000 areas covered by Directive 92/43/EEC, etc.).

In those fields, the Coast Guard carries out controls of the supply chain of the traffics of the refusals, with specific reference to the marine, coastal and harbour extents, of the water releases (d.lgs 152/2006) and on the introduction of pollutants into the atmosphere by ships, including under international conventions.

In regard of those dependencies, periodically, the Ministry of Ecological Transition stipulates with the Coast Guard, conventions for carrying out targeted activities of prevention and contrast against marine pollution and strengthening the surveillance in Marine Protected Areas and marine areas where oil platforms for the extraction of oily hydrocarbons insist.

With Ministerial Decree n. 38 of 09/02/2018, it has been approved the "Relaunch Plan of the environmental strategy" of the Coast Guard, through which has been set as objective the pursuing of consolidation and development of the functional lines in order to protect the marine and coastal ecosystem. In this context, the 3 Department "Plans and Operations" of the ITCG Headquarters, periodically prepares a program that involves all territorial Commands [3] in coordinating the activity of the aerial and naval assets and the specialized crew members for an integrated approach, which provides a synergic and coordinated use of all the specialized instruments of the Coast Guard (underwater, scientific [4], remote sensing), with the aim of covering the entire investigative spectrum and obtaining the maximum result in terms of surveillance, identification of polluting sources, coming from land or from maritime carriers, and assessment of the illegal activities that threaten the marine-coastal environment and its biodiversity.

This approach becomes even more essential in the development of certain Environmental Campaigns where the multiplicity of resources involved for the achievement of the different purposes (training, educational, media and operational [1]) requires a management capable of ensuring a coherent and coordinated use of the structures, organised on the basis of uniform national rules and procedures, governing the use of the components in the activities of support to the peripheral Maritime Offices.

Figure 1 and 2 – ITCG asset and sea water sampling operation.

Materials and Methods

In order to assure the role of the Coast Guard as an operational instrument for the implementation of the functions regarding the protection of the marine and coastal environment, on behalf of Ministry of Ecological Transition, a complex "Environmental Strategy" has been drawn up and approved, characterizing the activities of marine environmental police carried out by the ITCG staff.

As part of the Environmental Strategy, the operation "Environmental Campaign in the Mediterranean", planned and coordinated by the Plans and Operations Department of ITCG Headquarters, provided a coordinated and synergistic use of the specialist components. The main objective of the environmental campaign is summarized in a line of action that can combine the "protection of the marine environment, the defense of coasts and biological resources", closely related aspects, by the use of the aero-naval assets and the specialized supplied instruments finalized at discovering, analyse and immediately repress illicit phenomena that may affect the environment.

The ICG has deployed a Dattilo class Ships, able to carry out multipurpose operations including the command and control in complex scenarios and to use specialized teams, such as the aerial section executing environmental remote sensing activities, through airborne systems on fixed wing, such as the fixed wing ATR42MP, and the rotary wing AW139CP. Those assets are located at the Air Bases of Sarzana, Catania, Pescara and Decimomannu and can be scrambled throughout the national territory each equipped with different operational equipment:

Deadalus Scanner LLC AA 1268 EM (on ATR42MP)

The airborne multispectral scanner "Sensytec AA1268 ATM ENHANCED", is a multispectral scanning system, used for the realization of thematic maps - for example temperature maps - containing qualitative and quantitative information that properly elaborated and analyzed, can allow the identification and monitoring of pollution phenomena related to urban and industrial discharges, etc. With the acquisition of data of energy reflected and emitted from the surface flown over, wich can create up to 12 digital grayscale images, each of which, as a function in the electromagnetic range of relevance recording the behavior of the surface.

S.L.A.R. - Side Looking Airborne Radar (on ATR42MP)
SLAR is an active sensor that measures the "roughness" of the sea surface. Microwave pulse transmission (X-band) occurs on both sides of the aircraft, allowing coverage of a total area of about 40 NM. The operation of the system is based on the phenomenon of the reduction of capillary waves induced by the presence of oily substances on the surface of the sea, highlighting the area affected by the anomaly as a dark spot in contrast to the surrounding area and is able to detect even thin films of pollutants.

E.O. (Electro-optical) Turret Wescam MX-20 (on ATR42MP)
It's an electro-optical system that consists of the following sensors and provides georeferenced images and videos, such as: High-definition color camera (Daylight camera) - EOW (Electro-optical Wide); Dual channel spotter (Daylight spotter camera/SWIR camera) - EON (Electro-optical Narrow); I.R. Camera.

F.L.I.R. (Forward Looking Infra Red) STAR SAFIRE (on AW139CP)
It's an electro-optical system that consists of four sensors and provides georeferenced images and videos such as High Definition Color Camera (H.D.E.O.); Low Brightness Color Camera (H.D.L.L.); High Definition Infrared Camera (H.D.I.R.) and short wave infrared camera (S.W.I.R.).

Figure 3 and 4 – Remote sensing systems installed on board ATR42MP aircraft and AW139CP helicopters.

For underwater operations sub operators for the prospection of the seabed and the visual Census have been employed. The section of the Coast Guard makes use of 5 Divers Units (San Benedetto del Tronto, Napoli, Messina, Cagliari, Genova), which are entrusted with some important environmental tasks, including: monitoring and control of MPAs, water sampling for detection and monitoring of marine pollution; surveillance of archaeological marine sites; and inspection of ships, platforms and submarine pipelines. During the environmental police activities and campaigns, divers have been involved in the recovery of ghost nets which are harmful for the fish stock and the ecosystem.

Figure 5 – Divers engaged in the recovery of a ghost net during the environmental campaign.

On board the Dattilo class Ships, personnel belonging to the scientific section Environmental Analysis Laboratory was also employed for the execution of sampling and analysis of water.

The Laboratory Environmental Analysis of the ITCG "CF (CP) Natale DE GRAZIA" consists of 2 Mobile Environmental Laboratories (LAM) and a traditional Laboratory (LAB) located at Fiumicino local Office. The Laboratory is run by chartered biologists and duly trained technicians able to perform both the sampling and analytical phase, using LAM and LAB instruments.

The Laboratory, thanks to its peculiar organization, can operate in dual use: ITCG employs the LAM asset to carry out sampling activities and on field analysis, and LAB asset to perform the full range of analysis by using more advanced equipment to analyse the water samples provided by the local CG Offices.

In December 2021 an important milestone was reached: the accreditation of the Laboratory Environmental Analysis "CF (CP) Natale DE GRAZIA", which is added to the quality certification ISO 9001, issued by RINA in 2013.

ACCREDIA, Single National Accreditation Body, has issued the certificate attesting the competence, independence and impartiality of the Laboratory in compliance with the requirements of the technical standard UNI EN ISO IEC 17025 strengthening even more the validity of the analytical results obtained in the laboratory and used in administrative and criminal proceedings.

Figure 6 – Environmental Analysis Laboratory.

The planning of the environmental campaign has been divided into 3 different modules, involving the regions of Campania (first experimental phase), Apulia and Sicily.

The operational activities have been executed in the Italian Marine Protected Areas already established, since notoriously they are of particular value from the naturalistic and environmental point of view. Moreover, this decision is in line with the provisions of the agreement between MITE and ITCG Headquarters, signed on 21 December 2017, namely to carry out a targeted and enhanced supervision and surveillance activity in the Italian MPAs.

At the same time, the Coast Guard contributes to monitor and observe the temperatures and quality of marine waters, using electric and/or hybrid vehicles with low environmental impact and suitable technical instrumentation.

With the stipulation of a Specific Protocol, the ITCG Headquarters has committed to the Ministry of Ecological Transition: to implement services of observation and prevention of the impacts of climate change in Marine Protected Areas through the use of electric vehicles and related charging infrastructures to perform surveillance and monitoring activities in the MPAs, as well as of equipment for promoting and communicating sustainable mobility, energy efficiency and climate-altering emissions at local and central level; to monitor the biodiversity of plant and animal species, including initiatives to survey fish stocks, in order to have a constant knowledge of the resilience of ecosystems.


Figure 7 and 8 – Multiparameter probe and *in situ* monitoring.

In order to collect data useful to monitor the temperatures and quality of marine waters and to observe the effects of climate change and the consequent harmful impacts to natural ecosystems and communities, the ITCG has purchased and distributed no. 52 multi-parameter probes for the acquisition of some parameters in A, B and C zones of the MPAs. The information obtained is reported on the IT platform named "OCEAM" developed by the ITCG Marine Environmental Department (RAM), using the specific format "Temperature monitoring and water quality in MPAs." elaborated to this aim.

Since February 2021, values of 13 chemical-physical parameters have been recorded *in situ*, contributing to provide a general picture of the quality of water in the Italian MPAs. The parameters analyzed are: Redox potential, pH, Dissolved Oxygen, Electrical conductivity, Resistivity, TDS, Salinity, Density, and Temperature.

Operational and monitoring activities results

During the environmental campaign ITCG has employed two different naval unit (U. Diciotti and L. Dattilo Ship) and several specialized assets. The operational activities, reported in the table, were performed as described below.

Table 1 – Environmental campaign activities.

FIRST ENVIRONMENTAL CAMPAIGN			DAYS TOT. 3	
NAVAL UNIT	AERIAL MISSION	DIVING	SAMPLES	ANALYSIS
U. DICIOTTI	3 (ATR42, AW139)	5	24	200

SECOND ENVIRONMENTAL CAMPAIGN			DAYS TOT. 11	
NAVAL UNIT	AERIAL MISSION	DIVING	SAMPLES	ANALYSIS
U. DICIOTTI	2 (ATR42, AW139)	5	30	300

THIRD ENVIRONMENTAL CAMPAIGN			DAYS TOT. 10	
NAVAL UNIT	AERIAL MISSION	DIVING	SAMPLES	ANALYSIS
L. DATTILO	2 (ATR42, AW139)	5	30	300

Specifically, the use of the aircraft for TLR activities has highlighted some thermal anomalies at sea and on land, validated during the operational mission with the divers and the laboratory. During the first mission of the environmental campaign, the data received from the helicopter AW139CP allowed to detect discharges not surveyed later investigated by the Ischia local CG Office.

Figure 9 and 10 – Sampling operation on 23/10/2018 at a discharge in the marine protected area Kingdom of Neptune (island of Ischia) - thermal anomaly detected by remote sensing activity performed with FLIR.

The analyses carried out on the samples taken showed that certain parameters (COD and total phosphorus) set out in Table 3 of Annex 5 to Part Three of Legislative Decree 152/2006, the presence of which indicates the discharge of urban waste water, were exceeded.

As an example of the result obtained during the second module, the activity carried out at the MPA of Porto Cesareo is shown. In that context, the use of the aircraft for TLR activities carried out on 01.04.2019 revealed some thermal anomalies on the ground, including the following one, validated during the operational mission with the intervention of the laboratory staff. In particular the thermal anomaly n.18 of the section 2 has allowed to check on date 14.05.2019 the presence of an unauthorized discharge, sanctioned by the Porto Cesareo local CG Office pursuant art.124 co 1 of Legislative Decree 152/2006.

Figure 11 and 12 – Sampling operation on 14/05/2019 at a discharge in the MPA Porto Cesareo - thermal anomaly detected by remote sensing activity.

The analyses carried out on the sample showed that the total surfactant parameter established by Table 3 of Annex 5 to Part Three of Legislative Decree 152/2006, was exceeded; in addition, the presence of the bacterium *Escherichia coli,* which, although found with a value of colony-forming units of 300 CFU/100 ml and therefore much lower than the limit of 5 000 CFU/100 ml required by the standard, however, shows a contamination of faecal origin in a matrix that should be bacteria-free. Taken together, these data reveal the presence of urban waste water.

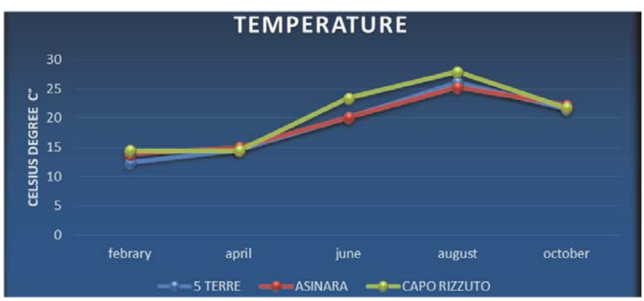
As an example of the result obtained during the third module, the activity carried out at the Isole Egadi MPA is shown. In that context, on 19.07.2019, during the inspection of the Marettimo island, the team verified the presence of an unlisted discharge at the quay of the old port.

Analysis of the sample showed that many of the parameters set out in Table 3 of Annex 5 to Part Three of Legislative Decree 152/2006 had been exceeded. In particular, the parameters ammoniacal nitrogen, sulphites, total surfactants, suspended solids, coarse materials and the bacterium *Escherichia coli* were found to be above the limits for discharge to surface waters. Taken as a whole, they indicate a discharge of urban waste water into the sea as it is.

Figure 13 – Sampling operation on 19/07/2019 in correspondence of a discharge in the MPA Isole Egadi (Marettimo island) - thermal anomaly detected by remote sensing activity.

In addition, in the course of the operations planned for the second and third modules of the environmental campaign, the crew on board and the personnel of the specialized assets have identified and collected both on the surface and on the bottom marine litter, of various types and of different origin, such as polystyrene containers, plastic bottles and small artisanal fishing gear as well as fishing nets. The plastic material has been identified in greater quantities in Marine Protected Area of Torre Guaceto (Brindisi - Apulia) and in smaller quantities in Sicilian MPAs. The presence and accumulation of this waste in the Torre Guaceto Marine Protected Area is presumably related to the presence of local currents and wave motion rather than to the actual improper tourist/ recreational activity in the protected area.

As regards the monitoring activity, by comparing the results obtained in 2021 with literature data available from open sources, it was found that none of the parameters examined showed outliers in relation to the average values found over time in the same areas. In particular, as reported below on the graph of the MPAs Cinque Terre, Isola dell'Asinara and Capo Rizzuto, the temperature range varies between 12 and 28 ºC during the various months of reference.



Graphic 1 – MPA Cinque Terre, MPA Isola dell'Asinara, MPA Capo Rizzuto – temperature values in °C - as can be seen from the graph the values fluctuate between 12 and 28 ºC in relation to the reference period and to the MPA.

Discussion

The activity carried out in MPAs of the Regions Campania (Regno di Nettuno and Santa Maria di Castellabate), Apulia (Porto Cesareo, Torre Guaceto and Isole Tremiti) and Sicily (Isole Egadi, Isola di Ustica, Capo Gallo and Isola delle Femmine) has been aimed to realize an efficient investigative tool that operates in a synergistic, coordinated and complementary way, in order to achieve the full spectrum of surveys in the field of environmental investigations. This approach is actually appreciated at regional level by the local Public Prosecutor's Office. On several occasions they have indeed invoked and invoke the intervention of the Coast Guard personnel and its specialized assets for the execution of specific environmental activities, trusting in their competence and expertise.

With regard to the monitoring of the parameters, it is reported that, to date, no abnormal values have been found for any of the recorded parameters, but to advance more precise considerations about possible changes in time, expects the availability of multi-annual data and time series, which will also be provided to ISPRA for further additional enhancement.

Conclusion

In conclusion, among the various strengths of the environmental campaign, it's worthy to highlight its innovative character; For the first time, in fact, the Plans and Operations Department has organized an operation so articulated, capable of implementing the core principle of the integrated approach to environmental protection; the multidisciplinary nature of the mission has made it possible to carry out a monitoring activity covering different areas among the ITCG institutional tasks, including fisheries supervision, environmental protection, investigation of any illegal activity in violation of the regulations of the MPAs. The prolonged stay in the area of the Coast Guard structure is a means of control for repressive purposes as well as an efficient preventive device for deterrence purposes. In addition, it is worth highlighting the readiness of the ITCG personnel to engage in activities other than purely institutional ones, such as the measurement of chemical-physical parameters for monitoring the quality of the marine environment. The synergic and multidisciplinary effort carried out by the ITCG has ensured significant results for the environmental protection, that has always been one of the most importance services provided by the ITCG for the well-being of the community. This integrated activity becomes even more important and impactful taking into consideration the current awakening of environmental consciousness and awareness in citizens and Institutions.

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BEACH MACRO-LITTER MONITORING ON MONASTIR COASTAL SEA (TUNISIA): FIRST FINDINGS

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Abstract – Monastir city is considered as one of the most important commercial capital in Tunisia. During the last decades, it has reported an increase in urban density and industrial activities (textile, agri-business industry, fishing activity offshore fish farm, etc.). The aim of this study is to provide information on the types, quantities, and distribution of marine debris and increasing public awareness of the coastline condition. The macrolitter monitoring activities was investigated on three beaches (Palmier, Marina, Karaia) and on Kuriat Island during four seasons (Winter, Spring, Summer, and Autumn). The operational toolkit used in this study was developed within the Interreg MED Plastic Busters MPAs Project and capitalized in the ENI CBC Med Common Project.
The highest abundance and density of macrolitter were recorded on Marina and Karaia beaches with respectively (13540 items/100 m; 8.49 items m^{-2}) and (6842 items/100 m; 6.11 items m^{-2}) during the spring season. According to the Clean Coast Index, these two beaches were classified as extremely dirty whereas Kuriat Island was considered as very clean. Plastic items corresponded to the highest concentration of litter in all studied sites and for all seasons varying between 69 % and 89 % of total items. Cigarette butts are the most frequent type of debris.

Introduction

Human activity and behavior, whether deliberate or unintentional, contribute to marine litter (debris). It is also the result of poor waste disposal and a lack of public awareness of the potential consequences of mismanagement [1]. Litter can be transported from land to the marine habitat via rivers, storm water, wind, and sewage, or it can be discarded directly on beaches and at sea [2]. There are numerous types of marine litter, including plastics, metals, glass, and textiles, which can be found on beaches, floating on the surface of the sea, or sunk to the seafloor. It is a global issue and a direct threat to the marine environment; whether social, economic, or ecological in nature [3]. Plastic litter accounts for the majority of marine litter in most of the world's oceans [4].

The Mediterranean Sea is a semi-closed basin with high densities of marine litter due to marine traffic, populated coastlines, complex currents, river inlets, and tidal flow, as well as limited water exchange via the Suez Canal and the Strait of Gibraltar [5]. The Mediterranean Sea has the world's fourth highest concentration of floating marine litter, with 22 000 t, accounting for 9 % of the total [6].

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Monastir Governorate (Tunisia, eastern Mediterranean) has a land area of approximately 1024 km^2 and a population of 548 000 people. Tourism and fishing are important economic activities in the area. Monastir is Tunisia's first seafood producer and the fishing sector is one of the main pillars of the local economy [7]. Furthermore, Monastir is one of Tunisia's most important tourism areas. What's more, the future marine protected area (MPA), Kuriat Islands, located in the north-east corner of Monastir Bay (Tunisia), has a high touristic appeal. For many years, the Kuriat Islands, particularly the small one, have served as a place of relaxation for visitors [7].

Anthropogenic pressures, the intensity of tourism and commercial ship traffic in Monastir Bay, and the large number of domestic and foreign tourists' activities, particularly during the summer, all contribute to marine pollution. Furthermore, the COVID-19 pandemic revealed some of the vulnerability of the Monastir Bay's social-ecological system. Monitoring beach litter in Monastir Governorate may be necessary for developing management strategies aimed at preserving the integrity and functioning of these vital ecosystems. The primary goal of this study is to assess and quantify the abundance, composition, and occurrence of marine litter in three beaches and Kuriat Islands in Monastir. This is, to the best of our knowledge, the first study on marine litter in this area. The current work contains the first recorded data.

Materials and Methods

Study area

Monastir city is considered as one of the most important commercial capital in Tunisia. During the last decades, it has reported an increase in urban density and industrial activities (textile, agri-business industry, fishing activity offshore fish farm, etc.).
The presence of marine debris along the coastaline of Monastir bay, was investigated in three beaches (Palmier, Marina, Karaia) and on Kuriat Island during four seasons (Spring 21, Summer 21, Autumn 21 and Winter 21) (Fig. 1).

Figure 1 – Location map of the beaches investigated.

The beaches were selected in order to fulfil the following requirements: composed of sand or gravel and exposed to the open sea; accessible to surveyors throughout the year; characterised by a minimum length of 100 m; lack of tourism facilities during the survey period; preferentially, not being subject to any litter removal actions.

At each beach, 100 meters survey section was chosen and cover the entire beach width, from the shoreline to the end of the beach identified with: beginning of vegetation, dunes, base of the cliff, road or other anthropic structures. The monitoring was performed with the help of NGB organisation. In each beach, the boundaries of each transect were geo-referenced using a GPS in order to ensure that the same sampling units were monitored in all surveys.

Beach monitoring

The beach litter surveys were performed in line according the same protocol as the one proposed by the European Environment Agency in the MarineLitter Watch program and it is used by other NGOs and research institutes. The operational toolkit used in this stydy was developped within the Interreg MED Plastic Busters MPAs Project and capitalized in the ENI CBC Med Common Project.

Walking through the sampling area, all macroscopic litter items larger than 2.5 cm in the longest dimension were collected, categorized and counted, ensuring the inclusion of caps, lids and cigarette butts. The surveys were conducted without disturbing the upper layer of the sampling unit (i.e. without digging to release litter buried in the sand), as envisaged by the protocol. Monitoring operations were usually carried out early in the morning. All collected litter items were identified by assigning them to different categories according to their composition: Artificial polymer materials, Rubber, Cloth/textile, Paper/Cardboard, Processed/Worked wood, Metal, Glass, Ceramics, Sanitary waste, Medical waste, COVID-19, Paraffine/Wax pieces and Food waste composed by 169 items, according to the classification list of marine litter items.

Data Analysis

To allow comparability with other publications on coastal litter surveys, litter abundance was expressed as total number of items per 100 meter of shoreline [items/100m], number of items per square meter [items/m^2] and weight per square meter [g/m^2]. For assessing the cleanliness level of the coast, the Clean Coastal Index (CCI)) was calculated using the formula below:

$$\text{CCI} = (\text{Total number of plastic parts /Sampled area}) \times K \qquad [8]$$

Consistent with the CCI index calculation [10], a coefficient K = 20 was inserted into equation (1) for statistical and convenience reasons. This index only takes plastic items with a size greater than 2 cm into account. The result corresponds to the beach CCI rank as: 0-2: very clean (no litter is seen); 2-5: clean (no litter is seen over a large area); 5-10: moderate (a few pieces of litter can be detected) 10-20: dirty (a lot of debris on the shore) and 20 or more: extremely dirty (most of the beach is covered with debris) [8]. The General

Index (GI) employed in this study is the same as proposed for the Clean Coastal Index but considering all types of debris instead of just plastic items.

Results and Discussion

Beach monitoring was carried out in 2021 on three beaches (Marina, Palmier, and Karaia) and on Kuriat Island. Except for Kuriat Island, where monitoring was only done in the summer and spring, all beaches were monitored throughout the year. Access to Kuriat Island was difficult for several reasons, including the difficulty of obtaining authorization for access, the bad weather, and the pandemic covid conditions.

Beach Litter Spatial and Temporal Distribution

Beach litter items varied greatly in composition and number across all beaches surveyed during this study. During all seasons studied, the total number of items accumulated ranged from 1125 to 21700 items. In the spring season, the density of collected items ranged from 0.004 to 8.49 items m^{-2} at Kuriat Island and Marina beach, respectively. (Table 1). Such values are somewhat higher than those recorded in many studies carried out along the Mediterranean sea. The average of litter density found on the Mediterranean coasts varied between 0.062 and 2.71 items m^{-2} [9].

Table 1 – Litter abundance at investigated beaches (items per 100 m beach sectors and items m^{-2}).

Beach	Spring		Summer		Autumn		Winter		Total Items
	N° Items	**Density**	**N° Items**	**Density**	**N° Items**	**Density**	**N° Items**	**Density**	
Marina	13540	8.49	3403	5.35	1916	2.80	2841	2.37	**21700**
Palmier	3230	1.16	1621	0.53	6205	2.00	5514	3.55	**16570**
Karaia	6842	6.11	2832	1.67	2933	1.72	3025	1.32	**15632**
Kuriat	103	0.04	1022	0.34	*	*	*	*	**1125**
Total Items	**23715**		**8877**		**11054**		**11380**		**55027**

In Moroccan Mediterranean coasts it ranged between 0.02 and 0.153 items m^{-2} [10]. At Ionian sea the litter density extended from 0.08 to 0.91 items m^{-2} [11]. In the Eastern Mediterranean region of Turkey, the litter density varied from 1.422 to 3.53 items m^{-2} [9]. However, in the Southeastern Black Sea beaches, the debris litter ranged between 1.22 to 4.2 items m^{-2} [12].

The average abundance for each beach and for all sampling seasons showed that Kuriat Island beach was the cleanest coastal site (average value: 563 items/100 m, or 0.19 items m^{-2}) and the Marina beach was the most litter-polluted (average value:

5425 items/100 m, or 4.75 items m^{-2}). The most significant differences were found between Marina beach vs. Kuriat Island. The highest content of litter at most polluted site can discourage beachgoers, and this can affect the economic value of a beach and also its adjacent economy (e.g., shops, bars, restaurants, etc.).

When all beaches were considered, litter abundance varied by season; for example, 23715 items (43 percent of all items) were collected in Spring, a decrease was recorded in Autumn and Winter with respectively 11054 and 11380 items or 20 percent of all items, and the greatest decrease was observed in Summer (8877 items or 16 percent of all items (Table1).These findings contrast with other findings that indicated that the most abundant litter was found in the summer. Indeed, the highest values of litter density were reported in the Mediterranean Sea during the summer [9]. The difference between our results and the other findings might be related to the period of beach monitoring. Indeed, our summer sampling was carried out at the first week of June, considered as the beginning of the summer season, whereas, in the other studies, summer sampling was done in August when the beach became actively used for swimming-sun bathing and picnic activities opened for summer [9]. Otherwise, local municipalities' cleaning efforts on the studied beaches are increased during the summer season. These investments are significantly greater, as is the number of beachgoers. During this time, beaches are frequently cleaned because there is an increase in litter due to increased tourist pressure.

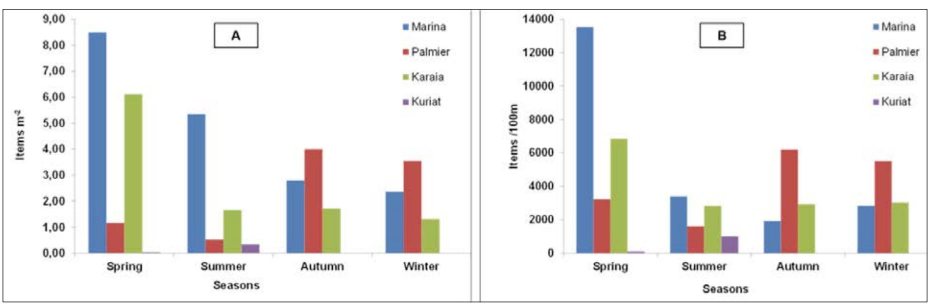

Figure 2 – Density (A) and Abundance litter (B) by beach in each season.

The highest values of abundance and litter density were recorded in spring at both beaches of Marina and Karaia whereas at Palmier beach, the most litter content was observed in autumn and winter. These findings might be related firstly to the reduction of beach cleaning operations realized by local municipality and secondly to the accumulation of debris transported by winds and storms. On the other hand, the increase of litter density recorded in spring at Marina and Karaia beaches is due to that beaches are located in the city center and therefore more frequented by citizens and used as a picnic area in spring season.

Composition of Beach Macro-Litter

Litter items were composed of different materials (Fig. 3): Artificial polymer materials is being the most represented (70 %–83 %), followed by Processed /Worked Wood (3-11 %), metal (2–9 %), cloth (1-6 %), paper and cardboard (1–5 %), glass (1–4 %), ceramics (1–2 %), rubber, sanitary waste and covid (1 %). Similar percentages, especially for plastics, were found in other studies carried out on different coastal zones: from 75 % to 83 % at the Adriatic Sea [13, 14], 82.6 and 83.5 % on Mediterranean coastal sites of Alicante Province (SE Spain) [15], 70.64 % on the Moroccan Mediterranean coast [10], 81 % on Mediterranean beaches [16] and 83 % on the coast of South Africa [17]. Furthermore, Chitaka and von Blottnitz, [18] indicated that plastics exceeded 90 % of the total debris composition at Cape Town in Africa.

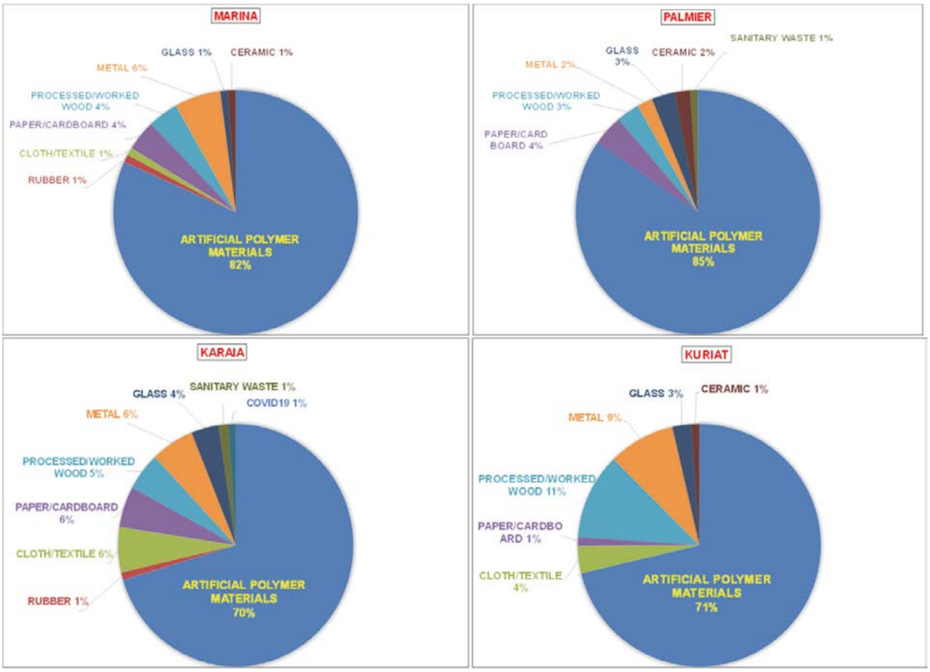

Figure 3 – Composition of litter items according to material categories in terms of number during all surveyed seasons.

Plastic items, which are made of land, had the highest concentration of litter in all the sites we studied. These findings are consistent with other related studies in developed and developing countries which have linked beach litter to land-based sources [19, 20]. Topçu and Öztürk [21] mentioned that plastic abundance is driven by input, great persistence, and high floatability. Of all the litter items observed in the four surveyed beaches, the most plastic abundance was recorded on Palmier and Marina beaches with respectively 82 and 85 % of total collected litter items during all sampling periods.

Figure (4) depicts the abundance of various artificial polymer materials at each investigated beach. Cigarette butts were the most abundant items in Karaia and Marina beaches with respectively 34 % and 21 % of the total plastic amount.

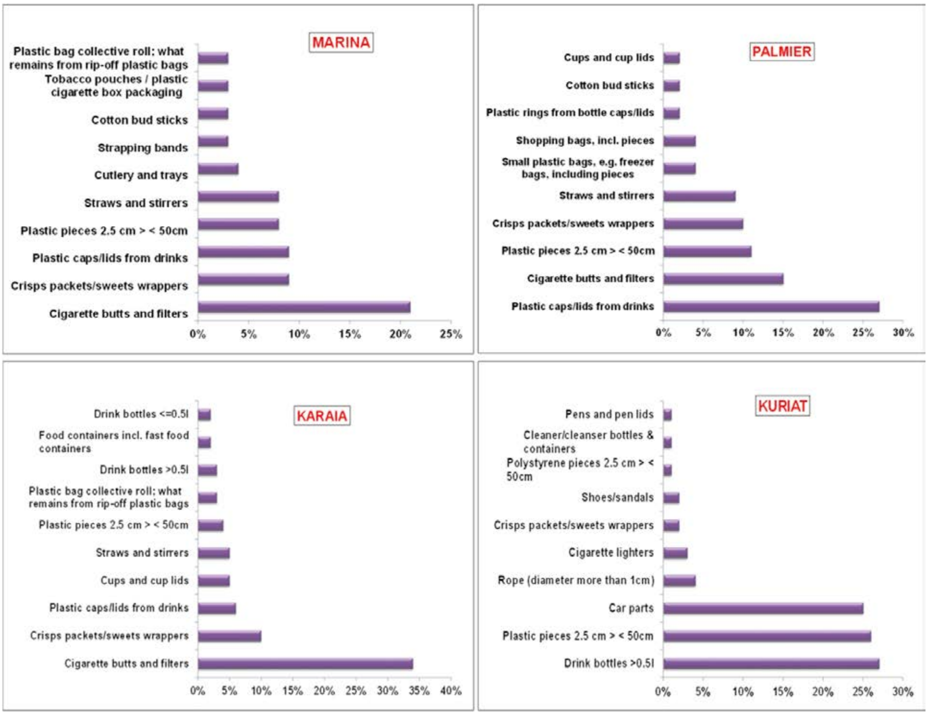

Figure 4 – Artificial Polymer Materials Top ten Items (%).

In Palmier beach the most abundant litter was plastic caps/lids from drinks (27 %) whereas in Kuriat Island the most abundant litters are drink bottles >0.5 l, plastic pieces 2.5 cm><50 cm and rope with respectively 27 %, 26 % and 25 %. These findings are in accordance with those observed on the Moroccan Mediterranean coast [10], where cigarette butts accounted for 31.5 percent of the total collected items. These results confirming observations in Spanish beaches where cigarette butts are the most abundant litter items [15]. Simeonova et al. [22] reported that the cigarette butts and filters were the highest in the artificial polymer material categories quantitative distribution in the Bulgarian coast and the significant amounts of in the summer period were related to the recreational activities. Cigarette butts were one of the most frequent litter items found on beaches in several areas in Europe [23].

The abundance of these type of items was attributed to their persistent in the environment [24]. In addition, mechanical cleaning is less effective for removing cigarettes butts than for general litter. The rest of the surveyed groups represented less than 11% and is also be attributed to beachgoers, such as drinking and food items, etc. [25].

In Kuriat Island no cigarette butts were observed which was aligned with findings observed on remote and rural beaches in Moroccan Mediterranean coasts. Plastic fragments, plastic bags (shopping bags), and plastic bottles were the most common plastic items found across all sites. These findings also support previous findings in other parts of the world that fragments are the most commonly occurring items in many of the world's coastal areas. Examples can be found in the United Kingdom and Spain [26, 27]

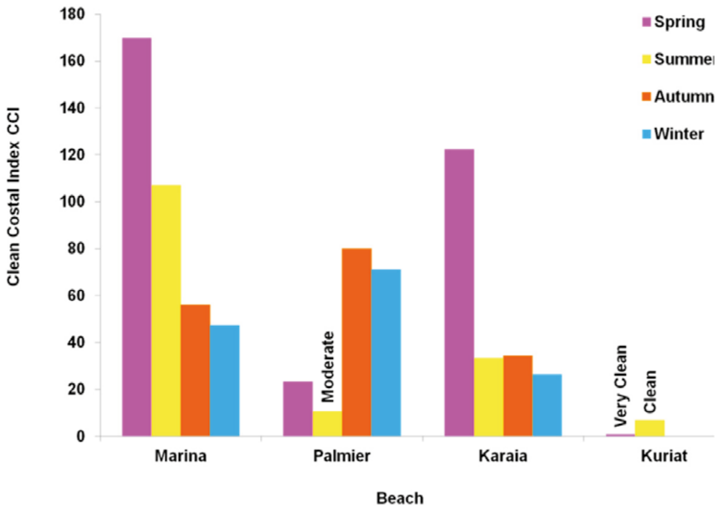

Figure 5 – Clean Coast Index (CCI) in all surveyed beaches during all seasons.

Clean Coast Index (CCI) is one approach to assess cleanliness levels of beaches [9]. The calculation result of CCI found that all beaches during all surveyed seasons were considered as extremely dirty except Kuriat Island which was indicated as clean in summer and very clean in spring and Palmier beach which was classed as moderate in summer (Fig. 5). Akyatan beach was also classified to extremely dirty [9] as it was found in Southeastern Mediterranean Sea. Similarly, Aytan et al. [12] using the same index in Black Sea beaches, found the beaches classified as extremely dirty. However, the same index was used in the Sinop coasts and the beach was found very clean. The marine litter amount of our surveyed beaches was found to be higher than the studies conducted in Black Sea and Mediterranean beaches.

Conclusion

Anthropogenic impact, lack of public awareness, poor waste management, and weather conditions all have a significant impact on the spatial and temporal distribution of marine litter. Our findings highlight the problem by collecting enough data and analyzing the distribution and composition of marine litter to fill a knowledge gap in the Monastir Governorate (Tunisia, eastern Mediterranean). In addition, for future decisions more data on marine litter is needed with a proper database, including records from ports' waste disposals (ship inputs and fisheries), input from rivers, and facilities near shores, in order to increase the coverage of monitoring rather than beaches. Finally, marine litter is a major issue that should be strictly avoided by limiting land-based pollutants, encouraging recycling, and improving waste management before it reaches the marine environment.

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COASTAL DUNES ALONG THE MARCHE LITTORAL (ADRIATIC SIDE OF CENTRAL ITALY)

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Abstract – An analysis of the main features of relict dunes and scarcely anthropized zones located along the littoral of the Marche Region is reported. The coast is strongly affected by man-made transformations mostly implemented from the '60s of the previous century to face beach erosion triggered by a reduction of river solid load derived from man-made interventions in the hydrographic basins. Presently, no real beach-dune still exists, but, locally, some eroded remnants can be found. The typical vegetation of dunes is very fragmented, depleted and strongly altered. Standing their extremely relevant ecologic function, it is instrumental to carry out actions aiming at preserving these relict dunal areas.

Introduction

The coastline of Marche Region (Adriatic side of Central Italy) [1, 2, 3] is mainly represented by sandy and/or gravelly beaches (about 150 km of 172 km).

After irregular alternances of progradation and retreat phases directly driven by climate up to about 2 millennia ago and then by agricultural activity (in turn, strongly influenced by climate conditions), the studied sector has been strongly affected by man-made transformations and presently shows an almost continuous series of coastal protection works: emerged and submerged breakwaters, seawalls, groynes and revetments. Moreover, harbor structures and channelized outlets locally interrupts the lateral continuity of the shoreline.

Such interventions were mostly implemented starting from the '60s of the last century to face beach erosion phenomena triggered by a dramatic reduction of river solid load. The latter, in turn, derived from man-made interventions in the hydrographic basins, such as construction of dams and check dams, gravel quarrying from the thalwegs, crops abandonment etc. Unfortunately, the lack of territorial planning for coastal intervention projects instead of solving the problem of shore retreat mostly brought to downdrift migration of erosional phenomena, thus requiring further interventions: in this way, almost all the regional shoreline was progressively artificially stiffened.

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In particular, in the 19th century, all along the Marche coastal belt several beach-dune systems were present, mostly close to the main river mouths. Many of these peculiar landforms were destroyed during the construction of the Adriatic railway (1862-63), while others survived up to the second half of the last century. Presently in the Marche Region, because of coastal erosion and construction of touristic facilities along the beaches, no real beach-dune still exists, even though locally some strongly eroded remnants can be still found, where natural habitats are severely degraded, and the typical vegetation of dunes is very fragmented, depleted and strongly altered.

Standing the extremely relevant geological, environmental and ecologic function of coastal dunes, mostly for protection from coastal erosion and habitat conservation, an accurate monitoring of their present remnants as well as of scarcely anthropized coastal areas has been carried out. Therefore, the study aims to provide an instrumental tool for preserving the coastal dunes and restoring the psammophilous phytocoenoses, which is fundamental for their consolidation, also favoring a proper management of the coastal belt.

The study area

The shoreline of the Marche Region stretches for about 172 km on the western side of the Central Adriatic Sea.

Three main morphodynamical sectors can be individuated ([4] and references therein):

1) The prevalently low coasts with the exception of the Mt. San Bartolo area wave-cut cliffs, which is located north of Ancona facing to the NE, and about 97 km long;
2) The pocket beaches intercalating wave-cut cliffs on the Mt. Conero headland (about 19 km);
3) The beaches of the «Piceno» coast to the south, facing about ENE (about 56 km).

The «dominant sea» (direction of provenance of the most frequent storms) is from SE (Sirocco), while the «regnant sea» (the direction of provenance of the most intense storms) is from N – NNE (Tramontana and Bora) (Fig. 1). Only very seldom waves reach heights up to 5 m (0.02 %) [5].

Except for the Mt. Conero area, the natural nourishing of all the beaches, and therefore their evolutionary trend, derives only from the solid load brought by the rivers draining the region, all of them showing an almost torrential regime.

The prevalent longshore drift is from south to north: only during the quite rare sea storms from N – NNE it reverts.

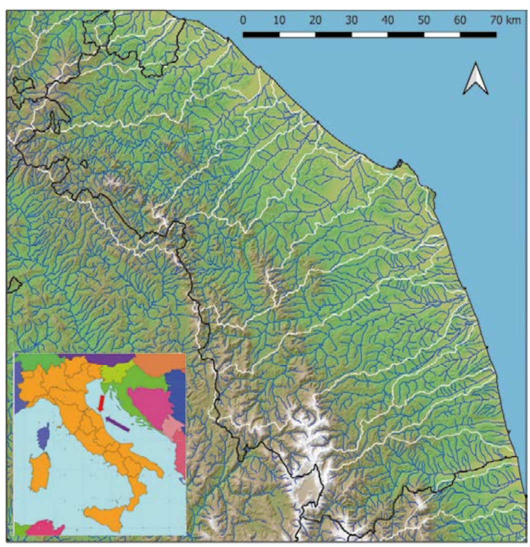

Figure 1 – Relief map of the Marche region.

All the main rivers of the region originate from the mainly calcareous reliefs of the Umbria-Marche Apennines and flow for most of their length over the more recent (Pliocene – Pleistocene) terrigenous deposits of the Outer Marche Basin (Fig. 2) ([4] and references therein).

The latter, generally being too fine grained, do not contribute efficiently to the natural nourishing of the littoral.

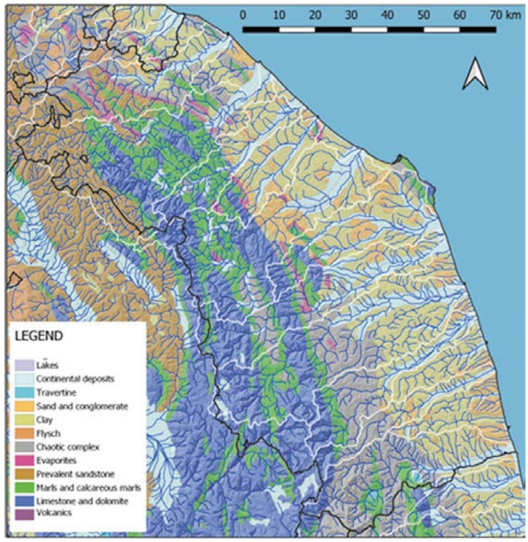

Figure 2 – Lithological sketch of the Marche Region.

Materials and methods

To reconstruct the historical evolution of the analyzed littoral we based upon geological, archeological and historical evidences, also considering the climatic records.

Starting from the second half of the 19th century the availability of reliable topographic maps allowed us to delineate more accurately the variations of the shoreline and of the emerged beaches. For the last decades large use of more accurate remote sensing imagery and digital vector maps has been done.

Present day environmental status and geometry of dunal remnants and scarcely anthropized coastal areas have been investigated by detailed field surveys.

All the above information has been used to implement a co-georeferenced geodatabase, used to carry out GIS based analyses and mapping.

Historical evolution of the littoral

After the emersion of the Umbria-Marche Apennines the coastline of this portion of Italy slowly advanced as a consequence of tectonic uplift. Anyhow, this progradation was not homogeneous, experiencing trend alternations as a consequence of intense climatic changes. Particularly, advancing, when the cold climate related to glacial ages lowered the sea level, and retreating, when better climatic conditions brought to massive ice melting.

During the last cold phase (Würm maximum, about 20 000 y. b.p.), the Adriatic Sea was some 120 m lower than nowadays and the emerged areas were mostly denudated, thus producing a huge amount of sediments that filled river valleys. All the rivers of the study area were right-hand tributaries of the Po River, whose low-stand delta was located a few kilometers to the SSE of the regional boundary [6, 7, 8, 9, 10, 11, 12].

During the Holocene, warm and humid climate (up to the so called "Holocene Climate Optimum") brought to a fast growth of the sea level (Flandrian transgression, 0.5 – 1.5 cm/y, up to about 6000 y b.p.).

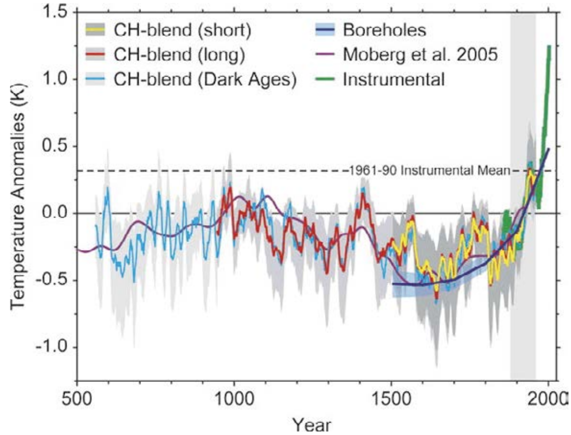

Figure 3 – Temperature anomalies in the last two millennia (after [36]).

At the same time, emerged areas were progressively colonized by vegetation and forests started to grow, thus strongly reducing the amount of sediments reaching streams; the latter, therefore, started to cut the previously accumulated thick alluvial deposits [1, 13, 14].

The lower reaches of rivers were inundated by the sea to form *rias* [14, 15, 16, 17], having at their heads gravelly pocket beaches, alternating with long active wave cut cliffs [17, 18, 19, 20, 21].

The first historical progradation of the coastline happened during the Roman age: it was not driven by climate (still warm and humid, with biostasy conditions) being the consequence of widespread deforestation following increase of population and, therefore, of need for cultivated areas and wood, which took place during the late Bronze age and, most of all, during the Iron Age [22].

After having filled the *rias*, rivers started to advance toward the sea, forming beach-lagoon systems [16, 23], anyhow still located some hundred meters inland, as testified by many archaeological findings ([4] and references therein).

Between the beginning of the 5th century and the mid 8th century, climate worsening and somehow related socio-economic problems determined a significant reduction of the population, which in turn brought to the abandonment of many previously cultivated plots, thus reducing debris production and reverting the previous progradational trend of shorelines [24, 25].

Then, when climate become warmer and more humid (Medieval Climatic Optimum, around 1100 A.D.) population growth again with consequent intense deforestation [17, 26, 27, 28] for agricultural purposes: this resulted in relevant increase of streams solid load, allowing river mouths and, after some time, beaches to advance [14, 17, 25, 29].

This progradation ended when the colder climate (Little Ice Age, beginning in XIV century) [30] started to reduce the population; then, the Black Plague (1363) almost halved the European population. Consequently, many areas were abandoned and forests began to expand themselves again, thus reducing the solid load of streams and inducing a generalized retreat of the coastline [14, 25].

Later, population slowly started to grow again up to present days [31], with subsequent progressive deforestation, increase of agricultural pressure and production of debris along slopes which induced a new progradational phase, mostly close to river mouths [4].

Almost all the wave cut cliffs become inactive during the last centuries, being protected by generally not very large gravelly-sandy beaches.

Recent evolution of the littoral

Up to the mid 19th century, beaches continued to show a progradational trend and coastal dunes were very frequent all along the coast ([4] and references therein).

The first impact on those sedimentary bodies derived from the construction of the Adriatic Railway (1862 – 1863) (Fig. 4), mostly built very close to the shoreline, often above the coastal dunes, thus avoiding crossing the hilly, more unstable area located a few hundred meters inland. Moreover, to protect the railway from the erosion deriving from the most severe sea storms, hard coastal protections (mostly revetments) were locally built (Fig. 4). In this way the local natural littoral dynamics and the related longshore sediment drift were severely modified, inducing erosion down-drift.

Starting from the beginning of the 20th century dams and check dams (Fig. 5) were built along the upper-mid reaches of most rivers, thus dramatically reducing their solid load.

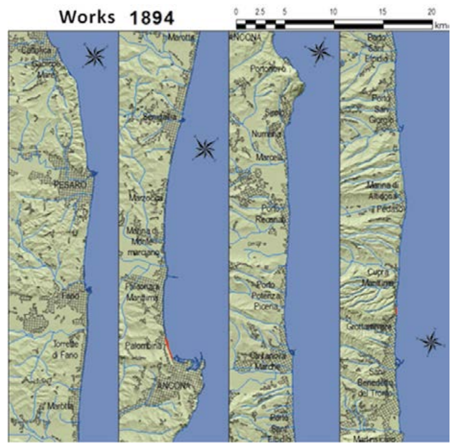

Figure 4 – Coastal protection works along the coastline realized before the 1894.

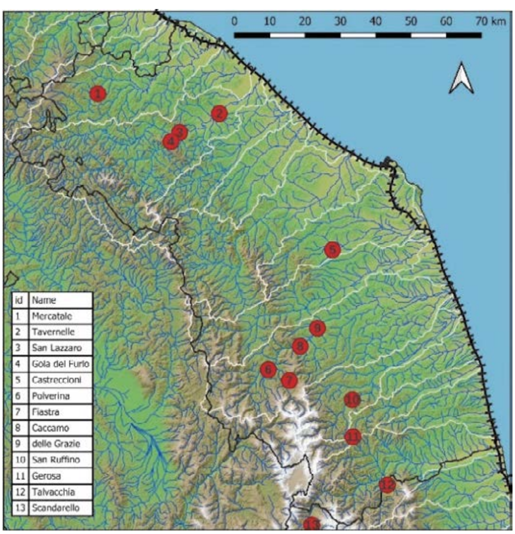

Figure 5 – The Adriatic railway (black line) and the main dams (numbered red dots) in the Marche Region.

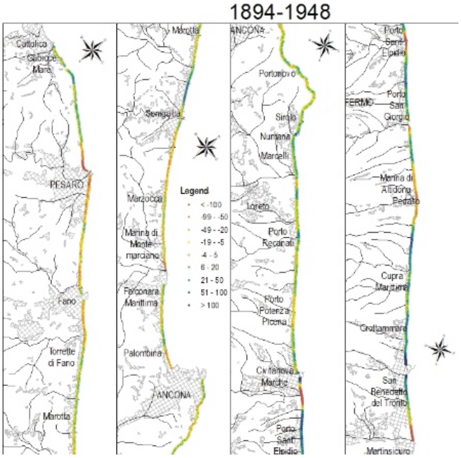

Figure 6 – Coastline changes from 1894 to 1948: orange to red tones indicate progressively stronger retreat, green to blue ones increasing advance. Bold black line highlights active cliff sectors.

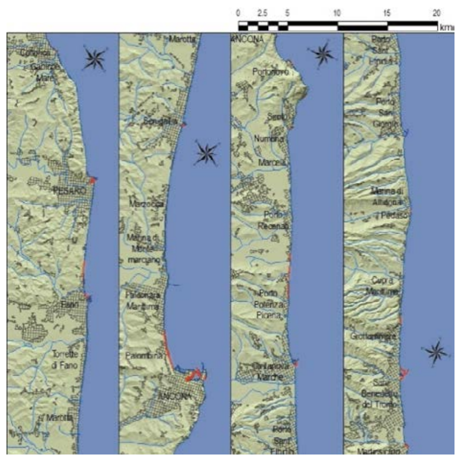

Figure 7 – Coastal protection works along the coastline realized from 1894 to 1948 (in red).

Moreover, piers and grayness built to protect the first harbors, locally stopped the natural longshore drift of sediments (Fig. 6).

As a consequence of all the above modifications of the natural equilibrium of the littoral, the progradational trend slowed down almost everywhere, even though in an inhomogeneous way, and some retreat phenomena locally started to take place (Fig. 7).

During the second half of the 20th century, the economic boom and the rapid growth of marine tourism induced a strong urbanization of the littoral stretches, and roads and facilities were built over many of the remaining dunes and emerged beaches.

Moreover, the industrialization brought both to field abandonment with subsequent reduction of erodibility of slopes and to very intense quarrying of gravel from riverbeds, thus inducing a sudden, very severe lack of adequate sediments reaching river mouths and, subsequently, widespread, locally severe, phenomena of coastal erosion (Fig. 8).

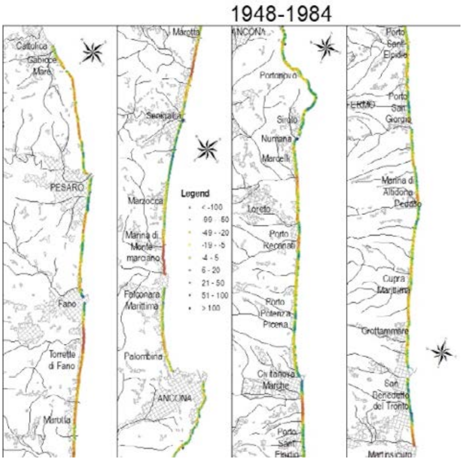

Figure 8 – Variations of the coastline between 1948 and 1984: orange to red tones indicate progressively stronger retreat, green to blue ones increasing advance. Bold black line highlights active cliff sectors.

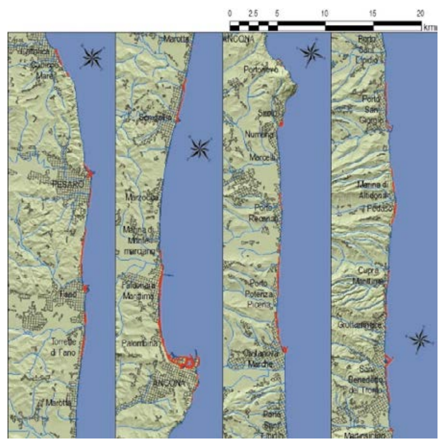

Figure 9 – Coastal protection works along the coastline realized from 1948 to 1984.

Shoreline retreat, having acquired a more relevant socio-economic relevance, was very often faced with many more "rigid" protection works (Fig. 9) of different types (emerged and submerged breakwaters, seawalls, groynes and revetments).

Unfortunately, most of these interventions were not supported by accurate investigations and therefore they often altered the natural longshore drift of sediments, thus causing downdrift migration of erosional phenomena. This almost continuously induced the stakeholders to build new and more extensive structures, thus altering even more the naturality of littorals.

Anyhow, these protection works, together with the prohibition to quarry gravel from rivers, allowed a significant mitigation of erosional phenomena toward the end of the last century (Fig. 10), but also brought to the beginning of creation of a mainly artificial, stiffened coastline (Fig. 11).

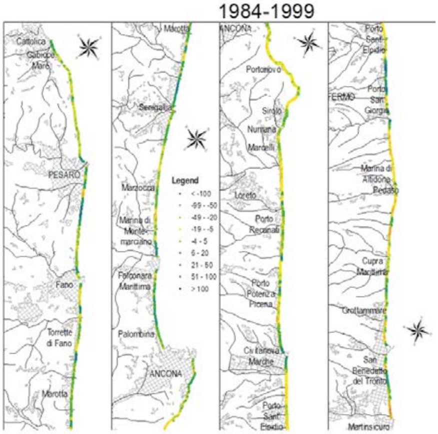

Figure 10 – Variations of the coastline between 1984 and 1999: orange to red tones indicate progressively stronger retreat, green to blue ones increasing advance. Bold black line highlights active cliff sectors.

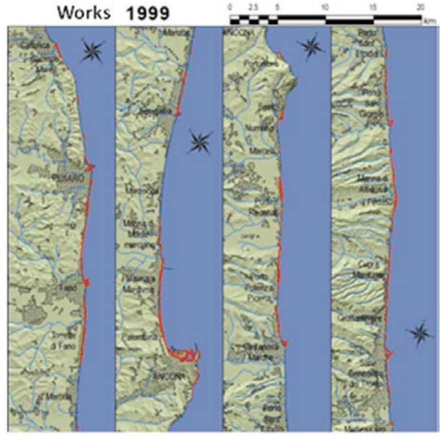

Figure 11 – Coastal protection works along the coastline realized from 1984 to 1999, in red.

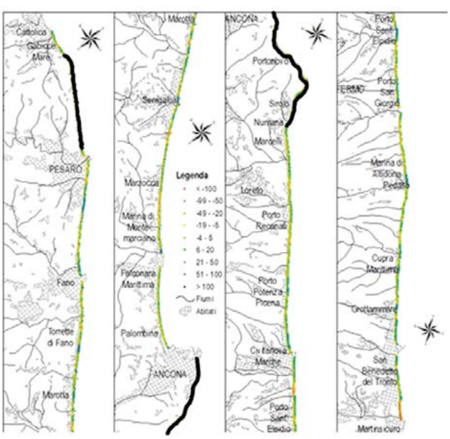

Figure 12 – Coastline changes from 1999 to 2020: orange to red tones indicate progresssively stronger retreat, green to blue ones increasing advance. Bold black line highlights active cliff sectors.

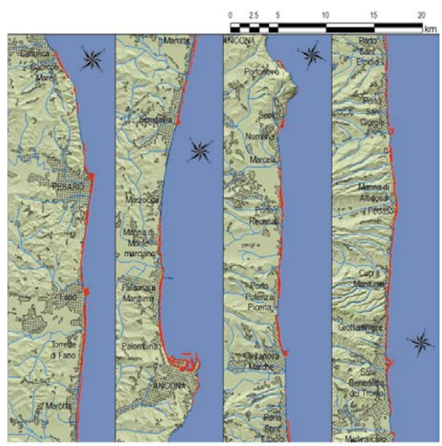

Figure 13 – Coastal protection works along the coastline realized from 1999 to 2020, in red.

During the last two decades, most of the coastline became stable or in slow progradation: unfortunately, this has been achieved only increasing the extension of protection works thus bringing most of the regional coastline to become artificial (Fig 12 and 13).

Anyhow, significant erosional phenomena locally still affect many beaches and further "rigid" protection works are supposed to be built in the next future.

Rare were the interventions adopting artificial nourishing: moreover, in some case they have been carried out with sediments whose grain size was too small to be stable for an acceptably long time or with amounts of debris too small to solve the problem.

Completely different has been the evolution of the pocket beaches of the Mt. Conero headland, where sedimentary supply mostly derives from mass movements (affecting the wave cut cliffs and the scarps bordering them inland) and it generally oscillates from one side to the other of the beach, without any interference among neighboring beaches.

Biodiversity of Dunes and coastal areas

Recently, a study has been carried out to survey all the relict dune deposits still present in the Region, as well as the scarcely anthropized coastal areas where dunes could start to develop, and to characterize them from morphological, sedimentological and botanical-vegetational points of view [32, 33]. At present, the coastal dunes bordering almost all the beaches of the Marche Region up to about 160 years ago, have been almost completely destroyed (Fig. 14).

Only less than 85 hectares of land still present dune sediments, mostly severely threated by sea storm erosion and, most of all, by wrong anthropic interventions. Among the others, still particularly interesting are the deposits located close to Fosso Sejore (between Fano and Pesaro, in the North of the Region) and those bordering the southernmost reach of the Marche coastline, in the Sentina Regional Natural Reserve (close to the mouth of the Tronto River).

Moreover, about 127 hectares not severely altered by human activities have been spotted that could be protected thus allowing dune growth.

As a rule, the investigated remnants of coastal dunes are small (as a maximum 2 m high and 20-25 m wide) and gentle reliefs located about 20-30 m at the back of the shoreline.

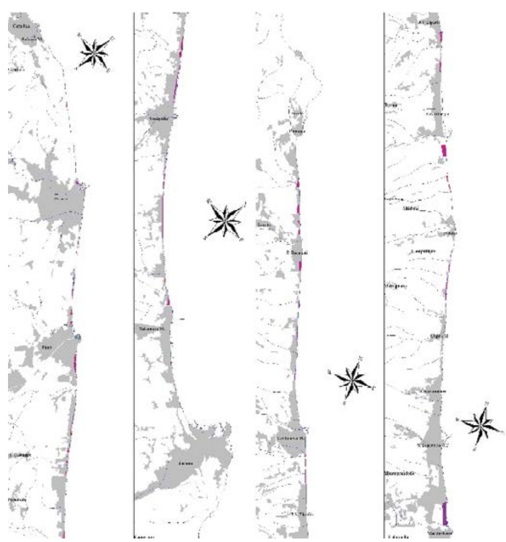

Figure 14 – Distribution of remnants of coastal dunes (in red and purple).

Locally, embryonal accumulations were individuated leaning against natural or artificial obstacles.

Sediments are represented by mostly siliceous fine sand showing rather homogeneous grain size.

From a botanical-vegetational point of view, the typical vegetation of dunes is very fragmented, depleted and strongly altered. The most common coenoses are those made up by annual species, such as *Cakile maritima* and *Salsola kali,* constituting the *Salsolo kali-Cakiletum maritimae* association (Fig. 15), often compenetrated by nithrophilous, sometime exotic, species. Perennial coenoses, such as the *Echinophoro spinosae-Agropyretum juncei* (Fig. 16), and the *Echinophoro spinosae-Ammophiletum arenariae* associations (Fig. 17), are much rarer: mostly the latter, still individuated only in a very few places along the studied coastal belt [34, 35, 36].

As it can be deduced from the above consideration on the recent evolution of the beaches of the Marche Region, coastal flora, vegetation and habitats have been profoundly modified and altered by human activities and are currently really poor and in an accentuated state of decay, thus making it difficult to imagine a significant improvement of their condition in a short while.

Figure 15 – *Salsolo kali-Cakiletum maritimae* association at the Sentina Beach (Southern Marche Region). a) The vegetated area; b) particular.

Figure 16 – *Echinophoro spinosae-Agropyretum juncei* association. a) the vegetated area; b) particular of the community in late summer.

Figure 17 – Remains of the association *Echinophoro spinosae-Ammophiletum arenariae*.

Anyhow, some small strips of dune vegetation have survived in a few places, where it is possible to find, although fragmented and impoverished, small nuclei of habitats 1210 [Annual vegetation of drift lines], 2110 [Embryonic shifting dunes] and 2120 [Shifting dunes along the shoreline with *Ammophila arenaria (white dunes*)]. These small remnants of habitat which importance is highlighted by the Directive 92/43/CEE of the European Unions, should make reflect on the need to preserve and, indeed, increase these habitats. Their preservation is of fundamental importance both for the good environmental status of the coastal belt, for effective and reliable contrast to the coastal erosion, and also for a differentiated recreational tourism and economic progress, in other words, for a modern Integrated Coastal Zone Management approach.

Conclusions

The study evidenced that the position of the shoreline of the Marche Region followed climatic variations up to about two thousand years ago, advancing when the climate was colder to retreat when it became warmer.

During the final part of the Bronze Age, anthropic interventions (namely deforestation to obtain wood and to gain cultivable land) became predominant, inducing the first progradation during a warm period. From then on, man made interventions within the river basins bringing sediments to the coast started to be the leading factors in determining the evolution of the littoral. Those interventions, anyhow, where strongly influenced by climatic variations, since the population increased during climatically more favorable periods to diminish when it was colder.

Starting from the second half of the 19th century, with the construction of the Adriatic Railway, the relevance of human interventions become even stronger, to further increase in time. Mostly with the economic boom of the ‘60s, river solid load (and therefore natural nourishment of beaches) was dramatically reduced by man-made interventions in the hydrographic basins, such as construction of dams and check dams, intense gravel quarrying from the thalwegs, crop abandonment, reforestation etc. At the same time, beaches started to assume a very high socio-economic relevance because of the blooming of seaside tourism, and structures (mostly roads and touristic facilities) were densely built over the residual coastal dunes and on the emerged beach. The result of the above combination brought to "savage" construction of protection works of various type, very often built without an accurate and detailed knowledge of local littoral dynamics. This, most of the times resulted in downdrift transfer of the erosional phenomena, thus bringing to an almost continuous request of further interventions to follow the above migration.

Therefore, presently most of the regional coastline is artificially stiffened by protection works and the natural coastal environments have been almost everywhere destroyed.

The coastal dunes bordering inland almost all the beaches up to less than one century and half ago are presently almost completely destroyed: only a few remnants, generally badly preserved, are still present, further endangered by wave erosion and anthropic activities.

The presence of dune phytocenoses is extremely altered and rarefied; there are still a few well-preserved nuclei in which it is possible to recognize the psammophilous communities typical of the dune series. Urgent actions need therefore to be planned and realized to protect the few remains of coastal dunes from environmental and geological point of view. This will allow the growth of more of such ecologically very relevant sedimentary bodies where the anthropic pressure is not too much invasive.

Summarizing, to avoid repeating the severe errors of the recent past, also considering the effects of climate change and the strong anthropic pressure on the coast (and its touristic relevance), the present coastal dynamics of the area requires detailed, accurate and continuous monitoring to be carried out, in order to allow sustainable integrated coastal management.

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TRIESTE, BACK TO THE SEA. DESIGNING SUSTAINABILITY AND DEVELOPMENT OF LOGISTICS AND INDUSTRIAL PORT AREAS AFTER THE PANDEMIC

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Abstract – This work traces the stages of a long process of safety and industrial reconversion of an iron and steel industry polluted area, a typical "brownfield" [1], within the port of Trieste. Since 2014, a series of phases have followed one another, implementing an articulated and complex process. In recent years, this process has had to deal with events and scenarios on a global scale that have significantly affected the port system of the site, with the logistical and geopolitical aspects, demonstrating the adaptability and dynamism of various subjects in knowing how to combine development and environmental protection.
The interest in the case of Trieste, provided for by the 2006 Environmental Code (Codice dell'Ambiente), is the first completed application of this law in Italy. The results obtained include the completion of the environmental safety program, the renewal of the existing industrial plant, the increment in logistics activities and the maintenance of occupational levels. Following these encouraging results, the activation of a new second agreement, currently in progress, demonstrates the effectiveness and repeatability of the procedure.

Introduction

On January 30th, 2014, the Program Agreement (*Accordo di Programma*) of the "Program Agreement for the re-development of industrial and port activities and environmental recovery in the complex industrial crisis area of Trieste" was signed [6]. The aim was to implement an integrated project of safety, industrial reconversion and economic development in a Polluted Site of National Interest (SIN) in order to reuse these areas in conditions of health and environmental safety. Subsequently, on November 21st, 2014, a more specific Program Agreement was signed "for the implementation of the integrated project for safety, industrial reconversion and economic production development in the *Ferriera di Servola* (Servola Ironworks site)" [5].

The significance of this initiative - in addition to its specific contents - lies in the fact that it was the first application of the procedure contained in art. 252-bis "National polluted sites of preeminent public interest for industrial conversion" (*Siti inquinati nazionali di preminente interesse pubblico per la riconversione industrial*) of the Environmental Code. A complex process that saw, among others, the Minister of the Environment and Protection of Land and Sea and the Minister of Economic Development, with the Minister of Labour and Social Policies, in agreement with the Friuli Venezia Giulia Region and the Port Authority of Trieste, enter into an agreement with the Arvedi Group, concessionaire of a large contaminated industrial area of over 270 000m^2 within the Port of Trieste, that has allowed the re-employment of 400 workers.

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From a historical point of view, the iron and steel plant of the Ferriera was born in the last years of the nineteenth century with the purpose of supplying cast iron and ferroalloys to the Austro-Hungarian Empire. From 1913 onwards, there was a progressive expansion of the plant with the construction of new blast furnaces and foundry areas with gradual implementations up to the second half of the twentieth century. After several decades of stagnation at the end of the 1990s, the plants that had been shut down over the years were restarted: the existing structures were strengthened through the refurbishing of the steel plant, a coke battery was built to replace the existing ones, along with the thermoelectric plant. The first workings on the sea landfill, refer to 1897, but many others followed, including the expansion of the quay (1907), the enlargement of the area adjacent to the *Scalo Legnami* (1931) and the conquest of a further 200 000 square meters of the sea (1960). At the date of the Program Agreement, the steel plant was spread over a total area of 500 000 square meters, partly under state concession as the areas were subject to the administration of the Port Authority System of the Eastern Adriatic Sea (*Autorità di Sistema Portuale del Mare Adriatico Orientale*). The excavations carried out over the years have been achieved with demolition materials from disused activities and with process waste (discards from blast furnaces), often improperly used as aggregates in the past. The "quality" of the waste used to create the landfill is linked to the process line that generated these aggregates. Therefore, the deeper layers that correspond to the older layers are the most polluted ones, as the production process and the quality of materials and additives have improved over time. Hence, it can be deduced that in the more superficial layers it is possible to find presence of a homogeneous mixture of earth and waste, while in the deeper layers, it is possible to find presence of heaps and waste, deposited as is.

The scientific interest of the specific case of Trieste, developed on the basis of a procedure foreseen by the 2006 Environmental Code, is due to the fact that this is the first application of the law completed in Italy. The objectives to be achieved concern environmental safety, the renewal of the industry plant, the increase in port logistics activity and the maintenance of employment. The verification of the achievement of these goals, can verify the effectiveness and repeatability of the procedure in other contexts.

Materials and Methods

This study intends to retrace the main stages of the process that has guided the transformation of the area since 2014, which is still currently ongoing. The meaning of the analysed procedure refers to the requirements of the Environmental Code, as a repeatable process. The sectoral literature does not appear to be particularly up to date, the most complete studies refer at the European level to the CLARINET [4] (Contaminated Land Rehabilitation Network for Environmental Technologies) project concluded in 2001, and to the Proposal for "Guidelines for Environmental Recovery and Economic Enhancement of Brownfields" [2], of the Agency for the Protection of the Environmental and for Technical Services of 2006. However, these guidelines refer to the previous regulatory context regulated mainly by Ministerial Decree 25.10.1999, n. 471, testifying to the need for new, updated insights. The basic materials analysed are the Program Agreements and the related attached documentation. These materials allowed the reconstruction of an administrative and procedural, but also operational path, of transformations and tangible investments.

Furthermore, an integration was added, an enhancement of the latest developments of the project born around the growth actions being applied in Italy in the post-pandemic phase.

An Unprecedented Plan

An annex contained in the Program Agreement of November 2014 illustrates the "intervention strategies" relating to the "Integrated project for environmental safety and reindustrialization" [8]. It is a fundamental document that has acted as a compass during all the phases of the long process, which is still under development today. Starting from the geological and hydrogeological characterization of the area, the project has identified the forms of contamination of both the soil and the aquifer. A risk analysis was carried out on the basis of this data, which made it possible to identify the operational solutions to be applied. In particular, the project has identified: the ways of disposing the so called "historical" heap and other Hot Spots identified in the area, the management plan of the waste present in the area today and of that produced at the time, the safety of the land, both in ownership and in concession, through sanitary prevention measures (capping), and the treatment of discharged groundwater, intended as a link intervention pending the construction of the water treatment plant.

This initial start-up phase was followed on November 2nd, 2015 by the international decree (Ministry of the Environment and Protection of the Sea, Ministry of Economic Development) approving the "Integrated project for safety, industrial reconversion and development economic and productive area of the Ferriera di Servola "pursuant to art.252bis DLGS n.152/2006 [9]. The Decree detailed some aspects of the project in terms of prevention measures, risk analysis, intervention phases, monitoring plans of environmental matrices, even focusing on very minute technical details, such as the methods of connection between the safety floorings, the so-called surface capping, and the foundation structures of the new industrial buildings.

The Technical Solution of "Capping"

The capping solution made it possible to physically isolate the contaminated soil from the external environment in such a way as to eliminate the health risk for users of the area. Furthermore, this solution minimizes the infiltration of rainwater and process water into the polluted soils, it minimizes the consequent washout and the decrease in quality of groundwater, and, in addition to the erosion of the polluted soil itself and the dispersion of contaminants, the new flooring also facilitates cleaning and collection of the materials used on the site. It is an industrial floor, a reinforced concrete hood with a reinforcement mesh, enhanced by a layer of geotextile on the intrados. A form of physical delimitation that, together with the barrier on the seaside, captures polluted soils, preventing the exchange of contaminating elements with the environment. An effective solution, but "hard" and necessary, to respond to the extension of the area and the stages of reuse, which consequently does not leave room for further ecological and landscape integrations (the area is located within a Costal Territory, protected by law pursuant to rt.142 C.1 letter a) of the Code of Cultural Heritage and Landscape). In fact, in order to ensure the safety of a heavily polluted industrial area, it was necessary to give up the permeability of the soils and the possibility of using mitigation elements such as tree plantings. The large squares also contribute to the formation of a “heat island” effect, typical of urbanized areas. In terms of land consumption, on the other hand, given that the soil was already compromised by pollution, the balance was unchanged from the execution of the clapping.

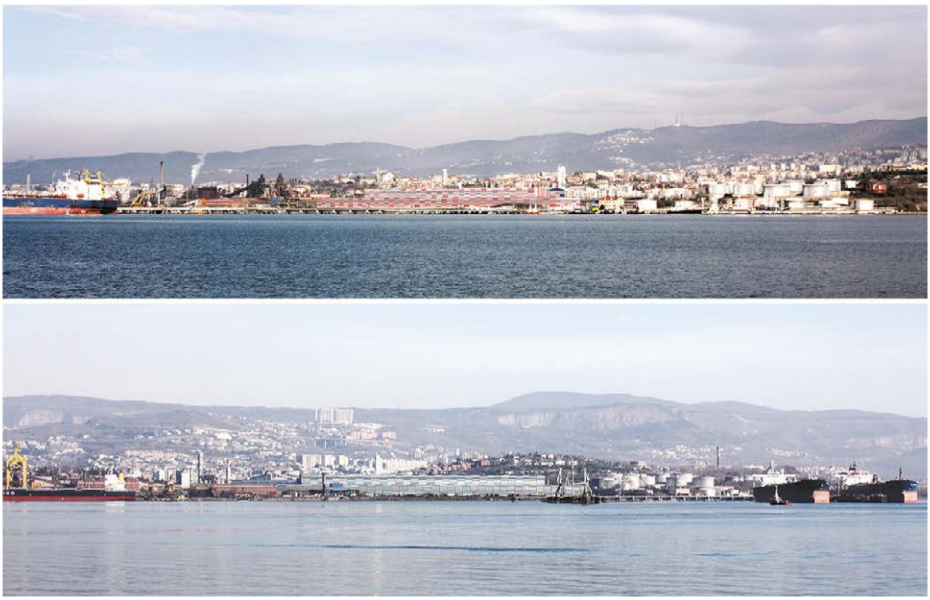

Figure 1 – Camouflage studies of the volumes of the Cold Area for the purpose of landscape mitigation (elaboration by the author, 2015).

Results Achieved

On the 18th of July 2019, the Autonomous Region of Friuli Venezia Giulia verified how the environmental activities in the field at the Arvedi Group had been complied with (over 100 activities are mapped with reference to the Program Agreement and the Authorization Decree in the report of the General Management Environment and Energy [10]). The renewal activities of the industrial plant were also put in place, restarting the production of cast iron in accord with what is indicated in the Integrated Environmental Authorization, setting up a new production unit called Cold Area for the pickling and rolling of steel coils from Arvedi plants in Cremona and increasing the railway logistics activity of the Port of Trieste for a total investment of 254 million euros. All while safeguarding the employment levels of the establishment.

A Renewed Plan

Six years later, the aims of the agreement have been achieved, and in June 2020 a new document was signed to give incentive to further transformations in terms of development and sustainability for a total of 100 million euros. The incentive comes from the Region's proposal for the closure of the so-called Hot Area, the production part of the plant that has the most impact from an environmental point of view. It is a large area characterized in particular by blast furnaces, the coking plant and two large size open-air carbon fossil and iron ore parks of a total of 54 000 square meters that the previous agreement envisaged to cover.

Figure 2 – Study of the roof of the fossil and mineral park of the Hot Area (elaboration by the author, 2018).

This is followed by an ambitious industrial plan by the Arvedi Group which provides for the decarbonization and conversion of the Hot Area on the principles of circularity, starting with the production of flat rolled carbon steel (the only European manufacturer) from an electric oven (therefore with lower operating temperatures) based on post-consumer scraps, rather than non-renewable raw materials. The project foresees a line of research and development aimed at reducing to zero the 29 % of cast iron produced at the Trieste site, which is still necessary to integrate 71 % of the waste used in the production processes. The decommissioning of the Hot Area also makes it possible to reconvert the Trieste power plant into a high-efficiency cogeneration (CAR) plant. Where the iron and steel process gases have been substituted by methane gas, with lowered consumption and high environmental performance. Consequently, the strengthening of the Cold Area was envisioned, with a new galvanizing and painting production line along with the relocation of the Hot Area workers.

Figure 3 - The hot area of the Servola ironworks undergoing demolition (author's photo, April 2021).

The First Executed Activities

The Hot Area shutdown procedure was consequently started in April 2020, and a new Program Agreement was signed on June 26, 2020, which aims to convert the part of the decommissioned production site into a logistics area and upgrade the remaining plants [7]. This phase also has a circular nature, the ferrous waste from demolitions will become the material at the base of the steel production cycle of the Arvedi Group, while the aggregates will be reused for the construction of the infrastructures of what will be the expansion of the new logistics platform by a new subject involved, I.CO.P., a group operating in the road construction sector, and special works. The so-called Hot Area with the old blast furnaces will make way for the expansion of the logistics activities of the Port of Trieste. The new cold rolling mill built in 2015, the core of the previous industrial reconversion project, will be doubled.

Planning

To obtain this result, it becomes necessary to reorganize the areas throughout a system of exchanges of lands, both privately owned and under state concession. Also necessary is a remodeling of the planning structures, currently in progress, which presuppose the development of industrial areas owned by the Municipality of Trieste as part of the General Town Plan of the Municipality of Trieste, while the areas under concession will be subject to the regime of the Port Town Plan.

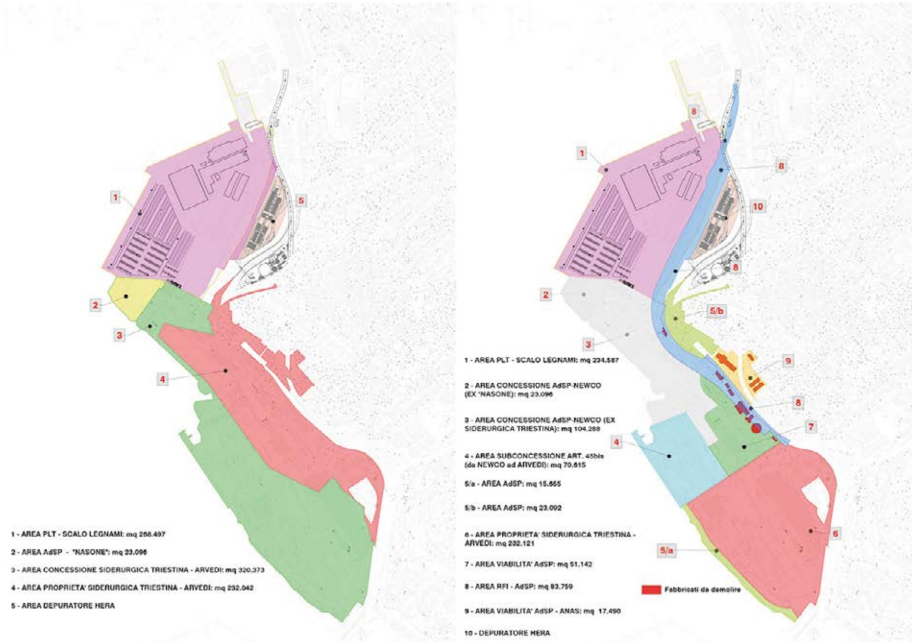

Figure 4 – The current and proposed layout of the areas (Annex 6 [11] to the Program Agreement). Legend on the left: 1) PTL Area – Timbers Shed; 2) AdSP area- "NASONE"; 3) Concession area of Siderurgica Triestina- ARVEDI; 4) Privately owned area by Siderurgica Triestina – AVREDI; 5) Hera depurator area. Legend on the Right: 1) PTL Area – Timbers Shed; 2) Concession area AdSP-NEWCO; 3) Concession area AdSP-NEWCO; 4) Sub-concession area; 5/a) Area AdSP; 5/b) Area AdSP; 6) Privately owned area by Siderurgica Triestina – AVREDI; 7) Viability AdSP area; 8) RF1 area – AdSP; 9) Viability AdSP area - ANAS; 10) Hera depurator.

The new plant will give an ambitious response in terms of eco-sustainable production, aiming at complete decarbonization and low-impact industrial production of the steel plant. Compared to the original contents of the Program Agreement, the energy will also be produced by a hydrogen plant whose electrolysation will be fuelled by the photovoltaic roof of over 95 000 square meters, house of the Cold Area plans building.

The Adriagataway Project

This further integration, the result of an initiative of the Arvedi Group, is in turn integrated with the Adriagateway project of the Port Authority System (*Autorità di Sistema Portuale*) [3]. Added to this scenario is the Port Authority's project: Adriagateway. A strategic plan of coordinated investments for the logistic/industrial relaunch of the port system of the Eastern Adriatic Sea in outlook of green and digital transition (2020-2026).

Figure 5 – Summary graph of the "Adriagateway Project" (AdSP, September 2020).

The Adriagateway Project, developed during the summer of 2020, defines a system of 57 potential actions (project components) to be implemented in the Port System, divided into 6 macro-categories and financed for 385 million Euros by the National Plan for Recovery and Resilience. For example, the electrification of the docks (cold ironing), which will reduce the impact of the generators of moored ships, which remain active during loading and unloading operations, as well as the strengthening of railway logistics, considered in terms of greater sustainability.

Conclusion

The scientific interest for the specific case of Trieste, developed on the basis of a procedure provided for by the 2006 Environmental Code, is due to the fact that it is the first completed application of this law in Italy. The results obtained include the completion of 100 environmental activities, the renewal of the existing industrial plant with a new production unit, the increase of port logistics activity and the maintenance of employment levels. Following these encouraging results, the activation of a second agreement, currently in progress, demonstrates the effectiveness and repeatability of the procedure. Furthermore, the new agreement introduces, compared to the previous one, new principles of “circular economy", both with regard to the disposal of existing buildings and plants, and with regard to the new production cycle, which is the subject of a specific research and development activity.

Industrial innovation, logistical implementation, environmental and landscape requirements, social protection and job opportunities, quality of life, ecological transition, are overlapping themes that outline a complex interdisciplinary scenario. The success of these operations is partly due to this holistic character, transversal to the convergence of actions carried out in different areas towards a single objective. What derives from this is also the value of a strategy based on the enhancement of relationships, connections, between different interests that no longer operate separate from each other. The ability to define development projects that also become environmental improvers is a complex vision, in a way, it could also be defined as creative. Time also plays a fundamental role; the effects of these transformations are measured on the passage of years. The process started in 2014, although many consequences are already appreciated, it has not yet been completed in its entirety, it continues to develop, it is progressively integrated. It has a dynamic, adaptable character.

"Bringing industry back to the sea" is a formula that has a precise and extensive strategic and planning significance. Today, logistics chains are getting shorter. This is a reduction of the excesses of globalisation. The pandemic in 2020, the blocking of the Suez Canal in the spring of 2021, and the Ukrainian war of 2022, have demonstrated the need to create regional buffers capable of absorbing interruptions in the distribution of goods and processing them while also creating added value. The case of the Port of Trieste can be a model to be studied in order to understand how to effectively govern these transformations, moving from the global logistics of the "Just in Time" to the more resilient structures that respond to the "Just in Case" logic, where the reuse and optimization of resources ensure achievement of outcomes on several fronts.

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MARINE LITTER SURVEYS ON BOCCASETTE BEACH (ROVIGO, ITALY)

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Abstract – This study aims to evaluate the abundance and accumulation of the beach marine litter in relation to the main human activities and during some different meteorological conditions. Five surveys were performed along Boccasette spit, in the Veneto Regional Park of Po Delta (northern Adriatic Sea), adapting the DeFishGear protocol for beach litter. The debris was collected and analysed, and the beach cleanliness was evaluated applying the Clean Coast Index. Boccasette beach can be classified as moderately clean from late summer to winter and as clean during spring and summer. The main litter macro-category is represented by artificial polymer materials (96 %), while the others macro-categories represent the 4 % of collected items. The main sources of the marine litter have been attributed to improper waste disposal and fishing/aquaculture activities. Our results suggest that specific management approaches are needed to minimize the impacts of river's flooding events. Finally, involvement activities of fishermen and fish-farmers should be performed in order to reduce the release of new marine litter and to implement the awareness regarding the plastic pollution.

Introduction

The presence of marine litter is a huge environmental problem, affecting beaches on a global scale, with physical, chemical, biological and economic implications [13]. Nowadays, the reduction of marine litter in the marine environment is recognised as a priority challenge to preserve the ecosystem and human health [1]. Since a large part of plastic debris is floating, an increasing load of marine litter is scattered over long distances, and then settle in sediments where it may persist for centuries [4] [5] [7] [17]. As a matter of fact, sandy shores are important sinks for debris, which after stranding generally becomes trapped in/under sand or might be blown farther inland [10] [11].

Considering all involved variables influencing the debris dispersion, it is difficult to establish sources, modes of transport and accumulation zones, even if such aspects are crucial to improve our knowledge on marine litter issues. Indeed, such information represents a primary tool for the development of the management strategies to reduce marine litter and to verify their effectiveness [13]. The understanding of how human activities influence the marine litter scattering in the Mediterranean Sea region assumes great importance, especially where the bathing seasons last long and beaches are generally crowded and close to residential areas [3] [15].

The main purpose of this paper is to perform an initial assessment of the abundance and accumulation of beach litter along a sandy beach in the northern part of the Po Delta, in

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relation to the main human activities and to meteorological events. Therefore, we try to answer to the following questions:

- What is the quantity and the composition of stranded marine litter?
- What are the differences in litter composition related to some different extreme meteorological events?
- What are the impacts of the human activities on the composition and distribution of the marine litter?

This study has been performed within the NET4mPLASTIC Project (European Programme CBC Interreg Italy-Croatia), which aims to develop new technologies for monitoring micro and macro plastic in the Adriatic Sea, in order to quantify the marine litter presence and its possible accumulation zones in four pilot sites.

Materials and Methods

The Po Delta area lies on the Natura 2000 Italian network that include Sites of Community Importance (Habitat Directive, 92/43/CEE) and Special Protection Areas (79/409/CEE). The coastal zones bordering the Po Delta are characterised by dune systems and bars, sometimes connected to spits that delimit wide lagoon areas [19]. Specifically, the Barbamarco lagoon lies in the Veneto Regional Park of Po Delta between the Po di Maistra river (to the NW) and Busa di Tramontana river (to the SE). The lagoon is separated from the Adriatic Sea by a barrier island and two sandy spits. Boccasette beach is located in Porto Tolle municipality (Rovigo, Italy), on the north-western spit of Barbamarco lagoon system, and is about 4.4 km long (Figure 1). Boccasette is considered as a semi-rural area [21], and the main human activities are generally fishery and aquaculture, while local tourist activities occur only during the summer season.

Figure 1 – Study area (Map created using QGIS, processed by Google satellite).

On Boccasette beach, five marine litter monitoring campaigns were carried out between November 2019 and October 2020. The meteorological conditions observed during the surveys, and the main information related to human activities affecting the environment are reported in Table 1.

Table 1 – General surveys information: cloud cover scale, Beaufort wind force scale and event notes.

Date	Cloud cover	Beaufort scale	Event notes
Nov 2019	Cloudy	7 – Near gale	At the beginning 1st sea-storm, high-water and flooding of Po
Dec 2019	Clear	4 – Moderate breeze	After 1st sea-storm; declining phase of high-water and flooding of Po
Feb 2020	Clear	4 – Moderate breeze	After 2nd sea-storm
June 2020	Clear	4 – Moderate breeze	After Covid-19 lockdown and before tourist season
Oct 2020	Clear	1 – Light air	After tourist season

The location of the sampling area was selected according to the following criteria [21]: minimum length of 100 m longshore for a fixed 100-metre stretch; low/moderate slope (~ 1.5 – 4.5°); breakwaters or jetties absence; easy beach access guaranteed all year round; no/few additional human cleaning activities.

Therefore, the sampling area covered a 100 m long shore-parallel line, on-field divided in 10 transects (10 m wide) with a variable length depending on hydrodynamic conditions (min. 19.61 m; max. 47.46 m). The boundaries of the sampling site and of each transect were measured using a dGPS (Leica GS16) and geo-referenced in the coordinate system WGS 84 UTM 32 N. In addition, a photogrammetric survey was carried out using an "Unmanned Aerial System Vehicle" (model 4 pro obsidian DJI phantom multirotor drone equipped with a high-resolution camera – 20 Mpixel) in order to generate an orthomosaic image for each campaign. The geo-referenced orthophotos were imported in QGIS software to calculate the sampling area in order to relate the number of collected items to a defined surface (Figure 2).

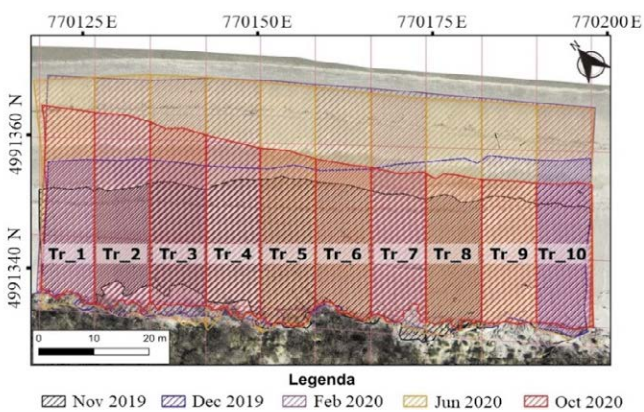

Figure 2 – Transects and sampling site for each survey, highlighted by five different colours (on February 2020 orthophoto).

Adapting [14], all stranded litter items (ranging from 2.5 cm to 50 cm) were collected and classified according to the potential main sources of release and buoyancy properties (i.e. density, weight and surface-to-volume ratio). Furthermore, the density of marine litter items per square meter [12] was calculated and then the beach cleanliness status was evaluated using the Clean Coast Index (CCI, Table 2 and Table 3) [2].

Table 2 – Clean Coast Index: value and definition for each quality class.

Quality	Value	Definition
Very clean	0 – 2	No litter is seen
Clean	2 – 5	No litter is seen over a large area
Moderate	5 – 10	A few pieces of litter can be detected
Dirty	10 – 20	A lot of litter on the shore
Very dirty	> 20	Most of the beach is covered with litter

Results

A total of 5578 debris items were collected and the average marine litter density is 0.35 items/m^2 (± 0.13 SD) (Table 3). In particular, the calculated density of autumn/winter period (Nov - Dec 2019 and Oct 2020) is higher than the late-winter/early-summer period. These values heavily depend on the dimensions of the beach and seasonality. The calculation of the Clean Coast Index (CCI) indicates that Boccasette beach was moderately clean during the autumn and winter season, and clean from February to June 2020 (Table 3).

Table 3 – Marine litter density and Clean Coast Index for each survey.

Date	Area (m^2)	Collected items (n.)	Marine litter density (items/m^2)	CCI [(items/m^2) • K]
Nov-2019	2326.94	1015	0.44	8.72
Dec-2019	2912.59	1203	0.41	8.26
Feb-2020	4372.92	1078	0.25	4.93
Jun-2020	4412.81	801	0.18	3.36
Oct-2020	3063.03	1481	0.48	9.67

Our results indicate that the collected items can be referred to 8 macro categories of materials (artificial polymer materials, rubber, cloth/textile, paper/cardboard, processed/worked wood, metal, glass/ceramics, unidentified and/or chemicals) and to 105 categories of items (identified by an alphanumeric code: "G + number"). The main macro-category of materials is artificial polymer (plastic), representing about 96 % of collected items, while the other macro-categories represent the 4 % of the total.

Depending on the main sources of release, the items have been categorized in:

- Improper waste disposal: 55 represented categories and 3708 items collected, referring to improper waste disposal and urban wastewater, whose release and transport into the marine environment is mainly driven by river; the most represented are: "G79 - Plastic pieces 2.5-50 cm" (17.75 %), "G21 - Plastic caps/lids drinks" (8.87 %), "G5 - Plastic bag collective role; what remains from rip-off plastic bags" (8.79 %) and "G95 - Cotton bud sticks" (8.58 %);
- Fishing/aquaculture activities: 14 represented categories and 1640 items collected, referring to maritime activities (including fishing and aquaculture), whose release may be more or less accidental; the most represented are: "G82 - Polystyrene pieces 2.5-50 cm" (47.13 %) identified as products of fragmentation or degradation of fishing boxes, and "G45 - Mussels nets" (41.16 %).

Regarding the two subsets, the values have been normalized (by dividing the number of collected items of each subset, with the number of total categories), and the relative percentage has been reported in Figure 3.

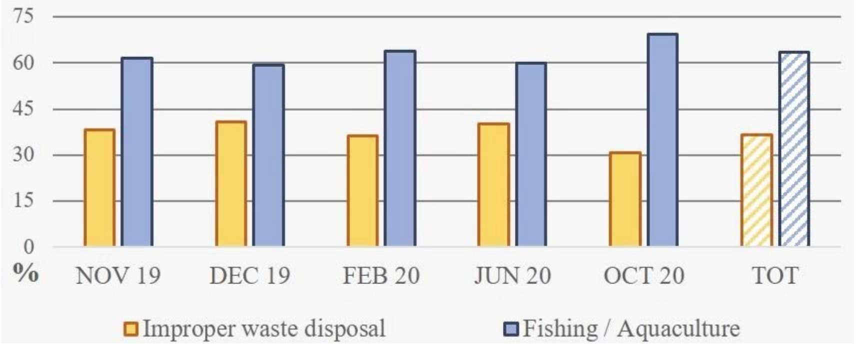

Figure 3 – Comparison of the percentage between improper waste disposal and fishing/aquaculture activities items, for each survey. Last columns: comparison of the total percentage.

In proportion, it is possible to observe a preponderance of the items attributed to the fishing/aquaculture subset compared to the improper waste disposal. Referring to the variation of items categories collected concurrently with the extreme meteorological events, we notice an increase of mussel nets and a substantial reduction of polystyrene pieces in November 2019 and February 2020. Furthermore, a considerable increase of polystyrene pieces (mostly fragments of fishing box) related to fishing activities has been observed during the survey of October 2020.

The classification of the items according to their buoyancy properties indicates that:

- Sinking items included 38 categories and 2524 items; the most represented are: “G79 - Plastic pieces 2.5-50 cm”, “G21 - Plastic caps/lids drinks”, "G95 - Cotton bud sticks";
- Floating items were associated to 30 categories and 2790 items collected; the most represented are: "G82 - Polystyrene pieces 2.5-50 cm", "G45 - Mussels nets", "G5 - Plastic bag collective role; what remains from rip-off plastic bags".

Even regarding the two subsets just listed, the values have been normalized and the relative percentage has been reported in Figure 4.

In general, there is a preponderance of the floating items compared to the sinking one, except for the survey of November 2019, in which it has been observed a considerable reduction of polystyrene pieces (floating) and an additional increase of plastic pieces (G79) and cotton bud sticks (G95).

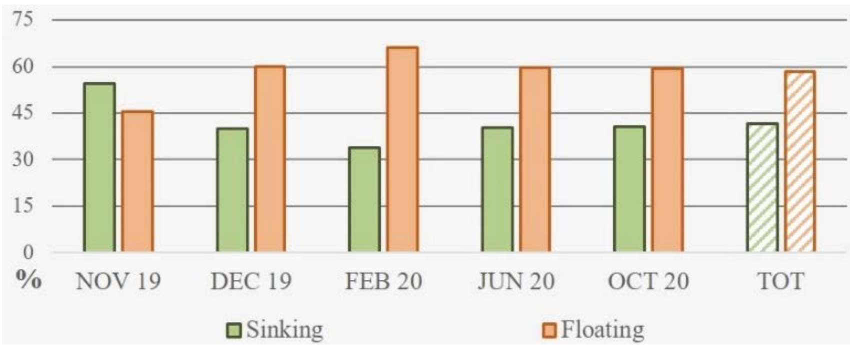

Figure 4 – Comparison of the percentage between sinking and floating items for each survey. Last columns: comparison of the total percentage.

Discussion

In this study, five marine litter surveys were performed to define the density of stranded items and the cleanliness level of Boccasette beach. The collected items have been referred to the main human activities that have caused the release in the environment. In addition, we linked the main results the items' buoyancy properties.

Regarding the beach marine litter density, our results (0.35 items/m^2, ± 0.13 SD) are in agreement with previous studies conducted on Boccasette beach (0.38 items/m^2, ± 0.26 SD) [21]. However, from field observations, it emerged that the marine litter accumulation mainly occurs in the upper sector of the beach, where the presence of vegetation or beach wrack may trap the items. Therefore, the effective marine litter accumulation zone is smaller than the whole beach, and this can result in marine litter density underestimation, but also overestimation of the results of Clean Coast Index. For this reason, despite for Boccasette beach the CCI values obtained, are encouraging, it would be more appropriate to use a multidisciplinary approach (for example, by also integrating the "Accumulation Index" [6]), that can take into account more local variables to define cleanliness level.

Concerning the marine litter composition, we do not generally observe a precise trend of the identified categories. However, the decrease of all collected items in June 2020 (Table 3), compared to the other surveys, can be explained as a result of some main contributing factors, which are: Covid-19 restrictive measures, forced interruption of human activities, delay of starting tourist season and beach management activities.

During spring 2020 the Covid-19 lockdown negatively impacted all human activities. Indeed, the fishing/aquaculture activities have been interrupted and the tourist season, that in Italy usually starts in May, in 2020 started in June. That caused a delay in the beach management activities along Boccasette spit, in particular the mechanized cleaning activities performed by the local authorities or the beach resorts' managers (usually carried out during summer seasons, close to beach facilities, located approximately 1000 m northward of the sampling site). Despite having been maintained the main criterion of site selection (no/few additional human cleaning activities), we believe that such cleaning activities may have directly influenced the marine litter abundance in June 2020.

It has been argued that the main human activities performed in a specific area affect the typology of the marine litter stranded on the adjacent coastal area (e.g. [8]). Our results show as the highest number of stranded marine litter on Boccasette beach are usually related to improper waste disposal. However, considering the scarce presence of items directly attributable to tourist activities (food packaging, beach use related cosmetic bottles, straws, etc.) on Boccasette beach the impact related to tourism can be considered less relevant compared to other studies (e.g. [18]). Moreover, the abundance of items referable to urban wastewater (e.g. cotton bud sticks, plastic pieces including many filters from wastewater spill), suggests that the study area is affected by a constant marine litter input, whose release and transport into the marine environment is most probably driven by the Po river.

Our results also indicate that fishing/aquaculture activities are also responsible of the presence of marine debris along Boccasette beach prevail over the improper waste disposal. Specifically, during October 2020 survey (just after fishery closed season, which occurs in August) it is possible to observe a considerable increase of polystyrene pieces associated to fishing activities. Similar results have been obtained by [20], which reported that high debris in autumn could also be related to intensive fishing activities. In addition, the increase of the marine litter observed at October 2020 could not be attributed to meteorological events since before the survey the marine and weather conditions were calm. Therefore, we believe that the restart of fishing activities (post-lockdown and post fishery closed season) may have mainly contributed to the accumulation of polystyrene fragments from fishing boxes on the beach.

Furthermore, concerning the aquaculture, an exceptional abundance of mussel nets (that also belong the floating subset) has been observed in February 2020 mostly as a consequence of some sea-storms occurred in winter season. In concomitance of extreme meteorological events, it is possible to observe a variation of specific collected items, also related to buoyancy properties. Generally, it has been generally observed a predominance of floating stranded marine litter compared to the sinking ones, except at November 2019. In fact, in this occasion sinking items prevailed on the floating ones. We refer this trend to the timing of the monitoring campaign, that has been conducted just at the beginning of the extreme events (Table 1). The increase of sinking items (also related to wastewater release) could be related to Po flooding and high-water. Such impact of flooding events on marine litter transporting has been reported by different authors. For instance, [9] observed a large amount of marine debris was washed up on the beaches of Geoje Island (South Korea) after a period of heavy rainfall in July 2011, affecting the island's tourism industry. Furthermore, the results of [16] showed a potential worldwide plastic mobilisation increase (even tenfold) during flood events. However, it is difficult identified when exactly the marine litter accumulates on the beaches, and further studies are needed to understanding the pathways of marine litter in the environment, and in particular in highly dynamic ecosystems as the lagoons.

Conclusion

In this study, the quantification and categorization of the macro litter along a sandy spit of the Po Delta have been analysed, in relation to meteorological conditions and main human activities. The results indicate that along Boccasette beach the evaluation of the marine litter density and Clean Coast Index can be used for management purpose. However, we suggest that the monitoring activities should be modified by dividing the stretch in different zones, according to geomorphological criteria, and integrating a multidisciplinary approach.

The distribution of the marine litter shows that most of the items were fragments of artificial polymer materials, of which the 69 % of the items were released from land-based human activities (improper waste disposal), while about 31 % were related to fishery and aquaculture activities. Consequently, much of the marine litter found on Boccasette beach can be associated to local economic activities, and also to external sources (wastewater), confirming the role of the fluvial transport and of the meteorological factors. Therefore, specific management approaches are needed to minimize the impacts of river's flooding events. In addition, our results suggest that specific educative activities for fishermen and fish-farmers should be performed in order to reduce the release of new marine litter and to implement the awareness regarding the plastic pollution.

Finally, the importance of human factors has been illustrated in relation to the Covid-19 specific situation. The low abundance of marine litter items collected during early-summer 2020 could also be related to the positive impact of the lockdown restrictive measures. Litter impacts on beaches include deterioration of coastal and marine environment, human health hazards, and substantial financial investments for cleaning activities. Therefore, additional data are needed regarding the spatiotemporal trends of marine litter in different coastal environments.

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THE ECONOMIC AND ENVIRONMENTAL IMPACT OF LARGE SHIPS ON THE TERRITORY, ON THE COAST AND ON THE SEA: THE MSC CRUISES CASE STUDY[1]

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Abstract – Cruise tourism is expanding almost everywhere, despite the pandemic generated by COVID-19 in this sector as well. According to estimates and reported by the CLIA (2021), between mid-March and September 2020, the economic damage was around 77 billion dollars, with a loss of jobs that exceed 500 000. The CLIA itself, however, records a significant increase in travelers who aspire to join a cruise, even among those who have never been there. Cruise ships and their economic impact have been the subject of research for many years and the data, which can also be obtained from various agencies and shipping companies, denote the importance of this particular sector, in the more general context of tourism. It is therefore increasingly appropriate to direct research towards an interdisciplinary and multidisciplinary analysis that considers the concept of environmental impact (now in many cases somewhat emptied of its deep meaning and become a sort of opportunistic slogan), so as to consider, in addition to the economic aspects, also the anthropogeographic ones (both negative and positive). In fact, the opportunity to enrich the technical and organizational changes required by the pandemic with second thoughts that also have a cultural impact, in addition to the usual environmental impact, is a delightful opportunity. Through the MSC case study, this contribution aims to partecipate in the reflection on the theme of sustainability, which is also abused lexically, to look at the possibility of directing cruise tourism towards a new way of introducing Man into the landscape.

Introduction - Man, Nature and the ship: “paleo-cruises” and “neo-travels”

We understand the importance of the topic, from the term “cruise” and the french derivative term *croiser* (to cross), with the meaning of patrolling a stretch of sea (to distinguish from the architectural significance[2]).

[1] The work is the result of the collaboration between the authors; however, it is possible to attribute paragraph n. 1 to Anna Rosa Candura; n. 2 to Emanuele Poli; n. 3 to Luca Fois.
[2] The etymology proposed on the site *sardegna-traghetti.info/crociera/* is interesting; however, we do not find homogeneity in the encyclopedic entries; by way of example, we recall, Treccani: «In aeronautical terminology, phase of the flight of an aircraft in which the speed and altitude are regulated so as to cover a given distance in the most economical way possible both in terms of costs consumption both in relation to the duration of the aircraft and the propulsion system.[..] Contract concluded for a c. tourist, that is, for a pleasure trip, mainly by sea and usually with a return to the starting point. It is a

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The first cruise in a contemporary sense (a sea voyage for tourism) dates back to 1833. In 1831 the Francesco I ship entered service which covered the Palermo, Civitavecchia, Livorno, Genoa, Marseille lines. The same ship made the first tourist cruise in the world, in 1833, more than 50 years ahead of those that followed: it lasted three months with departure from Naples, arrival in Constantinople (where it aroused the admiration of the sultan) and return with several intermediate stopovers[3]. However, it was the “Albert Ballin”[4] ship that set up the real cruise business from 1928; the first ship that exceeded 100 000 tons was built again in Italy, by Fincantieri.

Figure 1 – The ship Francesco I.

After recognizing this forgotten primacy in Italy, it cannot be argued that a precise historical moment should be established for the birth of an activity of which we can find much more than an ancient trace. Think, for example, of Luciano di Samosata who describes the arrival of the ship Isis, well analyzed by Tomassi. The arrival of the Isis in Piraeus attracts an extraordinary mass of onlookers, so much so that Adimanto gets lost in the crowd, without his friends noticing. In the 2nd century A.D., Piraeus was excluded from the great navigation routes and was animated mainly by tourists, intellectuals, and students, attracted by the monuments and by the renowned Athenian philosophical schools. Consequently, the arrival of a ship of impressive proportions could not fail to arouse the curiosity of the locals, accustomed to seeing boats of much more modest tonnage. However, the landing of a ship in the ration fleet (*flotta annonaria*) had to represent an extraordinary event even, in the busiest ports (more or less equivalent to the docking, at some docks, of modern cruise ships), as evidenced by the testimony of Seneca, according to which the arrival of grain ships from Alexandria in Pozzuoli was an event that attracted all the inhabitants of the place to the port,

typical membership contract stipulated between a travel agency, which provides for the organization, and individuals.» (treccani.it/enciclopedia/crociera/).

[3] Maresca, 2012, p. 129 (freely translated from the Italian text).

[4] The ship was built by the Blohm & Voss company of Hamburg.

as if it were a party[5]. In ancient times boats used exclusively for human transport did not exist and for this function they generally made up for merchant ships, on which travelers were offered a place to sleep and water to drink, while, for food or other types of drinks, they had to think themselves. As a result, merchant ships were often crowded with passengers who, in some cases, had to stay tight during the crossing, due to excessive crowding. For those who were leaving Italy for the Near East, or had to follow the opposite route, large ships such as the Isis were the fastest and safest means of transport. Unfortunately, we do not have any explicit information on how people got on board, since the first evidence relating to the space the passenger could have, the amount of free baggage, the rules relating to food and drink will only be available in the Middle Ages; for the ancient era, we find only hints, scattered in various kinds of texts, which in any case make it clear that only those who could afford it could obtain a more or less comfortable accommodation, otherwise people made do as they could, traveling in conditions often uncomfortable or even inhumane[6]. While it is not possible to establish a date of birth for the cruise, it is possible to identify reflections and data relating to the environmental impact that navigation produced in various areas. With regard to a reflection on the relationship with the landscape that can connect Man to the Planet (in a form that, today, we call "sustainable"), we can go back so far as to make the choice of possible citations difficult. In order to recall both Italian and Anglo-Saxon scientific thought, we therefore choose (for pure lexical opportunity) to recall two eminent scholars.

For Italy, we mention Sestini (1947), since he taught us to consider the locution "anthropogeographic landscape" almost equivalent to "sustainable landscape", thus demonstrating how Italian Geography has contributed to forging that planetary sensitivity which is so much in vogue today[7]. For the Anglo-Saxon context, increasingly, the best analysis (on the question of the changes that our Species has always made to the Earth) was offered to us by Marsh[8], in the preface to his famous work *Man and Nature; or, Physical Geography as Modified by Human Action* (1864). Here the naturalist reminds us that the purpose of the copious volume (560 pages) is to indicate the character and the extent of the changes produced by human action in the physical conditions of the globe and to illustrate the condition of Man who, both in the Species and in the degree, is a Power of a higher order than any other form of animated life[9]. The superior order to which Marsh refers is not,

[5] *Subito nobis hodie Alexandrinae naves apparuerunt, quae praemitti solent et nuntiare secuturae classis adventum: tabellarias vocant. Gratus illarum Campaniae aspectus est; omnis in pilis Puteolorum turba consistit et ex ipso genere velorum Alexandrinas quamvis in magna turba navium intellegit.* (Seneca, Epist. 9, 77,1).

[6] Tomassi, 2019, p. 108-110, *passim* (freely translated from the Italian text).

[7] Generally, in Italian scientific thought, naturalists emphasize the position of Man who has become: «the main modifying agent of the earth's crust» (Candura 1964, p. 3).

[8] He is considered the first American ecologist (Lowenthal, 2000); it would be better to define him a naturalist, in order to avoid confusing "ecology" with "ecologism", a word with a political meaning.

[9] «The object of the present volume is: to indicate the character and, approximately, the extent of the changes produced by human action in the physical conditions of the globe we inhabit; to point out the dangers of imprudence and the necessity of caution in all operations which, on a large scale, interfere with the spontaneous arrangements of the organic or the inorganic world; to suggest the possibility and the importance of the restoration of disturbed harmonies and the material improvement of waste and exhausted regions; and, incidentally, to illustrate the doctrine, that man is, in both kind and degree, a power of a higher order than any of the other forms of animated life, which, like him, are nourished at the table of bounteous nature.» (Marsh, 1864, p. III).

however, intended as moral superiority (as can be seen from reading his work); the naturalist refers to a potential superiority which makes especially necessary to develop that sense of responsibility to which Geography always refers. It is not the optimistic vision of Tertulliano who, in the second century, observed the domination of Man over Nature; Marsh manifests a cautious pessimism, accompanied by data and observations, from which we draw an in-depth study suitable for the theme of navigation. In Chapter III (*The woods*), where he extensively dedicates himself to the modifications made by Man to the forests, he inserts an interesting digression, recalling how, since the Middle Ages, the great naval navies of Venice and Genoa have caused an immense consumption of *limber*[10]; marine construction of that period employed far more lumber than modern naval architecture of most trading countries; the ancient techniques of building ships, of the Mediterranean area, have been handed down for a long time. Marsh also cites the geologist Karl Hummel (1855), for his observations around the Carso landscape, where the bare rock is swept by the Bora; the fury of this wind was once held back by fir trees, the trees that the Republic of Venice cut down in large numbers to build its fleets[11]. Since the nineteenth century, therefore, the environmental impact of navigation was very clear, even with regard to the procurement of building materials; we are not, therefore, narrating anything new or surprising, but we can certainly note the secular disinterest (or at least the superficiality) for the warnings of the "nature specialists" of various orders, degrees and eras.

The case of MSC Cruises

The significant case of MSC cruises bodes well, in the context of the containment of environmental damage. The shipping company MSC Cruises periodically publishes a sustainability program, in which the environmental and social policies promoted are defined, illustrating the objectives achieved and those on the agenda schedule (MSC, 2019). In the 2019 program report, (the year during which the company was not yet harmed by the pandemic) many issues are addressed (Trovato, 2021). With regard to gaseous emissions, MSC has invested five billion euros to power three future ships with liquefied natural gas (LNG), a fuel that reduces emissions of sulphur and nitrogen oxides by 99 % and 85 % respectively. MSC is committed to modernizing the rest of the fleet, installing advanced technologies that can significantly reduce SO_X and NO_X emissions. LNG will also make it possible to reduce CO_2 emissions by up to 20 %. The problem related to the use of this fuel

[10] «Limber is a sixteenth-century word used in the dialectical sense to refer to a cart shaft, alluding to its to and fro motion.» (dictionary.cambridge.org/dictionary/english/limber).

[11] «The great naval and commercial marines of Venice and Genoa must have occasioned and immense consumption of limber in the Middle Ages, and the centuries immediately succeeding those- commonly embraced in that designation. The marine construction of that period employed larger timbers than the modern naval architecture of most commercial countries, but apparently without a proportional increase of strength. The old modes of ship building have been, to a considerable extent, handed down to the present day in the Mediterranean, and an American or an English-man looks with astonishment at the huge beams and thick planks so often employed in the construction of very small vessels navigating that sea. According to Hummel. The desolation of the Karst, the high plateau lying north of Trieste, now one of the most parched and barren districts in Europe, is owing to the felling of its woods to build the navies of Venice. "Where the miserable peasant of the Karst now sees nothing but bare rock swept and scoured by the raging Bora, the fury of this wind was once subdued by mighty firs, which Venice recklessly cut down to build her fleets" – *Physiche Geographie*, p. 32.» (Marsh, 1864, pp. 218-19, nota †).

is the so-called methane slip, the escape of unburned methane through the engine, which MSC thinks it can reduce by updating its engines and technologies. MSC is investing in an innovative project in collaboration with Entrepose Group, the Chantiers de l'Atlantique shipyard and the French Commission for Alternative Energy and Atomic Energy to develop a power system that uses LNG batteries. The batteries would be recharged ashore at each shipyard, reducing CO_2 emissions by over 325 000 tons (MSC, 2019)[12]. For the sector of environmental innovations, various interventions are announced on the components of existing ships and the design of future ones: the exhaust gas cleaning system reduces the sulfur oxides produced by the exhaust itself by 98 %; the hull and propellers are designed and improved to minimize radiated underwater noise, which disturbs aquatic mammals; wastewater is treated through an advanced system that returns it to the sea practically drinkable; waste is pressed, sorted or incinerated, while residual waste is delivered to ports and properly disposed of; the hulls are covered with low environmental impact anti-vegetative paints; the total illumination of the ship is guaranteed by energy-saving LEDs and fluorescent bulbs. 63 % of wastewater is affected by advanced treatment and, as stated by the Vice President of Environmental and Compliance Operations, MSC's policy requires bilge and oil water to be landed and purified. In accordance with the International Convention for the Control and Management of Ballast Water and Ship Sediments, MSC is committed to eliminating any threats related to the transport of species through ballast water, to preserve ecosystems (MSC, 2019). MSC Cruises is therefore sensitive to the main sustainability objectives promoted, coordinating technological innovation, passenger well-being and scientific research. The results achieved are still insufficient, and not all shipping companies promote the same initiatives or respect environmental protocols (Carić, 2010 a).

Results

The case of MSC represents an example of sustainable planning, in the context of cruise tourism. The issue of the impact of cruise tourism is, in fact, complicated and embraces different and distant themes and disciplines. It is important to reconstruct a general picture of the effects that large ships have on the environment, considering the economic impact in light of the costs required to manage the impact of this important activity on the seas and oceans. The complexity of the topic is difficult to describe, but this should not discourage the attempt to analyze the different fronts.[13] What emerges, especially from the MSC sustainability program, is the importance that scientific research and technological innovation assume in inspiring the choices of governments and navigation bodies. The growing presence of multidisciplinary studies on the issue gives hope that, in the future, the definition of "impact" will be continuously updated and will be able to provide the scientific community with an increasingly detailed picture of that cultural, social, economic, environmental, and engineering phenomenon that is cruise tourism.

[12] See: Ytreberg, Eriksson, Maljutenko, Jalkanen, Johansson, Hassellöv, Granhag, (2020), p. 1.

[13] See, for example: Carić, (2010 b); Dosi, Musu, Rizzi, Zanette (2013); Milazzo, Badalamenti, Ceccherelli, Chemello, (2004); Nabi, McLaughlin, Hao, Wang, Zeng, Khan, Wang, (2018); Raudsepp, Maljutenko, Kõuts, Granhag, Wilewska-Bien, Hassellöv, Eriksson, Johansson, Jalkanen, Karl, Matthias, Moldanova, (2019).

Discussion - Man and the sea: for a sustainable economic recovery, between past and future

There are countless examples of the fundamental role that the sea has always played in the life of our Species, to describe the link between the sea and History. The great French historian Ferdinand Braudel wrote about the Mediterranean Sea: «The sea. We must try to imagine it, to see it with the eyes of a man of the past: like a limit, a barrier that extends to the horizon, like an obsessive, omnipresent, enigmatic immensity»[14]. Precisely the eyes of a man of the past - Lamberto di Saint-Omer - see him surround, dividing and characterizing an idealized Europe, a fraction of an ecumene reduced to the schematic O-T representation, typical of the medieval world.[15] Lamberto's image is accompanied by lists of geographic objects and peoples, so that the space - even the one drawn - is always covered by writing: everything in its place, every people in its land[16]. Real distances are canceled out by the ideal representation; the observer can gaze at the entire continent and its inhabitants, each with its diversity, just imagined.

Figure 2 – 1120 Cartographic representation of Europe from *Liber Floridus* by Lamberto di St.-Omer.

The respectful tack, the slow time of the crossing, are now drastically reduced by the speed of the machines and that ideal map has suddenly become real, however losing the

[14] Braudel (1998), p.19 (freely translated from the Italian edition).
[15] See: Harvey (1987); Woodward (1987).
[16] See: von den Brinken (1972).

sense of human and geographical differences. The thin and insurmountable limit of the sea is plowed by ever larger ships carrying travelers-tourists to the "discovery" of an exotic now only stereotyped and artificial, standardized by commercial needs. Thus the ship is no longer the heroic tool with which the Renaissance man imposes his thirst for knowledge on Nature. The oversized object-ship, full of historical significance, which appears in the historiated papers of the early modern age, such as the famous one by Sebastian Munster (1550), is totally canceled from a perspective aimed only within ships that are increasingly large and complex, but totally deprived of their symbolic strength, reduced to the mainland, to anonymous corridors of shopping centers, all identical, all falsely reassuring. The time of the journey is occupied by something else, the goal is just another activity among the many proposals, without interruption, without perception of the different.

Figure 3 – Sebastian Münster, 1550.

The need to reconstruct the right proportions between man and the sea, symbolized by the Münster map (1550), connects us well to contemporary cruise navigation; born as a pure economic activity, but containing suggestions and structures capable of contributing to the achievement of that goal (anthropogeographic balance) which, currently, is the absolute protagonist of the 17 objectives of the 2023 Agenda[17]. The tourist/traveler - often coming from far away and completely decontextualized - is transported from one place to another, without being able to realize precisely how he arrived, with the urgency to absorb as much information as possible, to see as many buildings, places, works as someone suggests to him to be important and unmissable. Other impacts concern the places and territories touched. The cultural offer, driven by profit, conforms to demand, diluting the peculiarities, depending on the short time of visits and the impossibility of further study. The economic opportunity causes societies and customs to change, somehow impoverishing all the actors involved. The

[17] This objective, however, requires a joint effort to bring down disciplinary barriers, facilitating connections and collaborations between researchers.

‘environmental’ impact of cruise tourism should therefore also take into account time and space as identifying elements of the places, not only the technical aspects of protection, recovering them, with the mediation of History and Geography in order to bring the journey back to its original dimension, less bulimic and more “human”[18].

Conclusion

In order to clarify the condition of cruise navigation in 2020, Kelly Craighead[19] says that: «For the cruise community, there is no denying that 2020 was not the year we anticipated. Still, the industry wasted no time adjusting course to address the challenges before us. With the year drawing to a close, we are pleased to share CLIA’s 2021 report that highlights the extraordinary steps that cruise community took to develop and implement enhanced public health protocols to keep putting people first, while continuing to focus on innovation and responsible tourism practices that make cruising the best way to experience the world.» (cruiselifestyle.co.uk/2020/12/28/state-of-the-cruise-industry-2021/). The desire to put people first, turning towards responsible tourism, has led us to believe that the MSC case study, summarized in paragraph 2, denotes an approach to “sustainability”[20], compatible with the desirable expansion of the cultural horizons of this specific tourist activity. However, this is a land, albeit fertile, on which the seeds of interdisciplinary collaboration are still to be planted. Even for human works related to cruise navigation (as for any other activity), the proposals for the future must be based on the foundations of experience, therefore of History. Citing once again a classic of scientific thought, Marsh (1864), we resume some of his observations, fundamental around the importance of a careful study of the consequences of Man’s actions on the Planet. The naturalist, cited in paragraph I, reminds us: «But it is certain that man has done much to mould the form of the earth’s surface, though we cannot always distinguish between the results of his action and the effects of purely geological causes; that the destruction of the forests, the drainage of lakes and marshes, and the operations of rural husbandry and industrial art have tended to produce great changes in the hygrometric, thermometric, electric, and chemical condition of the atmosphere, though we are not yet able to measure the force of the different elements of disturbance, or to say how far they have

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[18] «The management of natural and human resources settled in the various territories has become increasingly important as an instrument of economic development, especially in the tourism sector.» (Rizzo, Rizzo, 2022, p.1).

[19] CLIA President and CEO: «[...]the world’s largest cruise industry trade organization» (cruiselifestyle.co.uk/2020/12/28/state-of-the-cruise-industry-2021/).

[20] We refer, in particular, to the 2030 Agenda: «The 2030 Agenda for Sustainable Development is an action program for people, the planet and prosperity signed in September 2015 by the governments of the 193 UN member countries. It incorporates 17 Sustainable Development Goals - SDGs - into a large action program for a total of 169 ‘targets’ or goals. The official launch of the Sustainable Development Goals coincided with the beginning of 2016, guiding the world on the way to go over the next 15 years: the countries, in fact, are committed to achieving them by 2030. The Goals for Development follow up on the results of the Millennium Development Goals that preceded them, and represent common goals on a set of important development issues: the fight against poverty, the elimination of hunger and the fight against to climate change, to name but a few. ‘Common goals’ means that they concern all countries and all individuals: no one is excluded, nor should they be left behind on the path necessary to lead the world on the path of sustainability.» (unric.org/it/agenda-2030/).

been compensated by each other, or by still obscurer influences; and, finally, that the myriad forms of animal and vegetables life, which covered the earth when man first entered upon the theatre of a nature whose harmonies he was destinated to derange, have been, through his action, greatly changed in numerical proportion, sometimes much modified in form and product, and sometimes entirely extirpated.» (Marsh, 1864, pp.13-14).

What Marsh observed in the mid-nineteenth century is, to a large extent, still applicable to contemporary human activities and serves as a warning to us not to overlook the fundamental role of History and Geography as “ethical supervisors”.

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FISHING AND TERRITORY. STATUS AND PERSPECTIVES OF SARDINIA FISHERIES. THE CASE OF TRADITIONAL FISHERY IN ASINARA ISLAND MPA*

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Abstract – This contribution intends to suggest a survey on the dynamics related to fishing activity in Sardinia. Firstly, it will be proposed a quantitative synoptic analysis about the relevance of the aforementioned sector on a global, continental and national scale. This will be followed by a more careful analysis of the nautical and fishing sectors in Sardinia and, in particular, in Asinara Island. As regards the case study, through the consultation of institutional reports and cross-sector reference bibliography, there will be presented the specificities related to the state of the fishing fleet in Sardinia and to the data of the vessels carrying out fishing and aquaculture activities in Sardinian waters. In relation to the state and deployment of the fishing fleet at the major and minor port systems of the island, the main techniques and tools used by Sardinian seafarers will also be analyzed (fixed longlines, bottom trawls, purse seines, casting nets, driftnets). Next, the contribution will provide updated information about employment in fishing and about the importance of this sector for the local economy of an island with almost 1900 km of coastline and a marked vocation for seaside tourism. As a matter of fact, if fishing constitutes an economic and socially relevant activity in itself and an important historical and traditional heritage, it represents at the same time a possible trigger to read the territorial dynamics of coastal areas, to identify possible extensions and enhancements of the tourist offer (fishing tourism), to investigate the effectiveness and consistency of bottom-up governance formulas. Governability, however, is a complex concept with many dimensions and Marine Protected Areas (MPAs) are certainly a valuable tool to meet both conservation and socio-economic needs. Indeed, it has been extensively demonstrated that well-managed MPAs lead to an increase in species richness. The mapping and the identification of habitats and species fished in Asinara Island MPA made it possible to pinpoint the priority areas in need of protection and to define efficient fisheries management measures shared by all stakeholders. The study outlines small-scale fishing in the Marine Protected Area of Asinara Island and fosters knowledge and evolution of artisanal fishing activities in the study area. This work also intends to constitute the premise for future and more applicative lines of research.

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Fishery and Aquaculture: multi-scalar notes

The FAO report *The State of World Fisheries and Aquaculture 2020 Sustainability in action* [1] shows that global fish production reached approximately 179 million tons in 2018, with an estimated value of 401 billion USD. Compared to the total, 82 million tons, worth 250 billion USD, came from aquaculture production. 156 million tons of the overall total were used for human consumption, equal to an estimated annual supply of 20.5 kg per capita. The remaining approximately 23 million tons were destined for non-food uses, mainly to produce fish-meal and fish-oil.

Aquaculture accounted for 46 % of total production and 52 % of fish intended for human consumption. Most of the world's marine fish stocks are over-exploited; this leads to a decline in fish populations and drastic changes in food webs and in the functioning of the ecosystem [2; 3; 4].

As regards the European scale, we can deduce some contextual data from the report of the EUMOFA (European Market Observatory for Fisheries and Aquaculture Products) *The EU fish market* (2020) [5]. The production from fresh fish in the European Union, in 2018, amounted to 6656 million tons, with a decrease of 3 % compared to 2017. Over 5300 million tons of the total value were destined for consumption.

The state of Mediterranean stocks is particularly delicate [6; 7]. Its characteristic as a semi-enclosed basin makes it extremely vulnerable to anthropogenic pressures such as habitat degradation, over-exploitation of resources and pollution, especially in the context of global warming [8]. According to the FAO, 75 % of Mediterranean stocks assessed are over-exploited [1]. Nevertheless, the exploitation of fish stocks in Mediterranean Sea is not the same among the different fishing practices: 17 % of the vessels in the fleet are dedicated to trawling, dredging and seine fishing, while 83 % are dedicated to small-scale fishing [1; 4]. Although it is the most widespread fishing practice in Mediterranean Sea, few studies have analyzed stocks fished by small-scale fisheries, resulting in an important knowledge gap between large-scale and small-scale fisheries [4; 9]. The lack of data on traditional and small-scale fishing in Mediterranean Sea (fishing effort, catch rate) and biological information (species, catch size, weight) means that most of the fish stocks affected by this type of fishery are not evaluated [10] making their insertion into national and international management policies complex [11; 12; 13].

The Italian data, referred to 2020, as regards the tons of fish, was equal to 130 085 tons, which corresponded to an economic value of 642.45 million euro [14]. Compared to the fleet operating in Italy (Figure 1), 11 926 small boats and 145 302 large fishing boats were recorded in 2020, with a constant trend in decline since 2004, for a total of 928 127 kW of delivered power [14].

Regarding instead aquaculture, again in 2019, according to the ISPRA Report [15, p.1], 152 534 tons of fish were produced: 60.7 % mollusks, 39 % fish and 0.01 % of crustaceans. In the same report we read: "Veneto is confirmed as the first region in Italy by number of plants (25 %), while Emilia-Romagna is the first region by production volumes (24 %). […] Five regions (Veneto, Emilia-Romagna, Friuli-Venezia Giulia, Puglia, Sardinia) host 66.6 % of the aquaculture plants and contribute 66.8 % to national production. In most coastal regions, the use of brackish / salt water resources prevails, with plants located in transitional, coastal and marine environments [...]. Aquaculture production in the reference period 2013 - 2018 grew by 8.3 % overall, with an annual trend of + 1.7 %".

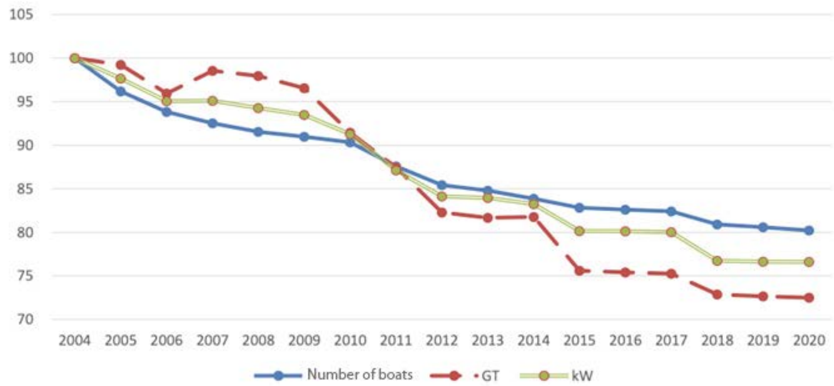

Figure 1 – Fishing fleet in Italy. Source: [14, p.6].

In 2019 in Italy, as evidenced by BMTI data [16], per capita consumption revealed that large families individually consumed less (on average 4 kg per capita in families with more than 5 members and an expenditure of 38 euro) and moved towards the purchase of less expensive products such as mussels and pangasius. Again, in the months of the pandemic, compared to the data relating to fish consumption, ISMEA 2021 data [17, p. 5] based on Nielsen calculations show that: "Fresh food, in the initial period of the lockdown, clearly suffered the effects of the limitations for the containment of infections, with an almost zero demand for quality products by the catering industry. But after a fluctuating trend, spending on fresh fish in the final phase of the year showed a clear recovery (in December it marked the best performance with a + 21 % compared to the same period of the previous year). This allowed the surpassing of the results of 2019 […] until in the first quarter of 2021 the sales of fresh fish products rose dramatically, reaching + 33.3 % compared to the same period in the previous year".

Sardinia as focus

With almost 1900 km of coastline and 15000 hectares of wetlands, Sardinia has a highly qualified landscape for fishing and aquaculture. CREA 2021 report [18] analyzes volumes, in terms of catches and revenues, relating to this sector in Sardinia in 2019: 8160 tons of catches (4.7 % of the national figure) and 63.2 million of revenues (7.1 % of the national figure). With respect to data on catches, we report below the historical trend 2008-2016 (Figure 2).

In this context, it is possible to provide an update through January 2020 on the consistency of the fleet as reported by Fleet Register - European Commission [20]: small boats amounted to 1326 (11 % of the national figure). In general, Sardinian fleet expressed a total tonnage of 14 914 GT (gross tonnage) and a total engine power of 53 748 kW.

452 of the 1326 ships belonging to Sardinian fleet were registered in a port in Northern Sardinia. This segment of fleet expressed a total tonnage of 4768 GT (out of a Sardinian total of 14 914) and an engine power of 22 652 kW (out of a Sardinian total of 53 748). Despite a negative trend over the years, Sardinian fleet remains one of the largest in the entire national territory.

This fleet is allocated in 18 ports [20; 21] as reported in the table (Table 1).

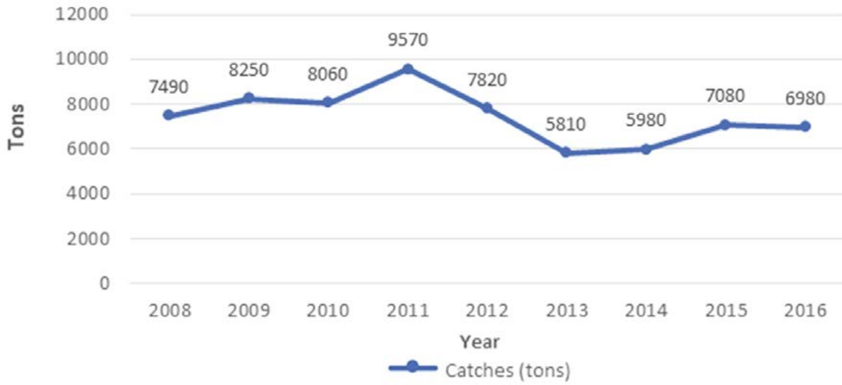

Figure 2 – Variations of catches in Sardinia seas. Source [21].

Table 1 – Fleet positioning in Sardinian ports. Source: Fleet Register - European Commission [20].

Port	Number of boats	Tonnage (GT)	Power (kW)
Alghero	91	1122	4447
Arbatax	47	661	1347
Bosa	39	127	824
Cagliari	189	4887	12270
Cala Gonone	6	311	949
Carlo Forte	38	245	1287
Castelsardo	42	173	1625
Golfo Aranci	48	176	835
La Maddalena	28	305	1605
Olbia	44	260	1017
Oristano	339	1061	4502
Porto Cervo	0	0	0
Porto Conte	1	14	397
Porto Scuso	17	150	819
Porto Torres	113	2018	9937
S. Teresa di Gallura	46	573	1965
Sant'Antioco	210	2293	8255
Siniscola	28	538	1667
Sardinia	**1326**	**14914**	**53748**

Concerning the reduction in terms of tonnage and engine power, the island's fleet follows a trend that has been going on for many years and involves the entire Italian fleet, and in general almost all of the fleets in Mediterranean Sea; this derives from the increase in production and fuel costs, as well as from the control policy by Europe (allocation of quotas for member countries) [19; 20; 21]. Also interesting is data on fuel consumption that represents an index of profitability of fishing activity. In the period 2008/2016 there was a decrease in fuel consumption which improved technical efficiency of production activity since, in 2016, for each kilogram of fish landed, an average value of 2.1 liters of diesel was estimated per kilogram consumed compared to the 3.1 liters per kilogram recorded in 2012.

In terms of value, small-scale fishing produced approximately 44 % of the total turnover of the regional fishing sector compared to 39 % produced by trawling. Therefore, considering data relating to gross salable production, it is evident the economic importance assumed by systems that use small boats and which as such do not involve particularly onerous investment decisions for operators. The better valorization of small-scale fishing production compared to trawling is also due to the better quality of the landed product and to the mix of species more concentrated on products with a higher unit value. Data analysis on the volume and on the regional production by species indicates that the most fished products on the island were: the common octopus or rock octopus (772.24 tons), sardines (455.67 tons), blotched picarels (499.12 tons), baby octopus (398.59 tons) and swordfish (344.31 tons). These species accounted for 35 % of regional catches in 2016 and 24.4 % of their value [19; 20].

The constant reduction in terms of tonnage, engine power and length of Sardinian fleet, together with the general age of the boats that constitute it, clearly affect the type of fishing that is carried out, which cannot be large. This is confirmed by the analysis of the main fishing gears used by Sardinian boats (Table 2). As can be seen from the table, in Sardinia there is a clear majority of boats that use fixed longlines as their main fishing gear. Almost 68 % of the boats use this type of gear, while in Northern Sardinia it reaches almost 70 % of the total fleet [20; 21].

A note should certainly be addressed precisely to the fishing techniques (Tab. 2) used and often linked to ancient traditions and pertaining to an intangible heritage of the highest value [20].

Table 2 – Fishing techniques in Sardinia. Source: Fleet Register - European Commission [20].

Lenght (m)	**LLS Longlines set**	**OTB Trawls nets Large tables**	**PS Purse seine**	**GNS Gillnets dropped**	**GND Drift nets**	**Total**
Alghero	68	9	8	6	0	91
Arbatax	32	7	5	3	0	47
Bosa	27	4	3	2	3	39
Cagliari	90	54	8	37	0	189
Cala Gonone	2	3	1	0	0	6
Carlo Forte	24	4	5	5	0	38
Castelsardo	31	0	11	0	0	42
Golfo Aranci	33	6	7	2	0	48
La Maddalena	15	5	6	2	0	28
Olbia	23	3	8	10	0	44
Oristano	289	28	17	3	2	339
Porto Cervo	0	0	0	0	0	0
Porto Conte	1	0	0	0	0	1
Porto Scuso	10	2	2	3	0	17
Porto Torres	78	16	19	0	0	113
S. Teresa di Gallura	40	2	4	0	0	46
Sant'Antioco	119	41	24	19	7	210
Siniscola	17	10	1	0	0	28
Sardinia	**899**	**194**	**129**	**92**	**12**	**1326**

Data available on types of gear used by Northern Sardinia fleet, connected with those on the length of the boats, generally depict a fishing sector made up of generally small boats (in Northern Sardinia more than 80 % does not exceed 12 m) which carry out a type of fishing that is mainly artisanal and therefore sustainable, with a modest quantity of fish, carried out in fishing areas not very far from the coast and the reference port. The choice to practice small-scale fishing seems to be dictated by several reasons, such as the limitation of means of work, the increasingly worse economic conditions of fishing sector in Italy, the European and national policies linked to the protection of environment and marine ecosystem services, but also an increasingly widespread awareness of fishermen on the need to preserve marine environment in order to conserve fish resources and, therefore, save their jobs [21].

As regards intensive and semi-intensive aquaculture only, Sardinian companies are currently represented by plants for the breeding of valuable fish species of both salt water and fresh water and shellfish. Sardinia is in fact one of the leading Italian regions in marine fish production, with the greatest potential for both quantitative and qualitative development.

As far as the system of enterprises linked to fishing and its consistency in 2019 in Sardinia, there were 702 fishing enterprises, with 3087 total employees. The most represented sub-category was “0311 - Fishing in marine and lagoon waters and related services” (575 companies with 2370 employees), followed by “0321 - Aquaculture in sea, brackish or lagoon water and related services” (58 companies with 407 employees). These two sub-categories together represented 90 % of the island's fishing enterprises [21; 22].

Nonetheless, territorial distribution of companies was not homogeneous. In fact, Provinces with the largest number of companies were that of Cagliari (282 companies with 1398 employees) and that of Sassari (286 companies with 548 employees), which together housed about 80 % of the fishing companies in Sardinia. The only sub-category in which the provinces of Oristano and Nuoro were more represented than the other two provinces was that of “0312 - Freshwater fishing and related services”. The municipal detail tells us that Northern Sardinia owned 293 companies in the fishing sector with 558 employees, thus accounting for 41 % of the total Sardinian fishing companies.

Compared to the legal form, the most evident data is that the highest number of enterprises were individual (356 enterprises with 239 total employees), confirming that Sardinian fishing was characterized by a type of artisanal and small-scale activity. This is followed by Cooperatives (190), which obviously have more employees (1934 total). Finally, of the 702 fisheries enterprises in Sardinia, 48 were female enterprises, 45 were youth enterprises and 7 were foreign enterprises. These categories of companies substantially had little impact on the overall Sardinian entrepreneurial total. In particular, female businesses accounted for 7 %, youth businesses 6.5 % and foreign companies less than 1 % [21; 22].

Traditional fishing on Asinara Island

Marine Protected Areas (MPAs) are certainly a useful tool for preserving biodiversity and promoting the sustainable use of resources. Fisheries management is important everywhere, but it is even more important in Marine Protected Areas (MPA) where, according to the objectives set by the Italian Framework Law on Protected Areas (Law No. 394/1991), the protection and conservation of environment and its resources must be guaranteed, in accordance with existing traditional activities. All this is even more important especially in areas where fishermen have a strong socio-cultural weight as it is a traditional activity. A cultural legacy of fishing on Asinara Island is certainly represented by fishing techniques practiced in Sardinia and beyond, which have had to adapt, as everywhere, to history, to the particular geographical, natural and atmospheric conditions present in the area. This heritage of teachings, result of infinite practice and repeated experiences, which have influenced human culture through work, were and are handed down to younger fishermen generations only rarely through oral stories, but mainly through example, practice, memorization [23]. Despite technology of modern boats can help, long practice of experiential teachings, which are learned at an early age, remains a fundamental characteristic of the fisherman's culture because “it is only by fishing that men acquire the knowledge that will allow them to have a right of use on what it will become a fishing territory for a community, a group, a family, a crew” [24, p. 95].

Marine Protected Area (MPA) of Asinara Island has an extension of approximately 108 km^2. The marine area is divided into zones with a different degree of environmental protection: zone A, an integral reserve; zone B, general reserve; zone C, partial reserve. Zones A, where access is completely forbidden, are located in three areas: in the stretch of sea between Punta dello Scorno and Punta del Porco, in the stretch of sea between Punta l'Arroccu and Punta Galetta and the stretch of sea between Punta Pedra Bianca and Punta Agnadda. Zones A cover about 5 % of the entire protected area, while Zones B and C cover, respectively, 65 % and 30 % of Marine Protected Area.

Since 2002, the founding decree of MPA (13 August 2002) establishes a ban on fishing on Asinara Island by all seafarers, with the exception of small-scale fishing in Porto Torres and Stintino seafarers which are granted the relative authorization at a distance from the coast greater than 150 m and with respect for fully protected areas.

The decree of the Ministry of the Environment of 28 November 1997 also provides for the absolute ban on trawling “within three nautical miles along the west coast of the island (from Punta dello Scorno to Punta Salippi) and, within the bathymetric depth of fifty meters along the eastern and southern coast from Punta dello Scorno to Punta Salippi” (art. 5); for which this activity does not fall within those permitted within MPA [25].

From the processing of the data contained in the Community Fleet Register in January 2020, the fleet belonging to Porto Torres and Stintino navy was equal to 113 units, while there were 48 boats that could potentially carry out fishing activities in MPA but of these only 14 units operated quite frequently in the MPA [20; 25].

The 48 vessels authorized to fish in the MPA were divided into four tonnage categories. 48 % of the boats (n = 23) had a GT equal to 1, 23 % of the boats (n = 11) had a GT between 2 and 5, 23 % of the M / p (n = 11) had a GT between 5 and 10 and only 6 % (n = 3) had a GT greater than 10. This data shows that the current fleet authorized to fish within the MPA was mainly represented by small boats. Furthermore, the few boats with larger dimensions (LFT> 12 m) were tolerated as they were considered a “historical” part of the current fleet [25].

Fishermen who can operate in Asinara Island MPA use tools like longline, pots and trammel net. In general, it is a rather selective fishing, although much depends on the practices adopted, the size of nets and hooks and the fishing area, on the basis of the target species and of the different seasons. From 2013 to 2017, Asinara Marine Animal Recovery Center “Centro di Recupero Animali Marini dell’Asinara” (CRAMA), in agreement with the Park, carried out a geo-referencing census of fishing signals in the seas of MPA; this amount of data made it possible to have a picture of the areas most affected by exploitation with different capture tools and provided a precise indication of the usage and of the possible overlap in the use of the seabed. The maps shown below (Figures 3 and 4) highlight the different sectors and the types of fishing practiced. These maps show that the sectors most affected by fish harvesting are the eastern ones [21; 23]. In particular, the areas to the east of the island were most affected by fishing with pots, while those to the west by the use of longline. However, the use of longlines is prevalent to the west of the island, where the dominance of the rocky bottoms is greater.

Generally, trammel net fishing is carried out constantly throughout the year, with different target species depending on the season; on the other hand, fishing with pots and longlines is mainly seasonal. The pots are mainly used in summer season, while longline in summer-autumn season (June-October) and in winter season (December-January). This type of strategic use of tools seems to be linked to the availability of resources according to seasonality, sea and weather conditions that allow greater usability of one tool compared to another. However, it is important to underline that MPA has become a strength for small-scale fishing activities, allowing precisely this strip of sea to act as an effective recruitment area for juvenile fish. All this was made possible thanks to the limitations imposed on human activities by Park Regulations and in particular by means of the prohibition of fishing within the first 150 meters from the coastline [21; 23].

Conclusion

If fishing is in itself an economically and socially relevant activity and an important historical and traditional heritage, it also represents a possible trigger to read the territorial dynamics of coastal areas, to identify possible expansions and enhancements of tourism (fishing tourism), to investigate effectiveness and consistency of bottom-up governance formulas. And it is precisely for this reason that it is necessary to emphasize the importance of participatory approaches since the long-term sustainability of Asinara MPA depends precisely on the adequate involvement of all the human elements involved in the management strategies, including the fishermen of the area. Compared to Sardinia (and in particular to Asinara), the qualitative-quantitative framework proposed in this work can become an important resource for future reflections on the management of complex systems such as that of an MPA. This contribution, which has drawn a multiscalar and quantitative framework, is to be considered the premise for a research of land aimed at identifying and designing efficient and effective management solutions in Asinara MPA. Specifically, to manage complexity in order to create consensus and reduce conflicts in the use of fishing resources, Stakeholder Analysis (SA) will be adopted precisely as a support to study and design efficient and effective management solutions for this resource; it will make it possible to highlight the strengths and weaknesses in the current management system of traditional fisheries in Asinara Island and it will recognize fishermen for their fundamental role in the bottom-up governance process as primary stakeholders.

In this regard, in fact, UNESCO defines fishermen as holders of “local and indigenous knowledge” to refer to “the understandings and skills developed by societies with a long history of interaction with their natural environment”, as in the case of communities of fishermen [26; 27]. Their knowledge includes seasonal species abundance, tracking systems or fishing gear practices, etc. Furthermore, it has been shown in numerous literatures that fishermen's observations can provide information on the presence of endangered species and ecosystems when traditional scientific data are scarce or absent [27; 28].

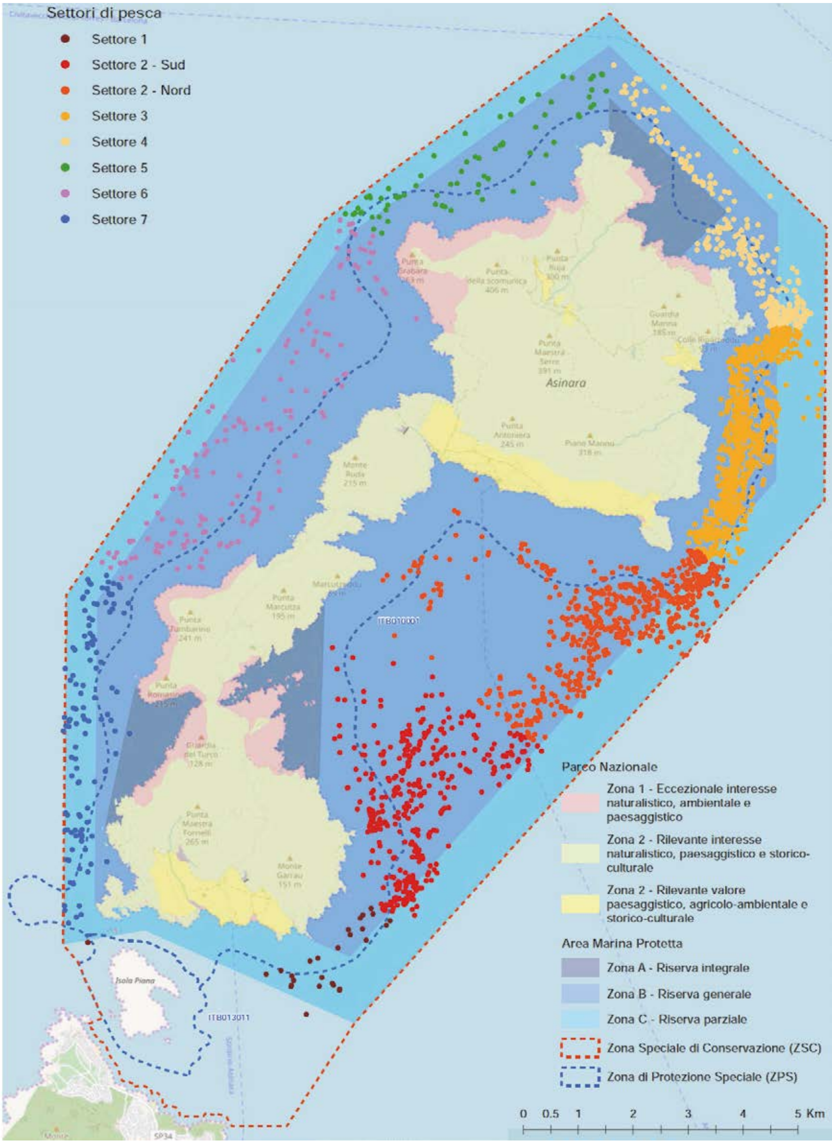

Figure 3 – Fishing sectors monitored in the years 2013-2017 in Asinara Island MPA. Source: [23] †.

† MONITORING OVER THE YEARS 2013-2017 - Fishing Sectors: Sector 1; Sector 2 - South; Sector 2 - North; Sector 3; Sector 4; Sector 5; Sector 6; Sector 7. National Park: Zone 1 - Exceptional naturalistic, environmental and landscape interest; Zone 2 - Significant naturalistic, environmental, and historical and cultural interest; Zone 2 - Significant landscape, agri-environmental and historical and cultural value. Protected sea area: Zone A – Integral reserve; Zone B – General reserve; Zone C – Partial reserve; Special area of conservation; Special Protection area

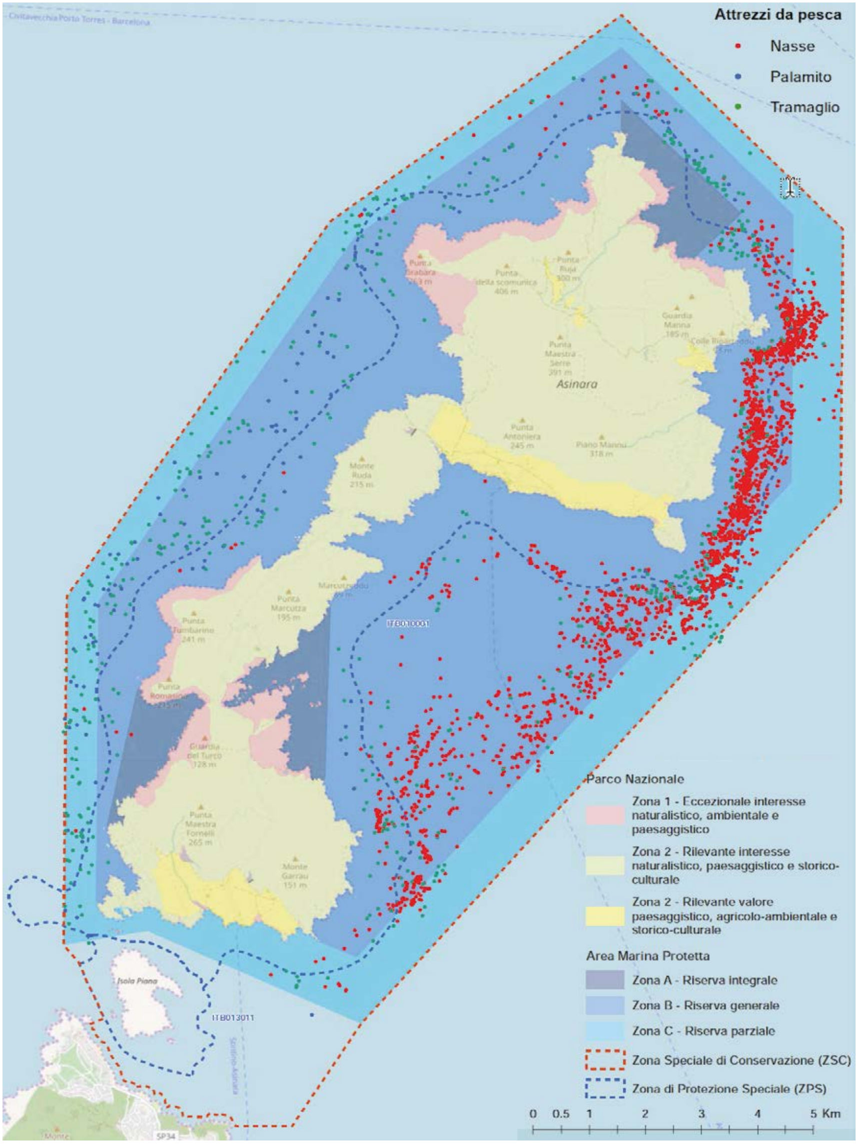

Figure 4 – Distribution of fishing effort in the years 2013-2017 by fishing area in Asinara Island MPA. Source: [23‡].

‡ MONITORING OVER THE YEARS 2013-2017 AND PROTECTED AREAS.
Fishing gears: Pots; Longline; Trammel. National Park: Zone 1 - Exceptional naturalistic environmental and landscape interest; Zone 2 - Significant naturalistic, environmental and historical and cultural interest; Zone 2 – Significant landscape, agri-environmental and historical and cultural value. Protected sea area: Zone A – Integral reserve; Zone B – General reserve; Zone C – Partial reserve; Special area of conservation; Special protection area.

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ANALYSIS AND SURVEY OF LAKE GARDA LEMON HOUSES: A TOOL TO UNDERSTAND AND MANAGE A MEDITERRANEAN LANDSCAPE IN LOMBARDY

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Abstract – Lake Garda mild microclimate allowed the settlement and flourishing of a peculiar cultivation, that of the *limonaie* (lemon houses), which, at the time of its splendour, during the Little Ice Age, was the Northernmost citrus cultivation in whole earth and exported citrus in Central and Northern Europe. In a contribution to the 8th edition of the Symposium we highlighted the Mediterranean character of the landscape of the lemon houses [6]. Here we enlighten how, in order to preserve this unique cultural heritage, there is an urgent need of a census accounting for both the current condition of the ancient productive sites and for all the agroecosystemic relationships between the *limonaie*, which contributed to shape their landscape. Due to the great water requirement of the citrus cultivations at mid latitudes, a particular attention is devoted to the traditional water harvesting and irrigation structures.

Introduction

Lake Garda, thanks to its mild microclimate, allowed in its North-West portion the settlement and flourishing of a unique cultivation, that of the lemon groves, which shares many architectural, technical and irrigation features with labour intensive Mediterranean landscapes (see our previous contribution to this Symposium, [6], for details on this point). Here a blooming citrus cultivation flourished during the Early Modern Age to export lemons, citrons and other citrus in Northern Europe. Despite the climate favour, the citrus cultivation nevertheless required a lot of care and attention to preserve the trees from winter cold. In fact, to make citrus growing possible in whole earth at this latitude (the most Northerly in the World), monumental stone greenhouses were built, the lemon houses (*limonaie*), set on long terraces shaped on the best exposed slopes to solar irradiation and most sheltered from cold winds. This is even more remarkable if it is accounted that citrus commerce flourished here during the Little Ice Age and reached its maximum development between the 18th and 19th Century [7, 8, 12] (Fig.1).

Historical sources document that the architectural layout of the *limonaie* was consolidated in all its essential components since at least the 16th Century (see again [6] for a review). During the 19th Century, up to 20 million lemons a year were exported to Northern and Eastern Europe, but from the end of the 19th Century various reasons led to the gradual abandonment of the production system [8, 28] (Fig. 2).

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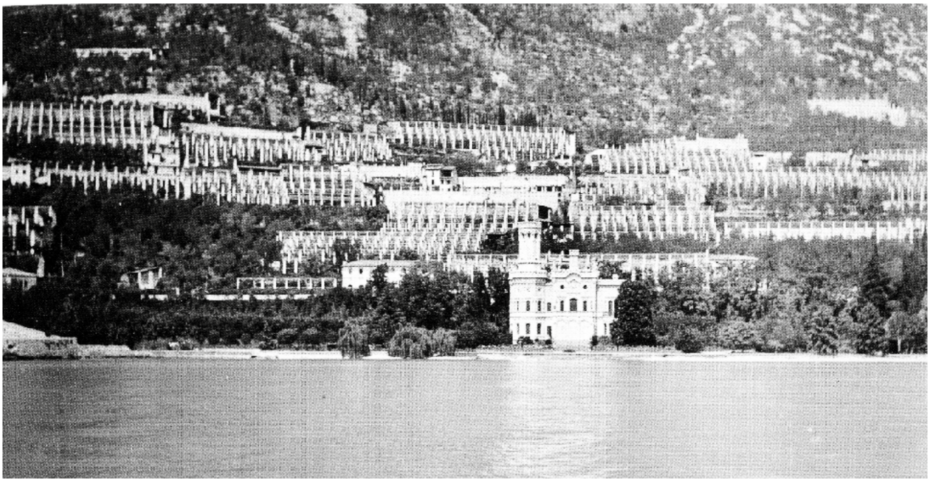

Figure 1 – Gargnano (Brescia, I) in 1911: the landscape is characterized by many *limonaie* still conserved and productive.

Figure 2 – Gargnano (Brescia, I): the map (by A. Cazzani) highlights in yellow the *limonaie* documented by the cadastral maps of 1851 and in green the lemon houses still active in 1905.

Compared to the 50 hectares destined to citrus groves at their maximum development in the 19th Century, today probably only 25–30 % of those areas are still cultivated with citrus fruits, but the historical agricultural landscape – despite the recent urbanization and territorial transformations – is still clearly readable as the numerous remains of lemon groves connected to terraced olive groves, vineyards, woods, laurel trees and typically Mediterranean vegetation (cypresses, capers, oleanders, myrtles, agaves…; Fig. 3).

Such an intensive citrus cultivation required to organize the surrounding landscape to provide the required resources, viz the water for the irrigation, the timber to support the lemon trees, the windows, the wood and the nails to close the green houses, the soil itself to grow the trees.

Therefore, the lemon groves and the landscape system related to them are the result of a complex process of territorial transformation and of a continuous maintenance work carried out for centuries by the same farmers who guaranteed its perpetuation. This complex landscape system was set and built without an architect plan. It fascinating meets Rudofsky's concept of "architectures without architects" [25] and the definition of the cultural landscape proposed by the UNCCD to describe the terraces of the Mediterranean area, where "the environment is not only the result of natural processes, but rather represents a cultural landscape where historical centres are the crystallization of knowledge appropriate to environmental management and maintenance" [29, p.51]. Therefore not only the future management of this peculiar traditional rural landscape will not be possible if policies and strategies are not aimed at the knowledge and promotion of this unique heritage rich in historical, architectural, landscape, botanical and agronomic and intangible cultural values, but also – again in the UNCCD perspective – the understanding of the dense network of relationships underlying the landscape will unveil the comprehension of the intimate "search for symbiosis and harmony intrinsic in local knowledge" [29, p.51].

For the above, in order to better understand and be able to enhance the extraordinary and unique heritage of the upper Garda *limonaie*, the paper intends to highlight how urgent it is to analyse the current state of the lemon groves system, by surveying the *limonaie* structures and counting the productive citrus plants in the municipalities of upper Garda. The first step will be an in—depth landscape analysis of the current situation, including a detailed investigation and classification of the present components, in order to collect reliable data on architectural and material characteristics, state of conservation of the sites, nature and number of properties, state of the irrigation and infrastructural system, landscape context, citrus fruit varieties, processing activities and types of products, etc. The census is not a purely analytical—cognitive phase: it is a pillar to define the intervention strategies, essential for the architectural and landscape enhancement of the *limonaie* system, for the promotion of biodiversity in the upper Garda and for the settlement of the production chain. The census is conceived as a GIS—based dynamic tool that allows continuous updates and additions to better manage and process all the data collected in the future. The goal of the mapping and census is to know the current state of the *limonaie* system, compared with the historical state documented by maps and archival documents and by previous studies prepared to define management criteria at the district level, identifying the compatible vocations and uses, and conservation, maintenance and management aims, hoping for possible incentives for owners to be actively involved in the valorisation of this precious landscape.

The landscape of the *limonaie*

The NW shore of Lake Garda is characterized by a mild climate with typically Mediterranean agricultural crops such as olive groves, vineyards and citrus groves. The citrus groves - already documented since the 15th Century [5, 7, 9, 10, 12, 18, 19, 20, 21, 23] - are undoubtedly the ones that most characterize this landscape. Even today the *limonaie* are a distinctive feature, particularly the tall, stone perimeter walls, some of them eight to ten meters high, built on the terraced land to protect lemon trees from the winds that blow down from the mountains behind (Fig.3). Thin stone pillars stand sentry—like along the terraces, built to secure a grid of wooden beams. A complex network was necessary to guarantee the irrigation for citrus trees.

Figure 3 – Gargnano (Brescia, I) today: this photo shows how much the *limonaie* (clearly recognizable by the terraces and pillars) still characterize the upper Garda landscape.

During the winter months, the *limonaie* were closed by wood plank roofs and large window panels facing the sun, turning the structures into seasonal greenhouses. These elements, assembled and disassembled with extreme care every year, were kept in summer in high stone warehouses adjacent to the lemon houses themselves: the *caselli*, rustic buildings that rise almost like a tower, higher than the pillars, communicating, at the top, with the roof of the lemon house in order to allow the covering and closing operations. The construction methods and the choice of materials were refined by centuries of experience so that the lemon houses became technically very functional greenhouses and highly productive structures. The cultivation of citrus fruits has therefore led to a strong anthropization of this landscape [5, 7, 18, 19, 20, 27]: not only the construction of unique artifacts in the world with the finding of the necessary construction materials, but also the construction of a water system, roadways, windbreak systems, the creation of a commercial network for the export of citrus fruits historically especially in northern and eastern Europe [8, 16, 17, 26]. The work and expertise of many people therefore revolved around the lemon groves, as did all the artisan and rural culture of entire generations, who from the trade mainly of lemons, but also of oranges and cedars drew the benefits of a prosperous economy until the end of the 19th Century, based on the uniqueness and excellent quality of the product.

Several socio—economic reasons, in addition to the discovery of the chemical formula to synthetically produce citric acid, led to the gradual abandonment of citrus cultivation from the end of the 19th Century. During his stay in Gargnano in 1912, the writer D.H. Lawrence was able to observe the lemon houses and notice the progressive decay that characterized them, comparing them to an archaeological landscape: “All summer long, upon the mountain slopes steep by the lake, stand the rows of naked pillars rising out of the green foliage like ruins of temples” [22].

During the 20th Century numerous lemon houses were converted into olive groves, vineyards, orchards and vegetable gardens and from the 1960s also into gardens or built areas and intensely transformed and only a few dozen *limonaie* remained active and productive according to traditional techniques. Of the 50 hectares historically destined to citrus groves, today only 30 % of those areas are still cultivated with citrus fruits, but a specific survey aimed at censoring the citrus groves and productive citrus plants in the municipalities of the upper Garda (in particular in Toscolano Maderno, Gargnano, Tignale and Limone sul Garda) has yet to be completed.

The lemon houses and the landscape system related to them are the result of a complex process of territorial transformation and of a continuous maintenance work carried out for centuries by the same farmers who guaranteed the perpetuation of this heroic agriculture. Although awareness of the unique and exceptional value of the lemon groves landscape has been growing in recent years, there is still the risk of losing the peculiarities of the tangible heritage and above all of the intangible heritage related to them.

The future conservation and management of this unique traditional rural landscape will be possible if policies are defined and strategies aimed at the knowledge, dissemination and promotion of this heritage rich in historical—documentary, architectural—landscape and botanical—agronomic values are issued. The *limonaie* should not be considered today as monuments of the past, only partially still existing, but as a fundamental resource and opportunity for the future of this area. It is therefore important to define management criteria, by carefully analyzing the current conditions of this landscape system, its level of permanence and present uses, by identifying compatible use vocations and conservation, maintenance and rehabilitation goals, hoping for possible public funding and incentives.

Architectural census and survey of the *limonaie*: an analytic and strategic tool

Considering the above, in order to better understand and be able to enhance the extraordinary and unique heritage of the upper Garda *limonaie*, it is urgent to analyze the current situation of the lemon houses system, also starting from specific censuses carried out in the 80s and 90s relating to the Municipalities of Gargnano and Limone sul Garda.

Specifically, the Municipality of Gargnano carried out a census of *limonaie* in 1983, only partially updated in 2011 and included in the Municipal Urban Plan (PRG, *Piano Regolatore Generale* in 1983, PGT, *Piano Governo Territorio* currently). 134 lemon houses have been registered, considering that the cadastral maps of 1851 document that about 400 lots were destined for "citrus gardens". The census [11] referred to structurally conserved or partially conserved *limonaie*, however recognizable as ancient lemon houses, while the traces have only been mapped. The census analyzed the lemon houses for the architectural and landscape role they present and not only for the productive function. Specific forms have been compiled that highlight: the site number, the name of the owner, the address, the location (in the inhabited center, in inhabited areas, on the lake, isolated), the orientation, the landscape—environmental value. An aerial photogrammetric map identifies the lemon house and its context. Some significant photographs are attached, located on the map. Other information concerns the current use of the *casello* (storage rural building) and the terraces, the state of conservation of the various construction components (perimeter walls, terracing walls, pillars, wooden beams, exterior and interior of the *casello*, irrigation system with specification of the presence of springs, wells or water collection tanks). The state of conservation is briefly defined as bad, mediocre, good, renovated (the component is transformed from its historical state, even if in good condition), absent if the components or buildings have disappeared and traces if the components are only episodic or partial. The survey also indicates the number of citrus plants present in the lemon house, highlighting adult or historical plants. The form includes a brief description of the characteristics of the site and an assessment of the historical, architectural and environmental values. If the lemon house is still cultivated with citrus trees, the census reports information on the tenant (farmer, hobbyist), on the area dimension, on the number and type of citrus plants, on the average annual production of lemons and on the materials and techniques of covering and closing.

The census forms were only partially updated in 2011 [24] and often do not report the current situation: there are no indications of several *limonaie* restored in recent years and of many citrus trees planted.

For the Municipality of Limone sul Garda there is a census of the *limonaie* of 1992 [13] made with the same goals and similar forms as the census of the *limonaie* of Gargnano. This census was updated in detail in 2006-2009, adding maps with the location of the architectural components and features of the lemon groves [14]. The Limone census aims to detect the *limonaie* present in the Municipality to protect their conservation and prevent their decay, identifying the historical components that are still visible: *caselli,* perimeter walls, terracing walls, pillars, any covering elements, to be able to read the historical identity of the *limonaie* system. The lemon houses by now completely transformed into hotels or private residences have not been surveyed. Overall, the census includes 12 *limonaie*, considering that in Limone many lemon houses were built during the 18th Century by the Bettoni-Cazzago family and have very large dimensions.

The data reported in this census are similar to those of the census of the Municipality of Gargnano, even if during the updating some data have been added, such as the distinction between "ancient" citrus plants and "new" trees (i.e. planted after the abandonment of citrus cultivation), a description of the significant elements and notes regarding the irrigation system (where and how it was fed), the treatments carried out over the years on pillars and walls, the interventions completed on the buildings and the specific historical facts of the site. In addition to the cadastral map and the aerial photogrammetric map, the research carried out a specific survey on a scale of 1: 500 - 1: 200 which precisely reports all the data and features analyzed. The form is completed by a detailed photographic survey.

In addition to the census and survey of the lemon houses, the Municipal Plan of Limone sul Garda includes a *Manuale tipologico degli elementi edilizi tradizionali (Typological manual of traditional building elements)* [15] which also concerns the features of the *limonaie*. In particular, the main components of the lemon houses (perimeter walls, terracing walls, pillars, *caselli,* wooden beams, irrigation system, accesses and stairs, other stone elements and other historical elements) are briefly described and specific rules are defined for each component in order to conserve the historical architectural, technical and material features and to prescribe the interventions to be carried out.

With reference to the censuses already defined, it is necessary to extend the study of the *limonaie* system to all the municipalities of the Upper Garda Riviera, and for Gargnano, in the past the center of citrus growing, to program not only the updating of the 1983 census but a more detailed research. The aims of this more comprehensive research are to detect more precisely and to critically evaluate the current landscape of the *limonaie*, also highlighting the transformations that have happened in the last 40 years that in several cases regard the recovery of the structure of the lemon house, the agricultural re—functionalization and the replanting of numerous citrus trees (Fig.4).

Figure 4 – A *limonaia* in Gargnano, recently restored following historic construction techniques and using past materials and maintained according to traditional methods, then closed and covered in the winter months.

It is important to remember that in some areas the *limonaie* are connected to each other and they create a single architectural and landscape complex: the good exposure, the availability of water, easy accessibility have led to the concentration of several lemon houses in specific areas. In the case of the Municipality of Gargnano, for example, in the localities of Villavetro, Quarcina, Tesolo, Crocefisso, San Faustino, San Giacomo, there is a very significant presence of *limonaie* that constitutes an emerging system of landscape and environmental, as well as cultural, value. This system must be analyzed in a unitary way, highlighting the various existing relationships: water and road network, trees in groups and in rows, settlements of buildings and agricultural areas.

An inventory / survey aimed at the knowledge of the tangible and intangible components of the *limonaie* must consider: (1) the architectural and material characteristics and their state of conservation, with particular attention to the analysis of traditional construction techniques and historical materials; (2) plant / agricultural components with identification of the different species and varieties; (3) the water harvesting and the irrigation system (presence and state of conservation of cisterns and channels and historical and current water supply sources), as highlighted in the following paragraph; (4) the landscape context and the pedological features; (5) current uses; (6) the property status; (7) historical and current cultivation methods, with particular attention to irrigation and cold protection methods for citrus plants; (8) current agricultural production; (9) the intangible components, often documented only by oral sources. A multidisciplinary team must develop the census, so that the historical—architectural as well as the hydraulic—infrastructural, landscape—naturalistic, agronomic—productive and social aspects are considered and evaluated. The census must also know how to involve, in addition to the local administrations and the Alto Garda Bresciano Regional Park, associations, committees and local cooperatives, schools, *limonaie* owners, experts and scholars to define an active participatory planning process that leads to the community most aware of the complexity and value of the *limonaie* landscape.

The census is therefore not just an analysis document, but the indispensable strategic tool to define recovery and enhancement interventions, both landscape— and production—finalized. The survey of some *limonaie* has already highlighted the importance and usefulness of a census thus conceived: for example, sites were found where only the terraces remain, but the hydraulic system is still preserved, rather than lemon houses used today as vineyards and olive groves, still with high pillars and intact and original roofing structures, or sites recently recovered using traditional materials and techniques and others in which contemporary materials have been used and modern features have been introduced (Fig.5). The survey in several sites also underlined how necessary it is to compare and to share different problems in order to define criteria that can solve some conservation and management issues. The census / survey makes it possible to read the stratification and the level of permanence and / or transformation of the landscape of the *limonaie* and to define a future for this heritage referred to principles of compatibility and sustainability, with the aim of preserving them and continuing the history of these extraordinary artifacts.

Figure 5 – The *limonaie* landscape: a *limonaia* in Gargnano, today used as a vineyard and lawn, that still conserves the architectural structure, the high pillars and the water distribution system.

The hydrological and hydraulic relationship with the landscape

The link between the landscape of the lemon houses and the irrigation is deep and close, because the cultivation of citrus fruits in a temperate climate requires a large amount of water. According to the present practice and to recent testimony it is estimated in 100 to 300 litres per plant every 8 days during the summer season, in agreement with (yet greater than) the amount estimated by the 16th Century agronomist Agostino Gallo at the threshold of the Little Ice Age [21]. The structural difficulty of finding water along the shallow—soil slopes of Lake Garda NW shore induced the farmers to bow the choice of the site for new lemon houses to the presence of water streams or sources, thus colonizing also steep slopes far from the lake, in order to settle nearby the sources or the streams, and to adopt a plant—to—plant distribution technique typical of the Mediterranean and Central Asia water scarce conditions. Whereas the irrigated agriculture is always recognized more labour intensive with respect to the arid agriculture [4], this aspect is even more emphasized in water—scarce conditions and plays a central role in the production. In our previous contributions [1, 3, 6] we provided insights on the structure of the irrigation system and on its technical functioning. Here, following as guideline the eight conjectures on traditional irrigation proposed by [2], we will recall its main aspects in relationship to the purpose and first results of a hydrological and hydraulic survey conducted in five lemon houses (*limonaie* La Malora, Fondo Campagnola, Fondo Crocefisso and Ragusini in Gargnano, and *limonaia* Pra' de la Fam in Tignale). Apart from La Malora, which is relatively small and dates back at least to the 17th Century, the others range from a medium to a big size and date back to the 18th Century.

The traditional hydraulic system of the *limonaie* is divided into three fundamental parts: (1) the water harvesting and storage works, (2) the water distribution network inside the lemon houses and (3) the drainage network to remove the excess water. The collection and storage works are always upstream of the garden or, more commonly, of the system of gardens which were irrigated with the same water supply. These works are in turn of three types: direct water intake from a stream, storage tanks and natural or artificial sources. The direct intake from a stream was separated from the irrigation channels by a stilling basin, from which the water was usually taken by means of a submerged intake. Tanks' volume ranged from about 1 m^3 to some hundreds of cubic meters, depending if they were used only as stilling and partitioning basins, or they were used as a reservoir for big lemon houses systems. The pumping of water directly from the lake was introduced in recent times and it is practiced only for those gardens that are located on the lake shore.

The surveyed lemon houses give an idea of the variety and complexity of the water collection and storage works. As an example, La Malora was part of a complex system which derived the water from a stream, the *Fosso dei molini*, to be used for many lemon houses and mills (*molini*) and of which only some traces may be found nowadays. Upstream the lemon house there are two small tanks which are still functioning – even if the water is no longer provided by the *Fosso dei molini* – and served as a stilling basin and as a partition basin respectively, to share the water between the terraces, the surrounding lemon houses and a mill settled inside the lemon house. The other three lemon houses surveyed in Gargnano were all mainly dependent on the upstream source of the *Ravere*, from which an aqueduct shared the water to a complex system of lemon houses, but at least two of them (Fondo Crocefisso and Fondo Campagnola) benefit

Figure 6 – Underground room at *limonaia* Fondo Campagnola (Gargnano) to collect and drain the water springing from the rocks.

also from internal sources and spontaneous water emergences from the rocks. Here a big cistern (some tens of cubic meters) connected to the aqueduct is still active and many small others were placed upstream the terraces to distribute the water to them. An interesting underground room, inspectionable by means of two vaulted tunnels, collected the water springing from the rock and presumably conveyed it to a cistern. Also the *limonaia* Fondo Crocefisso is still connected to the aqueduct, but at present it mainly uses water from an internal spring.

The water, conveyed by means of the external works toward the upstream terrace of the garden, was distributed to the plants by means of flumes running along the retaining walls upstream of the terraces and equipped with at least one little rectangular spillway at each field, i.e. every 4 or 5 m. The traditional flumes were mostly made of pink marble or grey sandstone, both being common in the area. Some flumes may be found also built in sided—up roof tiles but they should be attributed to more recent (yet not contemporary) interventions. The flumes were sustained by brackets, arches or, sometimes, by pillars, at a height ranging between one and two meters from the base of the wall. The measured slopes of the flumes range from 0.01 m/m (e.g. in the *limonaia* Pra' de la Fam, Tignale) to 0.1 m/m (e.g. in the *limonaia* La Malora, Gargnano). In the same lemon houses, measured flume sections are (reversed) trapezoidal and range 11 to 12.5 cm for the larger base, 5 to 5.5 cm for the smaller base, and the depth is about 6.5 cm. It is worth noting that almost all the observed sections show the same shape and dimensions, close to the section of least hydraulic resistance, and that all the components of the articulated distribution system (like many other functional elements of the lemon houses) are characterized by a remarkable degree of standardization. If the complex provisioning system is often neglected and hidden, the flumes are the most evident aspect of all the water management system and manifestly play also an aesthetical role inside the lemon houses, so that in most of the cases we found them in relatively good conditions. They are quite complete, with original pieces or anciently restored with roof tiles, even if some modern interventions to restore the continuity of the flumes with old pieces were not intended to use them for irrigation and therefore the presence of the spillways was frequently neglected. A part the ones of Fondo Campagnola, which original lemon house destination was abandoned tens of years ago, in most of the other cases the flumes can be activated or easily reactivated and, on the basis of the information collected, it seems that in recent times the consciousness of this peculiar core of the lemon houses is growing and many owners are interested either to maintain active or reactivate them, at least for cultural aspects. This growing consciousness is an important step along the route to recognize the traditional irrigation technique as a cultural heritage [2]. A remarkable artifact is the water partitioning box, in most of the cases installed upstream to the flumes, to share the water between the one irrigating the terrace and the one flowing to the downstream terrace through an underground pipe covered with stone slabs, the *caladrìa*. As in many ancient aqueducts, *caladrìa* was realized by means of terra cotta *fistulae* [6]. The drainage was guaranteed by either covered or free surface small stone channels placed at the foot of the uphill retaining walls (to drain the springs and rivultes coming from the uphill rock, in the *limonaia* La Malora) or nearby the downhill border of the terrace (traces referred by the owners of the *limonaia* Fondo Campagnola). Excess water either was returned to the stream, or it flew toward downstream lemon houses, or it was used for horticulture of the ancillary cultivations.

From these lines it appears how the irrigation played a key role in the lemon houses management, and how it innervated all the landscape, so that the knowledge of the hydraulic works and of the channels network is necessary to understand how deep the anthropisation of the landscape was and how great the real extension of lemon houses system was.

Figure 7 – Two activated spillways at the *limonaie* Ragusini (left) and Fondo Crocefisso (right).

Conclusions

In this paper we aimed at suggesting how complex and deep was the link between the lemon houses system and the landscape, and how important is, in view of designing a future for the lemon houses which respects and preserves this unique cultural heritage, to understand the relationships between the lemon houses and the surrounding environment.

In order to better understand the stratification of this heritage it is necessary to define a census / survey aimed at analyzing the current situation considering the historical—cultural aspects, but also the productive and agronomic ones. During the 20th Century, the lemon houses were described as components of the past, that had now lost their importance and meaning with the decline of citrus groves: only some isolated sites could be restored and used as a museum. In the 21st Century, the role of *limonaie* as an extraordinary component of the upper Garda landscape that must be enhanced and reused for productive purposes has increasingly been highlighted. It is about heroic, quality agriculture, linked to sustainability criteria and territorial promotion, with the aim of encouraging awareness of traditional values and the link between landscape and products. The census illustrated here is intended to constitute the operative reference for knowing the complexity of historic building techniques, traditional materials, construction details and related conservation problems to define preservation guidelines and management criteria for the *limonaie*, as they return to being living and supporting elements of the upper Garda territorial system.

By investigating the external capture works, which the lemon houses often shared with mills and other factories, it will be possible (1) to estimate the effective territorial and social extension of the phenomenon of citrus cultivation – an operation relevant for historical, educational and tourist research purposes – and (2) identify any abandoned waterways that could be restored for the agricultural recovery of some terraces. The study of the water resource management techniques inside the lemon houses (1) will allow to verify the level of standardization of the techniques themselves, characterizing any local differences and (2) it will contribute to an efficient agricultural recovery of the lemon houses based also on a resilient water management.

It is therefore very important now that conservation and recovery interventions are carried out not only with particular attention to maintaining the historical, landscape and documentary significance of the *limonaie*, but also to the agronomic and productive value, with the perspective of preserving the landscape ecosystem services. There is in fact a risk that the historical cultivation techniques are lost and that construction elements, materials and plant species are introduced that are not congruent with the historical landscape. Through a process of conservation and rehabilitation not only of the structure of the *limonaie*, but also of the hydraulic, infrastructural and landscape components, conserving and increasing species and cultivars traditionally cultivated in the upper Garda, it would be possible to strengthen a rural economy that could support and valorise monuments that are unique in the World[1].

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MONITORING OF THE EVOLUTION OF “BARENE” BORDERS AND THE SAFEGUARD OF THE VENICE LAGOON MORPHOLOGY: A CONTRIBUTION FROM THE 'COASTAL CHANGE FROM SPACE' PROJECT RESULTS

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Abstract – Optical satellite imagery is widely used to monitor various earth phenomena and to understand their evolution. Thanks to the Copernicus program and the Landsat missions we can access a huge amount of data over a wide time and area span and with high revisit frequency.
This research proposes the acquisition of a time series from optical satellites to observe changes in the Venice lagoon, an ecosystem which is very challenging to monitor by means of in situ survey activities, let alone using remote sensing techniques, given the presence of land and sandbars (vegetated intertidal areas), very difficult to discern.
Following the successful delivery of the Coastal Erosion from Space project [1] an extension has been commissioned by the European Space Agency, which brought in ISPRA as a new partner and user community representative and included additional sites in Italy, among which, the Venice Lagoon.
We will present the manner in which co-registration improves image spatial accuracy and allows us to obtain a long time-period, high revisit rate and highly accurate waterline/shoreline time series. The work that will be presented describes the specific validation process performed by ISPRA on the results obtained by this method as applied on some target sites of the Venice Lagoon, both natural and partially artificial islands, using fully artificial islands as reference.
The evolution of the natural structures of the Lagoon is normally slow, but some anthropogenic actions may force rapid change in such dynamics; examples of this are the navigation channels and the vessels-induced waves.
An important role in safeguarding the morphology of the Venice Lagoon, with respect to both anthropogenic drivers and sea level rise (expected as the result of climate change), can be managed by the possibility of developing tools to provide frequent monitoring of the evolution of the sandbars in the Lagoon.

Introduction

Since time immemorial, the beauty and the life itself of Venice has been linked to the balance that the city could build-up and maintain with the lagoon environment it inhabits. This unique balance has been officially recognised as a World Heritage Site by

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UNESCO in 1987. According to the "Lagoon Atlas" [2], the Venice Lagoon system is composed by about 60 islands, over an area of about 550 000 km^2. From 2014, its northern part has been included into a regional environmental and anthropological Park, with protection measures set by the regional and national laws.

The ecosystem is very peculiar and full of many specific bio/ecotopes, like the "barena" (vegetated saltmarsh), "velma" (sandbar emerged at low tide), "ghebo" (tidal creek), "chiaro" (salt pan), along with many semi-natural or artificial landscapes. In Figure 1, we show an overall view of the whole Lagoon area, with the study areas highlighted and with a characterisation of the land cover/land use obtained by a semi-automatic classification procedure which will be further described in the following chapters.

Needless to say, this eco/anthropic system is very fragile, both from the anthropic and the environmental point of view, as each component is strictly interlinked and exposed to peculiar stresses, again, both natural and man-made; nevertheless, the vulnerability of the natural environment is much higher than that of the human settlements/activities, so that a strong focus on protection measures is needed, taking into account all of the drivers acting on the area.

The evolution of the natural structures is normally slow, but some anthropogenic actions may force rapid change in such dynamics; throughout the past century and more, this delicate balance has been increasingly compromised by human actions, especially industrial activities, the use of motorized vessels and cruise liners and the construction of protection constructions. A substantial part of the natural areas of the lagoon have disappeared as a result of these actions; as these natural settings are very important in the hydraulic and environmental balance of the Lagoon system, the national and local governments were forced to act, both assessing the impacts and considering mitigating actions to reduce or reverse their effects. Presently, the defence of the lagoon environment is addressed by means of several regulations and laws, limiting human activities, thus trying to prevent the loss of natural habitats [3-5].

Particular reference should be made to the Morphological Plan for the Venice Lagoon, a tool for combating lagoon degradation and an update of the first Morphological Plan drawn up in 1993 [4]. The main objective of the update developed in these years is to use new knowledge and the results of previous interventions to combat and minimise erosion of intertidal lagoon forms, identifying the entirety of restoration and conservation measures [5-6].

More than a constant monitoring, accessing historical data is essential to understand the natural evolution of the lagoon and the impact of anthropogenic pressure on its natural balance. Freely accessible satellite mission such as Landsat and Sentinel-2 allow us to access EO data starting in 1984 with the launch of Landsat 5. Their temporal resolution and spatial extend provide frequent snapshots of large area to analyse dynamics at a regional scale. The Coastal Erosion from Space project, 4000126603/19/I-LG, was commissioned under the Science for Society slice of the 5th Earth Observation Envelope Programme (EOEP-5) of the European Space Agency. The aim is to develop innovative EO derived products to improve coastal monitoring and better support policies maker and the stakeholders communities. Within the Coastal Erosion from Space project the delivered waterline, shoreline and coastal classification map have been evaluated and validated by national hydraulic and geological experts for various tests sites. The resulting data set was validated by the British Geological Survey, the Institute of Hydraulics at Cantabria, ARCTUS working alongside the University of Quebec at Rimouski and the Geological Survey of Ireland.

Materials and Methods

Optical satellite imagery is widely used to monitor various earth phenomenon and to understand their evolution. Thanks to the Copernicus program and the Landsat missions we can access up to 25 years of data at high temporal frequency, almost one image every 5 days in optimum conditions for the Sentinel-2 constellation [7] with high pixel resolution, 10m for Sentinel-2, 15 m for Landsat 8 and 30 m for Landsat 5. Moreover, their wide acquisition extent allows us to easily access a large snapshot (100 km x 100 km for Sentinel-2) and thus repeatedly monitor multiple sites at the same time and under the same conditions. This research proposes to use a time series of satellite derived products to monitor changes in the Venice Lagoon.

Following the successful delivery of the Coastal Erosion from Space project by ARGANS Limited and its partners IsardSAT, AdwäisEO, the British Geological Survey, Geological Survey Ireland, IHCantabria (Spain) and Arctus (Canada), the European Space Agency has initiated a change note to the contract 4000126603/19/I-LG commissioned under the Science for Society slice of the 5th Earth Observation Envelope Program (EOEP-5). The extension is supported by the user community and aims to:

- Extend the coverage of satellite derived product over the past 25 years for new sites, for the four countries engaged in initial contract: UK, Spain, Ireland and Canada;
- Add additional sites in a new country and a new partner ISPRA (Italy);
- Update the key coastal state indicators delivered in the initial contract by improving and enhancing the algorithms part of the processing chain.

Waterlines represent the instantaneous land/ sea boundary at the time the satellite pass over the scene. The waterline shape and extent are thus link with the coastal morphology and the water level at that time. This general principle, in the Lagoon, mainly applies to the morphological element velma; differently, the vegetation of the barena, as well as the artificial works form a vertical barrier, so that the shape is not varying with the tide.

Waterlines are extracted from every suitable satellite images available to build a dense and continuous data set. Image selection is essentially based on cloud coverage, a minimum of 70% of could free coastline is required to keep the image. Once all images have been selected, a pre-processing step is required to co-locate the full data set. If all satellites acquire data for the same scene, the resulting images are not perfectly overlapping each other. Only between Sentinel-2 acquisition, this spatial shift can reach 12 m [8]. A co-registration step first re-locate all acquisition on a highly spatial accurate very high resolution (VHR) reference image such as SPOT, WorldView, etc [9]. First, a Sentinel-2 clear image is co-registered on the VHR and is then used to co-register the remaining HR data set (Landsat and Sentinel-2). Thanks to the spatial accuracy of the VHR, co-registered Landsat and Sentienl-2 reach a vertical and horizontal spatial accuracy within 3 m. Satellite derived waterlines showed a higher precision accuracy within the mission pixel resolution.

The validation of the WL performed by ISPRA has been based on two main references: the layers provided by the “Lagoon Atlas”, focused on the morphology of the lagoon elements [2], and the layers produced by ISPRA on coastal survey and planning [10].

The Atlas provides high-definition layers with the characterization of the lagoon elements; in particular, those reporting the morphological elements "Natural Barena", "Artificial Barena", "Velma" and "Emerged Land" were used. The layers were published in 2013, based on data covering the time period 2003-2009 for the natural elements and 2012-2013 in the case of "Artificial Barena" and emerged land.

For about twenty years ISPRA has been producing information layers that serve for the environmental analysis of the entire Italian coastline; the main layers are the Coastline, the Backshore Line and the Emerged Beaches. Such data constitute the national reference for the INSPIRE regulation and have been adopted in various European (Marine Strategy, EmodnetGeology, etc.) and national (ISTAT, Ministry of Health, etc.) contexts, as well as being the basis for the elaboration of the environmental indicators provided by ISPRA for the coastal subject matter. Recently, the data series have been included in ISPRA's “Portal of the Coasts”, where they can be freely consulted and downloaded.

For the present case, the Coastline layer referring to the years 2000 and 2020 was taken as the reference. The layer for the year 2000 is the result of the digitization and characterization of the 1998-99-2000 aerial images made available after a Ministry of Environment (MiTE)-funded survey: the panchromatic images, with 1 metre resolution, are accessed through the WMS services of MiTE’s National Cartographic Portal. The update of the coverage, mostly referring to the period 2017-20, has been performed using the Google Maps satellite images, with a definition in the range of tens of centimetres, as reference.

The objective of the validation was to show how the WL drawn up by Argans can “read” the reality of the lagoon structure and its changes over time. The method was carried out in two main steps: relating the polygons of the morphological elements provided by the Lagoon Atlas to those defined on the basis of the ISPRA Coastlines, then comparing those two references with the set of WLs provided by Argans.

First of all, an area of interest was defined in which much of the territory is made up of natural barene and velme, but where intense human activity is also observed, with various built, inhabited and cultivated areas, hence the consequent vessel traffic, sources of pollution and disturbance to lagoon habitats. The choice fell on the area around the island of Burano, north-east of Venice (Fig.1).

Within that area, eight islands and Barene were selected, some of them classified as natural, some artificial. The aim was to be able to analyse a sample of elements large enough to detect some of the main phenomena in the evolution of natural elements, also having some fully artificial, mostly stable, land as a reference.

In particular, the set of areas of interest consisted of three islets, Burano, Santa Cristina and Crevan, and five natural formations, identified by fancy names.

As mentioned above, thanks to the availability of the Lagoon Atlas shapefiles, the first step was to compare the Atlas data with those derived by ISPRA Coastline (LC00 and LC20), in terms of shape and classification.

Figure 1 – Overall view of the north-east part of the Venice Lagoon. The thematic layers of natural and artificial "barene" and "velme" from the Lagoon Atlas are shown. The white box corresponds to the study area of figure 2.

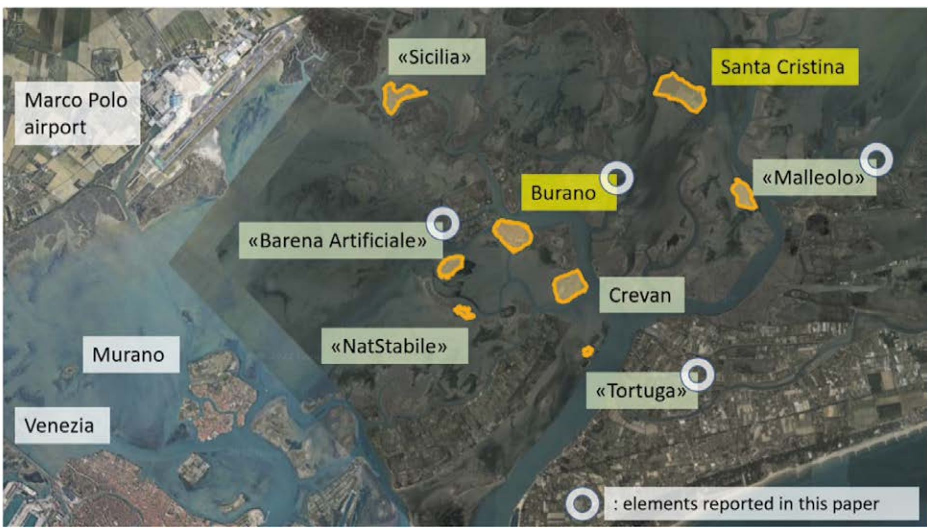

Figure 2 – Study area locating the 8 islands studied; yellowish box indicates fully artificial islands.

Once the reference levels of the Lagoon Atlas and ISPRA's LC00/20 had been compared, and - if necessary - adjusted, we proceeded with the actual validation of the Argans WLs, for which an indirect method was used, i.e. comparing the surfaces of the polygons obtained by the “convex envelopes” of the LC00/LC20 contours of the chosen lagoon elements with those similarly obtained from the hundreds of WLs provided by Argans, as processed from the Landsat 5-8/Sentinel 2 images. In this way, through simple statistical comparison of the surfaces, we investigated how and to what extent these WLs follow the definition of the areas under investigation and their evolution over time.

For this purpose, the ArcGIS tool ‘Minimum Bounding Geometry’ was used, which creates a feature class containing polygons which represent a specified minimum bounding geometry enclosing each input feature. The ‘Convex Hull’ option was chosen as the type of geometry that allows the shape of the islands to be approximated by creating convex polygons: this approximation makes it possible to evaluate shape variations in all those cases in which a variation would lead to null values. In other words: if for an island a surface variation that leads to a null difference (the same quantity is lost and accumulated) occurs over the observation time, the envelope curves of the two areas can still describe the variation.

With such a huge amount of WLs available, it was necessary to make a selection on the basis of the Quality Coefficients defined by Argans as an attribute of each line, related to length and shape. We chose to evaluate only the envelopes of lines with a QC_intern >= 50, not a very high threshold, in order not to exclude too many lines derived from Landsat 5 data, which cover the entire temporal period 2000-2012 but are fewer than those derived from Landsat 8/Sentinel 2 images, covering only more recent years, though. But not only the “quality” indicator has been used as a driver for the selection of the WLs because, especially for the natural elements, quite a few of the computed WLs showed a large deviation from the shape of other WLs in the same spot, probably due to the very peculiar environment in terms of water-mud (or sand, or vegetation) interface. The initial idea was to set up "influence buffers" capable of intercepting the WLs with respect to a certain morphological element identified by the LC00/20, choosing as a reference half the distance between an island/barena and the adjacent one. This approach proved to be limiting because it assumes that the ISPRA lines are correct, whereas they are WLs, too, and therefore variable with the tide in the case of the presence of mudflats. For this reason, user-defined 'clip areas' were set, both to select and clip the WL with respect to the morphological element being analysed.

In this case, too, the analysis of the various elements started by comparing the elements that have not changed over the years and are not affected by the tidal excursion, i.e. the two fully artificial islands of Burano and Santa Cristina, and then the work moved on to the natural or semi-natural elements selected.

Results

Table 1 shows the absolute and relative difference values of the surface areas as calculated according to the various methods and data sources described in the previous section. The first elements to be compared were the recorded surfaces of the two artificial islands of Burano and Santa Cristina (columns 4 and 5) by the GIS data from the Lagoon Atlas classification, and from the ISPRA Coastlines, as these are the lagoon elements that have practically remained unchanged over the years and are not affected by tidal excursion. The comparison of the two methods is important in order to understand the issues arising when working on datasets deriving from surveys at different scale and precision, and it will be the basis also for the assessment of the reliability of the computed WLs by Argans.

Table 1 – Area of the surface of the islands studied and of the envelopes built as defined in the text, along with relative differences.

ISLAND/BARENA	velme	barene naturali	barene artificiali	SUM (ATLAS OF THE LAGOON)	LC00_Polygon	LC00_Envelope	% diff. Poly-Envelope	% diff. Atlante-LC00	LC20_Polygon	LC20_Envelope	% diff. Poly-Envelope	% diff. Atlante-LC20	% diff. LC20-LC00
	area (mq)								area (mq)				
Burano	0	0	0	212238	226631	240115	**5,9**	**-6,4**	226209	244168	**7,9**	**-6,2**	**-0,2**
Santa Cristina	0	0	0	185295	305288	360929	**18,2**	**-39,3**	305097	359989	**18,0**	**-39,3**	**-0,1**
"Sicilia"	26473	146415	0	172888	179566	261117	**45,4**	**-3,7**	154822	233757	**51,0**	**11,7**	**-16,0**
"NatStabile"	32618	9842	0	42460	-	-	-	-	28493	42666	**49,7**	**49,0**	-
"Barena Artificiale"	0	0	137416	137416	-	-	-	-	97481	109828	**12,7**	**41,0**	-
Crevan	120295	71392	62138	253825	149655	193118	**29,0**	**69,6**	202901	213892	**5,4**	**25,1**	**26,2**
"Tortuga"	17712	11693	0	29405	-	-	-	-	13337	15814	**18,6**	**120,5**	-
"Malleolo"	60568	15140	0	75708	63140	72890	**15,4**	**19,9**	116317	131749	**13,3**	**-34,9**	**45,7**

The deviations found for the two islands show quite a different amount, but in both cases it can be explained by the fact that the LC polygons embed the inner channels of Burano and the quite large artificial pools of Santa Cristina. The comparison went on to the surfaces of the natural or semi-natural elements (rows 3-8), which proved to be affected by the time differences of the respective surveys, as declared in the previous section. We observe an increase of the discrepancies, which may arise from two main contrasting factors: firstly, the ISPRA coastlines are defined as waterlines, therefore they suffer from the recognition error in the visual interpretation of the aerial photo when the boundary between land and water is made up of mudflats; the second is the temporal differences between the surveys with the possibility that the variations are truly due to the evolution of the morphological elements, an evolution that may be natural or due to human actions. How to assess the digitisation errors and to discern the real change in the waterlines/areas is definitely the goal of this work and it has been addressed through the validation process, which also included expert judgement over the aerial and satellite images. In this process, we observed both natural (sandbanks "Sicilia", "Tortuga") and anthropic (Crevan Island, "Barena artificiale", "Malleolo") variations, which are recorded by the variations observed in the LC20 dataset, when compared to the LC00 (columns, 9 and 5, respectively).

We now turn to the analysis based on the areas of the envelopes defined from the LC00/20 and Argans' WLs. First, we again checked the effect of approximating the surface of the islands by the forcedly convex envelope defined above, by the analysis of the surfaces of the envelopes built over the ISPRA datasets for the artificial islands (Burano and S. Cristina). The data in Table 1 show the extent of the overestimation of the “true” surface brought about by the envelopes. Due to their shape, the effect is different in the two cases (average 6 % for LC00 and LC20 in Burano, 18 % in S. Cristina). These observed features are taken into account in the next steps of the validation assessment.

The analysis of the envelope surface calculations for the Argans’ WLs is shown in Figure 3 for the island of Burano, from which we notice a tendency for the WLs to define larger envelopes. The graph in the right part of the figure plots, for different acquisition dates the relative surface difference between the envelope derived from the 2020 ISPRA Coastline and those computed from the Argans’ WLs; bars with negative percent values

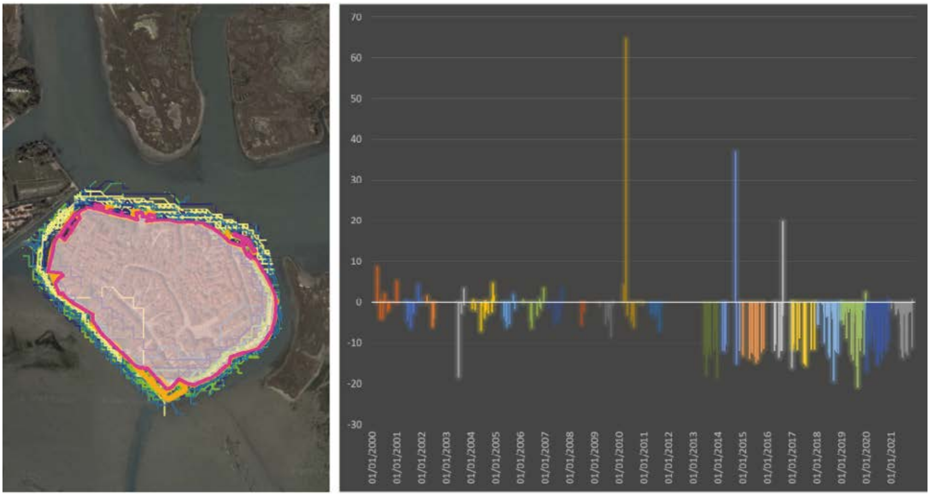

Figure 3 – Analysis of the envelope surfaces for the artificial island of Burano.

means that "Argan's envelopes" are bigger than the ISPRA LC20 ones: this overestimation is contained to an average of 10 %. Approximately the same overall results was obtained in S. Cristina island.

Going further on, the analysis of the partially artificial islands and salt marshes showed more marked differences. In this case, the differences between the data acquisitions have less influence than in the Atlas-ISPRA comparison, because the data made available by Argans start from 2000, almost at the same time as those of the LC00, which in these areas was defined with respect to images from 1998, and the WL series reach 2021, thus including the period of the survey used for the LC20, i.e. 2019.

That of the sandbar named by us as 'Sicily' (figure 4) represents a case in which the two LC20 / WL data are in fairly good agreement, with the bulk of the surveys not deviating by more than 10-15 %. This is a sandbar that from the ISPRA survey appears to be regressing by about 16 % (11 % if estimated by the envelope).

The plot shows negative average values around the year 2000, i.e. it indicates that for those years there are higher average values for the envelopes of the Argans WLs than for those derived from the LCs, while these average differences become positive on the right side of the graph, thus showing differences in favour of the envelopes calculated on the LC20. The presence of a sort of oscillation of the differences in the period 2006-2018 is being further investigated.

A different case concerns the barena we called "Malleolo" which surface grows as a result of specific human actions. In that case, the construction of specific artifacts between the years 2012-13 determined a considerable growth of the area (from ISPRA data about 45 %) and this phenomenon was also recorded in the comparison with the surfaces of the envelopes.

Figure 4 – Analysis of the envelope surfaces for the barena "Sicily" (fancy name).

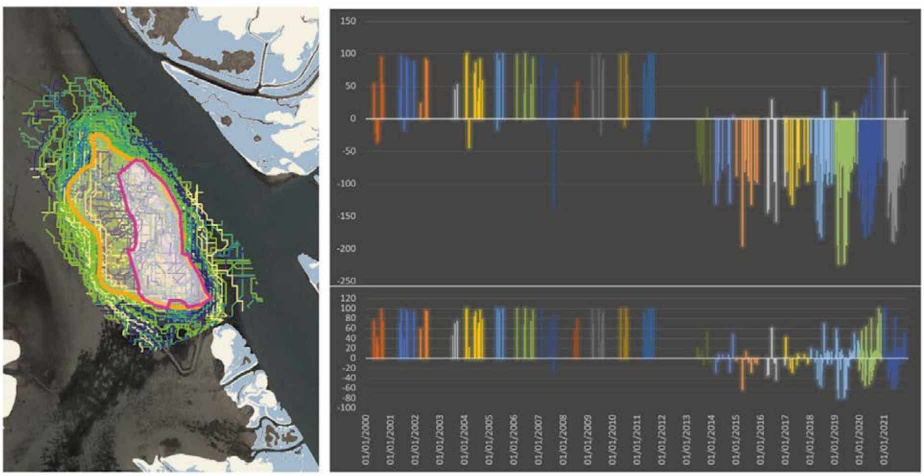

Figure 5 – Analysis of the envelope surfaces for the barena "Malleolo" (fancy name).

In particular, the two tiled graphs of fig. 5 show the envelope areas differences as defined before, but this time also that of LC00 is shown (upper graph). The left part of both graphs, corresponding to the years covered by Landsat 5 data (2000-2012) shows most values close to 100 %, meaning that the surfaces subtracted from the envelope values of the LCs are negligible; this, in turn, indicates that the WL data derived from the Landsat 5 in that area fail to identify significant polygons. In contrast, the second part of the graphs refers to the envelopes constructed on the Landsat 8 and Sentinel 2 lines, and they define a very precise phenomenon, in fact while the comparison with the data derived from LC00 returns a constantly higher area for the Argans envelopes (up to more than 100 %), the comparison made with the envelopes derived from LC20 gives, in the average, a much more consistent result.

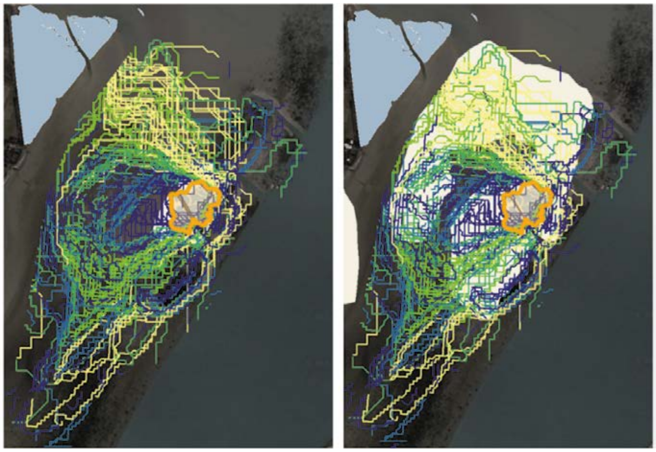

Figure 6 – Analysis of the envelope surfaces for the barena/velma system "Tortuga" (fancy name).

Lastly, the case of the small sandbar we called "Tortuga" (fig. 6) shows another kind of condition. The set of WLs that seems to refer to that lagoon element occupies a very large area, so much so that the envelope polygons that were defined around the lines under consideration outclassed in area those defined by LC20. In this case, however, it is not necessarily a case of data degradation in that area: the concordance shown between the layers of the Lagoon Atlas and that of the LC20 may tell only part of the story. There is a layer that can be loaded via the Lagoon Atlas WMS services, containing further geographical data on the velme, but whose data period could not be retrieved at the moment. This layer shows in some areas substantial differences with the layer published on the webGIS and used in this paper [11]. This alternative layer of the Lagoon Atlas seems to define a large area of velma right in the area affected by the Argans WLs, so as to explain the shape of the computed lines.

Conclusion

We have presented the first results of the validation and analysis of the huge dataset of waterlines, as calculated from satellite images by Argans Ltd algorithms, applied to a very complicated study area, such as the Venice Lagoon. The validation process included the use of the information layers made available by the Lagoon Atlas which contain very accurate information but suffer from referring to data that for salt marshes and natural mudflats go back to 2003-2009. We also used the information layers produced by ISPRA, namely, the Coastline digitised over the whole country, from aerial ortophotographs and satellite images, for two nominal time frames: 2000 and 2020. However, such data are recorded following a method that actually returns Waterlines, which in the Lagoon can lead - for example -to define normally submerged mudflats as dry land.

Although a test phase over additional case studies is still needed, these results showed that the Earth Observation technologies that have been developed within the ESA-funded project "Coastal Erosion from Space", can identify both morphological objects and changes over time due to natural causes or human action. The application of these techniques, integrating them with other field data and applying them to orthophotos of higher definition and with possibly higher acquisition frequency, will be able to be an effective tool for monitoring the coastline and even a territory as complex as the Lagoon.

Acknowledgements

We wish to thank Andrea Bonometto e Rossella Boscolo Brusà, from the ISPRA offices in Venice for the fruitful discussion which led to the identification of the ideal study area for our analysis.

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MARINE PROTECTED AREAS AND THE PROBLEM OF PAPER PARKS

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Abstract – The ocean makes the Earth habitable for humankind and careful management of the ocean is of utmost importance for sustainable future. Marine Protected Areas (MPAs) are a key instrument of ocean protection. According to *UN World Database on Protected Areas* more than 15000 MPAs protect 7.68 % of the ocean while IUCN recommended that at least 30 % of the ocean should be protected effectively by 2030. The *International Union for Conservation of Nature* (IUCN) defines protected area as: *A clearly defined geographical space, recognised, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values*. In the report *Conversion of paper parks to effective management: developing a target*, paper park is defined as: *A legally established protected area where experts believe current protection activities are insufficient to halt degradation*. Many MPAs exist on maps but offer little real protection. Understanding and explaining the ineffectiveness of MPAs is a difficult task due to the complexity of MPAs social-ecological systems that require a multidisciplinary study approach. The aim of this paper is to briefly overview paper parks problem regarding MPAs, to emphasize the causes of the phenomenon as well as to address the possible solutions of the problem, as highlighted in reports and scientific literature.

In the process of MPAs establishment, human dimension plays important role, since social, economic, and institutional factors significantly affect MPAs effectiveness. According to Pieraccini et al. (2017), key obstacles limiting conservation effectiveness of MPA include inappropriate planning, poor governance, low enforcement level, few socio-economic incentives for compliance, conflicts among stakeholder groups and little community involvement in the management. There are many examples of paper parks in the literature, and the lack of effective surveillance of MPAs is considered as the greatest obstacle inhibiting success of MPAs. MPAs will be effective if surveillance and enforcement mechanisms are strong. According to Ferse et al (2010), the poor performance of MPAs can be result of failure to include effectively local communities in the design and implementation of relevant measures and aspects of community-based management should be incorporated into a hybridform of management upon existing local management practices.

The IUCN has recognized good governance, sound design and planning, as well as effective management as basic criteria for the global standard of best practice for area-based conservation and has set the first global standard of best practice for area-based conservation - *The IUCN Green List of Protected and Conserved Areas*. In a document *The World Wildlife Fund (WWF) 2017 Report Preventing paper parks: How to make the EU nature laws work*, it is highlighted that European Union protected areas were at risk due to lack of proper implementation of EU laws by member states and the Commission legal actions. WWF 2019 Report *Protecting our ocean. Europe's challenges to meet the 2020 deadlines* assesses that 12.4 % of the EU marine area is designated for protection but only 1.8 % of is covered by

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MPAs with management plans and far less than 1.8 % is under effective management and monitoring. The WWF Reports demonstrates the importance of management plans as well as the importance of involving all stakeholders in management plan developing process. 2020 report *Unmanaged = Unprotected: Europe's marine paper parks* reveals the current network of European MPAs is not well-managed and not restrictive enough to limit increasing pressures mostly due to a race to MPA designation to meet European and international targets, which has sacrificed quality for quantity. The analyses shows that about 80 % of plans were incomplete and had often been seriously delayed. Most of the assessed plans were weak due to a lack of deadlines for implementing measures, a failure to manage specific features for which sites were designated; a failure to address major threats and the absence of provisions for surveillance and monitoring. Although, management plan is critical element of MPA, the existence of management plan does not guarantee effective management. Detailed assessments including stakeholder user surveys are required in order to estimate if MPA is effectively managed. Without effective management, designated MPAs remain mere paper parks that provide little to no real protection of species or habitats and creates a false impression of achievement.

Introduction – the importance of the oceans and MPAs

Ocean covers more than 72 % of the earth's surface and drives global systems that make the Earth habitable for humankind [1]. The ocean provides food, jobs, and recreation for population [2] and careful ocean management is a key feature of a sustainable future [1]. According to [3] the ocean economy contributes to global value added in the order of 1.5 trillion US$ annually and it could more than double its economic contribution to GDP equivalent until 2030.

Marine Protected Areas (MPAs) are a key instrument in protecting the ocean and they have to be effectively managed in order to reduce overfishing, marine pollution and ocean acidification [1]. The International Union for Conservation of Nature (IUCN) defines protected area as: *A clearly defined geographical space, recognized, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values* [4].

According to IUCN (IUCN-WCPA, 2018), MPAs *are parts of intertidal or subtidal environments, together with their overlying waters, flora and fauna and other features, that have been reserved and protected by law or other effective means*. According to Briggs et al. (2018), the term MPA reflects a spectrum of management objectives from delivering sustainable exploitation to protecting biodiversity or sites of scientific and/or cultural interest [5]. MPAs can be classified according to:

- Their Main Aim: MPAs vs Other Effective Area-Based Conservation Measures (OEABCMs): only sites whose primary declared aim is biodiversity conservation can be deemed MPAs. [4]
- Management Objectives: The IUCN established six protected area categories according to their main management objectives: Category Ia: Strict nature reserve; Category Ib: Wilderness area; Category II: National park; Category III: Natural monument or feature; Category IV: Habitat/species management area; Category V: Protected landscape/seascape; Category VI: Protected area with sustainable use of natural resources. [6]

- Their Legal Background: MPAs may be statutorily designated or established through voluntary agreements by stakeholders: voluntary MPAs.

As defined by the Guidelines for applying the IUCN Protected Area Management Categories to Marine Protected Areas [7], essential MPAs characteristics should be:

- conservation focused with nature as the priority;
- defined goals and objectives which reflect these conservation values;
- suitable size, location, and design that deliver the conservation values;
- defined and fairly agreed boundary;
- management plan or equivalent, which addresses the needs for conservation of the MPAs major values, and achievement of its social and economic goals and objectives;
- resources and capacity to effectively implement.

According to UN World Database on Protected Areas more than 15000 MPAs protect more than 27 million square kilometres of ocean (7.68 %) [8] while IUCN recommended that at least 30 % of the ocean should be protected effectively by 2030 [9].

The UN Sustainable Development Goal 14 and Aichi Target 11 under the Strategic Plan for Biodiversity 2011–2020 of the UN Convention on Biological Diversity highlighted the need for networks of effective MPAs [7].

The *Protocol concerning specially protected areas and biological diversity in the Mediterranean* (*SPA/BD Protocol,* 1995) [10] *stresses the importance of protecting and improving the state of the Mediterranean natural and cultural heritage, in particular through the establishment of specially protected areas and also by the protection and conservation of threatened species***.** In Annex I of *SPA/BD Protocol* common criteria for the choice of protected marine and coastal areas that could be included in the Specially Protected Areas of Mediterranean Importance (SPAMI) list are given.

The *EU Biodiversity strategy for 2030* (COM (2020) 380 final) [11] states that improving and widening network of protected areas is neccessary in order to put biodiversity on the path to recovery by 2030. The Annex of the *EU Biodiversity strategy for 2030* presents action plan that will be taken forward in line with the better regulation principles, including evaluations and impact assessments as appropriate.

Many MPAs exist on maps but offer little real protection. For some countries, it is estimated that majority of MPAs exist primarily on paper (80 % - 90 %) [12]. In the report *Conversion of paper parks to effective management: developing a target*, paper park is defined as: *A legally established protected area where experts believe current protection activities are insufficient to halt degradation* [13]. There are many examples of paper parks (*i.e. designated protected areas that are not ensuring a high level of protection on the ground*) in the literature [14].

Establishing of MPAs requires long-term political and financial commitments that go far beyond simply declaring new parks [15], as well as their usefulness depends upon a number of ecological, management, and political factors [16]. Understanding and explaining the ineffectiveness of MPAs is a difficult task due to the complexity of MPAs social-ecological systems that require a multidisciplinary study approach [14]. The aim of this paper is to briefly overview paper parks problem regarding MPAs, to emphasize the causes of the phenomenon as well as to address the possible solutions of the problem, as highlighted in reports and scientific literature.

Results and discussion - the management of MPAs and problem of paper parks

According to Dudley (2008), protected areas have a wide range of management aims and are governed by many different stakeholders [6]. MPAs are more easily created and managed by governments in national waters while in Areas Beyond National Jurisdiction (ABNJ) it is more difficult to create MPAs due to the complex legal [8].

The [17] and the Convention on Biodiversity (CBD) recognize four broad governance types for protected areas:

- Type A: Governance by government (at various levels);
- Type B: Shared governance by diverse rights holders and stakeholders together;
- Type C: Governance by private entities (often land owners);
- Type D: Governance by indigenous peoples and/or local communities (at times referred to as ICCAs or territories of life).

IUCN principles of good governance for protected areas includes:

- Legitimacy and voice;
- Direction;
- Performance;
- Accountability;
- Fairness and rights [18].

In order to improve governance of protected areas or a specific site, the IUCN and CBD have published *Guidelines for assessing, evaluating and planning for action* - an analysis of the historical, socio-cultural, institutional and legal contexts, a spatial analysis of governance and the status of conservation of nature, including an assessment of biological, ecological and cultural values and their potential association with governance diversity, quality and vitality [19].

In a paper *Recommendations to IUCN to Improve Marine Protected Area Classification and Reporting*, Briggs et al. (2018) evaluated global targets and MPA definitions, highlighted key recommendations for improving the application of the IUCN categories for MPAs together with improved reporting standards. The authors stated that policy makers should favour highly and strongly protected MPAs as the most effective means of achieving global conservation targets. According to Briggs et al. (2018), levels of protection and biological benefits of MPAs are difficult to determine due to broad definitions of MPA and generalized progress reports and that strengthening the IUCN Protected Areas Categories and improving reporting standards is an essential [5].

According to [20], it is vital to have in depth knowledge of the area but also to have the support of the public and established techniques for surveillance and monitoring of compliance.

Oregon State University, IUCN World Commission on Protected Areas, Marine Conservation Institute, National Geographic Society, and UNEP World Conservation Monitoring Centre published a science-based framework to categorize, plan and track MPAs: *The MPA Guide* [21]. There are wide-ranging types of MPAs with various goals and expectations according to Stage of Establishment (proposed/committed, designated/MPA exists on paper, implemented and actively managed, with ongoing monitoring and adaptive management), Level of Protection (fully protected, highly protected, lightly protected, and minimally protected), Enabling Conditions and Outcomes. *The MPA Guide* stresses that not all MPAs are equal for conservation or social outcomes and that the likely outcomes of an MPA depend directly on stage, level, and conditions to succeed [21].

In the process of MPAs establishment, human dimension plays important role, since social, economic, and institutional factors significantly affect MPAs effectiveness [22]. Bruner et al. (2004) [15] state that while funding is only one of several basic needs for creating functional protected-area systems, inadequate financial support plays a central role in the loss and degradation of important natural resources, as it limits both the management effectiveness of established protected areas and the coverage of protected-area systems. Rife et al. (2013) [23] found that funding for management was not the limiting factor in MPA efficacy, although funding for enforcement might be deficient.

According to Pieraccini et al. (2017), key obstacles limiting conservation effectiveness of MPA include inappropriate planning, poor governance, low enforcement level, few socio-economic incentives for compliance, conflicts among stakeholder groups and little community involvement in the management [14]. The socio-legal studies of MPAs ineffectiveness are very important and they can provide the insight into non-compliance motivations not only of regulatees but also of regulators, to outline a number of inter-linked causes leading to non-compliance and to provide policy recommendations [14].

There are many examples of paper parks in the literature, and the lack of effective surveillance of MPAs is considered as the greatest obstacle inhibiting success of MPAs [14, 24, 25]. MPAs will be effective if surveillance and enforcement mechanisms are strong, because actors comply with the management rules due to their fear of subsequent sanctions, especially if the amount of the penalty outweighs the benefits of non-compliance [11, 26]. According to Ferse et al (2010) [26], the poor performance of MPAs can be result of failure to effectively include local communities in the design and implementation of relevant measures and aspects of community-based management should be incorporated into a hybridform of management upon existing local management practices. Baldwin and Black (2008) [27] point out that more external surveillance and enforcement will not raise environmental knowledge, but will increase levels of mistrust between the actors. Therefore, efforts should be directed towards the building of trust, increasing environmental knowledge and communication between actors (*Really Responsive Regulation*) [14]

The IUCN has recognized good governance, sound design and planning, as well as effective management as basic criteria for the global standard of best practice for area-based conservation. IUCN has set the first global standard of best practice for area-based conservation (national parks, natural World Heritage sites, community-conserved areas, nature reserves…) - *The IUCN Green List of Protected and Conserved Areas* [28]. The Standard has recognized 59 well-managed and well-governed protected and conserved areas in 16 countries. According to the Standard, the time from application to certification depends on the management quality of the site at the time of application.

The *World Wildlife Fund (WWF) Report Preventing paper parks: How to make the EU nature laws work* [29] states that European Union protected areas are at risk due to lack of proper implementation of EU laws by member states and legal actions started by the European Commission. The WWF Report encourages Member States and the Commission to complete the designation of marine Natura 2000 sites, develop conservation measures and management plans for all Natura 2000 sites, increase investment and strengthen enforcement. Member States should ensure that the designation and management of Natura 2000 sites is transparent and science-based process that involves local stakeholders. Member States should make additional efforts to define and implement conservation measures, if the Natura 2000 network consists of paper parks. The case studies included in *WWF Report* demonstrate the importance of good management plans based on well-defined conservation objectives and highlights the importance of involving landowners, resource users and other key stakeholders in the process of management plans developing. The WWF Report highlights the importance of participation of a broad range of stakeholders for successful management and societal support for Natura 2000 sites as well as the importance of raising public awareness. [29]

WWF's 2019 Report *Protecting our ocean. Europe's challenges to meet the 2020 deadlines* [30] assesses the spatial coverage of all designated MPAs, MPAs with a management plan and effectively managed MPAs (are areas that have been designated, have an implemented management plan and are carrying out actions for conservation and/or active nature restoration that results in actual protection). It reports that 12.4 % of the EU marine area is designated for protection but only 1.8 % of is covered by MPAs with management plans and far less than 1.8 % is under effective management and monitoring. 11 out of 23 marine EU Member States have not reported any management plans for their MPAs and eight Member States have management plans for less than 10 % of their marine area (more data may be available within individual Member State databases). In addition to the lack of protection currently provided, EU MPAs fail to function together as a network. [30]

WWF's 2019 Report states that in order to provide effective protection, MPAs must have comprehensive management plans based on the IUCN model which addresses details ranging from legislative authority, site description, its value to general and specific conservation objectives, existing uses, regulation of human activities, and monitoring of progress towards objectives and enforcement [31]. Although, management plan is critical element of MPA, the existence of management plan does not guarantee effective management. Detailed assessments including stakeholder user surveys are required in order to estimate if MPA is effectively managed [32].

Besides that, WWF recommends that EU Member States commit to the goal of reaching at least 30 % effectively managed MPAs by 2030 that will function together as network, as well as to increase transparency of the protection of MPAs by ensuring timely and accurate reporting. Without urgent actions to enforce and implement effective ocean protection, nearly all EU MPAs stand at risk of remaining protected on paper, but not in practice [30].

2020 report *Unmanaged = Unprotected: Europe's marine paper parks* [33] reveals that only 0.5 % of European seas are protected within real MPAs. The current network of European MPAs is not well-managed and not restrictive enough to limit increasing pressures mostly due to a race to MPA designation to meet European and international targets, which has sacrificed quality for quantity. The analyses shows that management plans were reported to exist for only 47 % of the 43 sites assessed according to official information provided by countries to the European Commission. About 80 % of plans were incomplete and had often been seriously delayed [33]. Most of the assessed plans were weak due to a lack of deadlines for implementing measures, a failure to manage specific features for which sites were designated; a failure to address major threats and the absence of provisions for surveillance and monitoring. The report urges the European Commission, EU Member States, and the UK to significantly step-up efforts to manage their MPAs, deliver proper protection and restrict the most impacting human activities. The European Commission should improve the standardised reporting of management measures by EU Member States.

Without effective management, designated MPAs remain mere paper parks that provide little to no real protection of species or habitats and creates a false impression of achievement [34].

Conclusion

The ocean makes the Earth habitable for humankind and careful management of the ocean is of utmost importance for sustainable future. Marine Protected Areas (MPAs) are a key instrument of ocean protection. According to *UN World Database on Protected Areas* more than 15000 MPAs protect 7.68 % of the ocean while IUCN recommended that at least 30 % of the ocean should be protected effectively by 2030. The *International Union for Conservation of Nature* (IUCN) defines protected area as: *A clearly defined geographical space, recognised, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values*. In the report *Conversion of paper parks to effective management: developing a target*, paper park is defined as: *A legally established protected area where experts believe current protection activities are insufficient to halt degradation*. Many MPAs exist on maps but offer little real protection. Understanding and explaining the ineffectiveness of MPAs is a difficult task due to the complexity of MPAs social-ecological systems that require a multidisciplinary study approach.

In the process of MPAs establishment, human dimension plays important role, since social, economic, and institutional factors significantly affect MPAs effectiveness. According to Pieraccini et al. (2017), key obstacles limiting conservation effectiveness of MPA include inappropriate planning, poor governance, low enforcement level, few socio-economic incentives for compliance, conflicts among stakeholder groups and little community involvement in the management. There are many examples of paper parks in the literature, and the lack of effective surveillance of MPAs is considered as the greatest obstacle inhibiting success of MPAs. MPAs will be effective if surveillance and enforcement mechanisms are strong. According to Ferse et al (2010), the poor performance of MPAs can be result of failure to include effectively local communities in the design and implementation of relevant measures and aspects of community-based management should be incorporated into a hybridform of management upon existing local management practices.

The IUCN has recognized good governance, sound design and planning, as well as effective management as basic criteria for the global standard of best practice for area-based conservation and has set the first global standard of best practice for area-based conservation - *The IUCN Green List of Protected and Conserved Areas*. In a document *The World Wildlife Fund (WWF) 2017 Report Preventing paper parks: How to make the EU nature laws work*, it is highlighted that European Union protected areas were at risk due to lack of proper implementation of EU laws by member states and the Commission legal actions. WWF 2019 Report *Protecting our ocean. Europe's challenges to meet the 2020 deadlines* assesses that 12.4 % of the EU marine area is designated for protection but only 1.8 % of is covered by MPAs with management plans and far less than 1.8 % is under effective management and monitoring. The WWF Reports demonstrates the importance of management plans as well as the importance of involving all stakeholders in management plan developing process. 2020 report *Unmanaged = Unprotected: Europe's marine paper parks* reveals the current network of European MPAs is not well-managed and not restrictive enough to limit increasing pressures mostly due to a race to MPA designation to meet European and international targets, which has sacrificed quality for quantity. The analyses shows that about 80 % of plans were incomplete and had often been seriously delayed. Most of the assessed plans were weak due to a lack of deadlines for implementing measures, a failure to manage specific features for which sites were designated; a failure to address major threats and the absence of provisions for surveillance and monitoring. Although, management plan is critical element of MPA, the existence of management plan does not guarantee effective management. Detailed assessments including stakeholder user surveys are required in order to estimate if MPA is effectively managed.

Without effective management, designated MPAs remain mere paper parks that provide little to no real protection of species or habitats and creates a false impression of achievement.

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AN INTEGRATED APPROACH FOR MARINE LITTER HOT SPOTS IDENTIFICATION

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Abstract – Marine litter is defined as any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment, and it is among the most important environmental problems which are affecting the sea nowadays. In this work, we present an integrated approach to the marine litter hot spots identification. The results come from a coordinate activity of filed campaigns, satellite monitoring and numerical model simulations. A dynamical view of the marine litter is at the core of the approach, so numerical models for the simulation of the floating pollutants dispersion in the sea are one of the key tools involved in the hot spot identification. Among all the available codes, the class of Lagrangian models is considered the most suitable to simulate the journey of the marine litters; specifically, the NOAA PyGnome software is the tool implemented for the purpose. The ability to monitor wide and hardly accessible coastal areas, using remote sensing imagery, is the second source of independent information used to identify the marine litter accumulation prone area. The routinely and operationally available ESA Sentinel 2 mission data has been considered for the purpose. Due to the coarser spatial resolution of the remote sensing data, with respect the typical marine litter size, the identification of floating or beached debris requires the analyses of the spectral reflectance, for each pixel in an image, searching for spectral signatures of the marine litter presence. Both modelling and satellite results are combined to pick up the coastal areas to be likely candidates for marine litter hot spots. Results of the method are encouraging, since the simulated accumulation areas clearly emerge from the background and the link to the sources is straightforward because of each simulated trajectory allows to know the origin of each beached Lagrangian element. It is expected the presented approach will help in planning actions to remove beached debris and to identify the sources mostly contributing in input the floating waste material in the marine environment. The method currently is applied on the Adriatic basin as part of the MARLESS INTERREG IT-HR project.

Introduction

Marine litter is among the most important environmental problems which are affecting oceans and the sea nowadays. All over the world, there is no sea basin free of solid elements, mostly floating, that are transported and dispersed by currents. Their size ranges from macroscopic dimensions, that is larger than about 2 centimetres, down to nanometres

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and, of all circulating objects, a part has natural origin, for example parts of trees, pollen and other biological stuff, but a relevant amount is litter.

Marine litter is defined as any persistent, manufactured or processed solid material discarded, disposed, or abandoned in the marine and coastal environment, so their origin is strictly identified in human activities. Because of the relevant impact on the marine ecosystem, plastic marine litters are those most monitored and studied.

When a floating litter is released in or it reaches the sea, then it starts a journey that can last for years, according to the sea currents and the surface wind. It is well known that the interaction of water mass with the coast, besides the water circulation patterns, bring marine litters to accumulate in some areas, while they are efficiently dispersed in others.

So, it is extremely important to identify the areas where the marine litter accumulate, which are referred as marine litter hot spots, because restoring action, meant to remove the pollutants from the environment, can be focused of those hot spots. Furthermore, the identification of starting points of the trajectories, showing the litter journey, are helpful to link the sources of pollutants, that is the environmental pressures, with the hot spots.

In this work, we present an integrated approach to the marine litter hot spots identification. The results come from a coordinate activity of filed campaigns, satellite monitoring and numerical model simulations carried on as part of the MARLESS INTERREG IT-HR project [1]. The method integrates the applications of a numerical dispersion model, the NOAA PyGnome code [2], and explores the opportunity to improve the quality of the results using a cutting edge lagrangian model, the PARCELS model [3] and the systematic analyses of satellite images collected by ESA Sentinel missions [4].

The dispersion model runs simulate the litter transport, after the release from known sources of pollutants. We will show that, besides the tuning of the parameterization of physical effects causing the litter to move, to include the litter beaching and refloating action is mandatory to achieve a realistic description of accumulations areas. The likelihood of those areas can be increased using the analysis of the backward trajectory distribution across the studied basin and assuming the main pollutants sources known with high probability, like river mouths and coastal points with high anthropic density.

The simulated hot spots have been monitored systematically using the Sentinel 2 spectral imagery and the probability for a hot spot candidate is included in the identification process. In this content, we will describe in details the process to produce the spectral fingerprint for specific materials, like plastics, and the need of neural network application to elaborate massively all the imagery available from Sentinel mission.

Materials and Methods

The basics of the two approaches for marine litter hot spots identification are describe in this section. In particular, first we present the modelling procedure and then that based on the satellite imagery.

Lagrangian models are the widely adopted tools in simulation of material dispersion in the sea; they simulate the motion of each Lagrangian Element (LE) as a point like parcel, therefore they focus on individual particle's trajectories. The Lagrangian models use (pre-computed) Eulerian velocity data derived from observations or models to compute the pathways of particles, by integrating the equation of motion given the velocity field.

Their application to nearshore systems with complicated geometry are less mature and it has been shown that the Lagrangian connectivity of nearshore flows depends strongly on the horizontal resolution of the underlying Eulerian hydrodynamic data [5]. The data required to simulate the dispersion are the wind field and the sea surface currents; the turbulence motion needs to be represented by ad hoc random motions. Static boundary condition, such as coastlines maps, are relevant to get a realistic scenario on the shoreline and to consider the possible beaching of the dispersed elements.

The Lagrangian model chosen to conduct this research is GNOME (General NOAA Operational Modelling Environment), a simulation system designed for the modelling of pollutant trajectories in the marine environment [6].

GNOME is a modular and integrated software system that accepts inputs in the form of maps, bathymetry, outputs of numerical circulation models, location, oceanographic and meteorological observations and other environmental data. The LEs are modelled in GNOME as particles, whose trajectories depend on "movers" (winds, currents and horizontal diffusion). The model generates two results one called the "best estimate" solution, that shows each LE position evolution, with all of the input data assumed to not affected by uncertainty, and another called the "minimum regret" solution, which displays the Les trajectories that incorporate the uncertainties, since models, observations and forecasts are not uncertainty free.

Moreover, there is the possibility to use the set of python bindings and utilities which are called pyGNOME, that can be used to write customized models using the GNOME code base [7]. The advantages of this model are the possibility to implement the hindcast simulation mode, in order to traceback from where the possible marine litter came from; the chance to simulate turbulent horizontal diffusive processes by a random walk; the possibility to adjust the wind action on the LE depending on how much the litter is above the sea surface. The latter function is called windage: different percentage of wind speed can be selected in such a way to simulate different material, e.g., fishing nets will have low windage (1% of the wind speed) since they are prevalently under the sea surface as shown in figure 1.

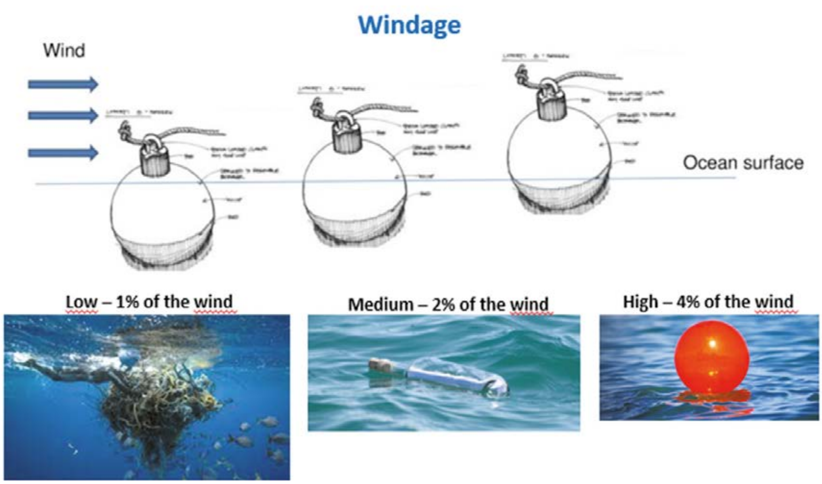


Figure 1 – Windage values that depends on the litter buoyancy.

Another important parameter that is used to simulate different marine litter is the "refloat half-life parameter". It empirically describes the adhesiveness of the litter to the shoreline. It summarized different parameters (such as substrate porosity, the presence or absence of vegetation and other physical properties and processes of the environment). It represents the number of hours in which half of the material on a given shoreline is expected to be removed, thus higher values of refloat simulates litter that generally stay beached for longer time. The half-life parameter could be set to different values along different segments of the shoreline depending on the beach type.

Coming to the satellite source of information, in the latest years, several studies have demonstrated the advantages of imaging Earth's surface with space-borne instruments to search for marine litter accumulation over the sea or shorelines. [8][9] Among all the space missions operating nowadays, the ESA Sentinel-2 mission is the major one adopted and addressed to be a valid choice to monitor marine and coastal areas. In particular, the monitoring campaigns conducted by Topouzelis and Themistocleous in Mytilene and Cyprus have shown the potential and tested the limits of Sentinel-2 to detect plastic marine litter by imaging floating artificial handmade rafts made of plastics. [10][11][12]

Sentinel-2 is a space mission that consists of a pair of identical satellites placed in sun-synchronous and polar orbits. They orbit around Earth with a phase of 180°, letting this little constellation passing over the same area on the globe's surface almost every five days. [13]

The two satellites are equipped with an imaging instrument, the Multispectral Instrument (MSI), which acts as a passive sensor, i.e., collects reflected light by objects on the ground when the sun illuminates them. MSI cameras allow to record those signals from the Visible up to the Near-Infrared part of the electromagnetic spectrum with 13 bands heterogeneously distributed and having three different spatial resolutions (see Fig. 2) [14]. The arrangement of the camera lens and the height of the satellite let it to have a swath width of about 300 km, this causes a partial overlapping within two consequential orbits which is particularly relevant at the middle-high latitudes. Sentinel-2 imaged globe's surface is ultimately divided into a grid of tiles of 100 x 100 km^2 size that are partly or completely filled with the sensed surface.

Sentinel-2 data are available to download under free data policy via the Sentinel mission web portal (https://scihub.copernicus.eu/); here the user can retrieve a zip file containing all the bands data plus auxiliary information about the sensing conditions for each recorded image. Each band data is provided as a raster image where each pixel is referred to lat/lon geographical coordinates and its content corresponds to the reflectance measured at the same location[1]. At the best spatial resolution, a single band pixel contains all the light collected within the band wavelength range from a real-world area of 10 x 10 m^2. Unwanted effects such as adjacency light incoming from the surrounding pixels or atmospheric disturbance can alter the original signal emitted from the surface although several techniques are available to correct those disturbs if needed. To speed up the aforementioned corrections a cut of the original tile is usually done, by means of a single or multiple polygonal shape that have to contain the area we are interested to analyse. When all these steps are done, i.e., the pre-processing phase of the image is concluded, we can proceed with the extraction and the analysis of the physical information we are interested in.

[1] Sentinel-2 products are provided already georeferenced and orthorectified, moreover the MSI cameras recordings are already converted into dimensionless reflectance values. Products with all these corrections are labelled as 'Level-1C products' and are freely downloadable by Users.

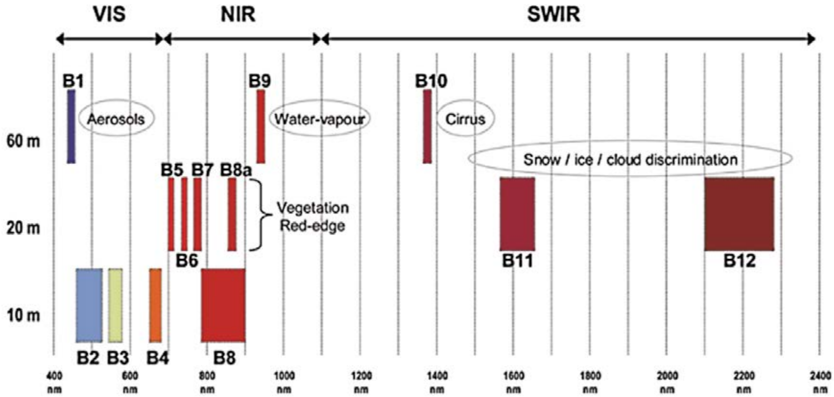


Figure 2 – This picture shows the portion of the electromagnetic spectrum covered by the MSI cameras. The broadening of the Sentinel-2 bands respect to the horizontal axe refers to their FWHM [18]. On the vertical axis are reported the three different spatial resolution allowed by the MSI instrumentation. Bands B2, B3 and B4 corresponds to the blue, green and red colours. The bands from B5 to B8 are dense and thin and serves primarily to investigate surface terrain properties such as vegetation coverage or soils state of health. B11 and B12 are more distant and sparse respect the bulk of the other bands, but they are useful to discriminate ground features such as seawater, since water, in any of his thermodynamic state, is black in the SWIR. The bands at 60 m of resolution are dedicated to the measurement of atmospheric properties and then are not used in the proceeding of this work. Picture taken from [10].

Collecting all the reflectance values of every band and putting them in a Reflectance vs Wavelength plot produces the *spectra* of that given pixel; the shape of such spectra depends on the amount of reflected light emitted from the different objects into and near the pixel and their extension. Each material produces its own particular spectra, which is usually referred as the material *spectral signature*. Laboratory and well-characterized on-field measurements allow recovering spectral signatures of various elements (see figure 3), these samples are the benchmark to investigate the true composition of the mixed spectra pixels extracted from the Sentinel-2 raster.

The final goal of the satellite image analysis, developed in the MARLESS project, is to find marine litter hot spots, that is searching coastal areas looking for spectral signatures that cannot be referred to known environmental features (such as seawater, sand, breakwaters rocks, etc.) and that can be instead associated with a particular marine litter component (wood from beached logs, plastics, and so on). Thus, the reliability and the efficiency of the detection of pixel containing marine litter rely on the richness and the accuracy of the well-known spectral signatures database we use. The spatial extent of sub-pixel scale objects is also an important limit in marine litter detection, as already proved for plastic litter by Topouzelis [11].

To construct our own database and test the spatial detection limits of Sentinel-2, we have defined two classes of case study areas, i.e., the "*high confidence*" and the "*medium confidence*" ones (see Table 1). Only with the characterization of such case of study is possible to proceed with the analysis of the most generic cases ("*open scenario*") whose extensions and positions are provided by the results of the model outputs.

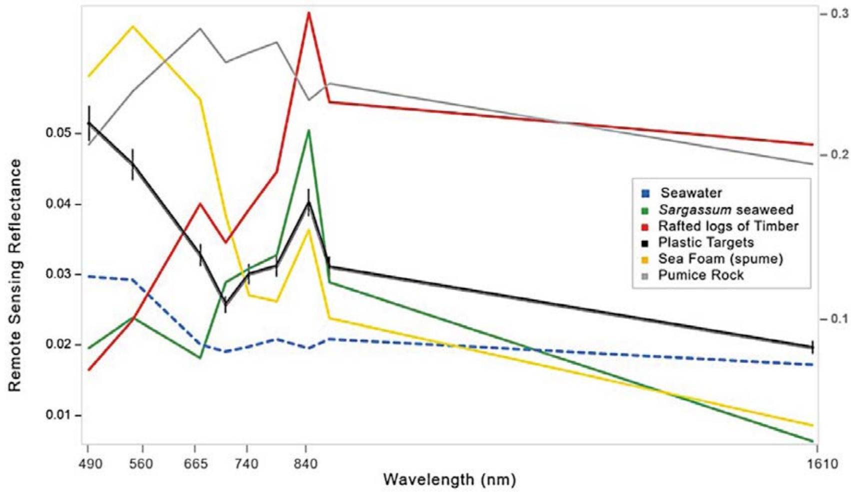


Figure 3 – This picture shows a sample of averaged spectral signatures for different materials as detected by Sentinel-2. The log and pumice rock spectra have higher intensity than the other materials and their reflectance axis is on the right of the plot. Further details are provided in [10].

Table 1 – Properties of the different case study classes defined to: i) create a reliable database of spectral signatures, ii) test limits of identification of sub-pixels scale objects, iii) search marine litter following modeling prompts.

	High confidence	Medium Confidence	Open Scenario
Main Objective	Computing spectral signatures of selected materials	Testing limits in detection of sub-pixel scale objects	Finding marine litter hot spots along shorelines
Surface properties	Extended areas (more than 5x5 in pixel size) occupied homogeneously by the same material	Area mostly occupied by an “high confidence” material but including sub-pixels features of different materials	Areas with mixed composition pixels mostly of unknown origin.
In-situ information	Mandatory to correctly detect the materials extension and their environmental status	Mandatory to correctly detect the materials extension and their environmental status	Not available or not referred to the same day of the satellite image.

Results

The application of the modelling approach has been conducted using three different half-life parameters, namely: 76 days, i.e. the resuspension timescale obtained for the Mediterranean with analysis of GPS trajectories of drifter buoys [6]; 150 days and 273 days considering the resuspension timescale of plastic debris with different size found in this research [16]. No variations in the beach type are implemented and the windage is selected randomly from a range of 1 %-4 % of the wind speed. The LEs are released from 16 sources (see Table 3) (harbours, rivers, city near the shorelines) using the PyGNOME utilities; the release is continuous with 10 particles per hour for a temporal duration of 9 months. The “minimum regret” solutions are considered.

The points with more accumulation of LEs have been studied and specific evaluations are made in order to select beaches to be analysed with the satellite analysis. Only the areas with less anthropic material and with less vegetation coverage are taken (see Table 2): one is located near the Reno's mouth, one near the Tagliamento's mouth, another near the Grado lagoon's mouth (Bando d'Orio beach), one near the Marano lagoon's mouth (Isola della Marinetta beach).

Table 2 – Location with the greatest amount of accumulation of beached marine litter.

Location	LEs counts
Tagliamento's mouth beaches	82087
Reno's mouth beaches	20428
Isola della marinetta's beach	11248
Bando d'Orio beach	7917

For each of these studied areas, considering the different half-life parameters (76 days, 150 days and 273 days), a statistical analysis was performed computing the minimum, maximum and median daily values from the hourly beached LEs. Finally, for each source the extreme minimum, maximum and mean values are identified; these results are available for each area and for each half-life parameter. The same statistical values are computed for the median daily values too including the 5 % and the 95 % percentiles. From that statistics, we evaluate the contribution of each source in the accumulation of beached material.

The results of each half-life parameter have been aggregated to get the overall contribution of all the marine litter type (Table 3).

Table 3 – Contribution of the LEs accumulation of each source considering all the reflaot half-life parameters.

Source	Contribution (%)			
	Banco D'Orio	Isola della Marinetta	Tagliamento's mouth beaches	Reno's mouth beaches
Trieste	5.44	3.66	1.10	1.23
Monfalcone	0.08	0.07	0.20	0.04
Isonzo	2.80	3.77	1.20	1.80
Grado	69.79	6.27	3.38	2.81
Laguna di Marano	0.88	74.31	5.59	1.01
Tagliamento	1.13	1.68	84.94	1.07
Livenza	0.15	1.06	0.61	1.62
Piave	0.01	0.04	0.13	1.45
Laguna di Venezia	0.01	0.01	0.01	0.26
Brenta-Adige	0.48	0.53	0.12	0.27
Po	0.53	0.09	0.21	2.97
Reno	0.08	0.55	0.05	82.30
Koper	5.88	2.11	0.81	1.34
Piran	8.79	3.29	1.06	1.05
Rovinj	2.97	1.85	0.44	0.30
Pula	0.98	0.73	0.15	0.48

In the following, for two accumulation points, that is the Tagliamento’s mouth and the Reno’s mouth beaches, the contributions of each source is shown in two maps considering all the kinds of marine litter (Figure 4 and Figure 5).

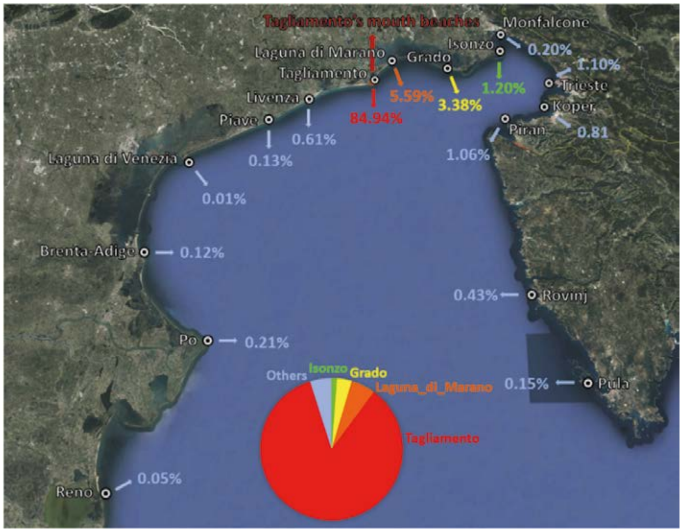


Figure 4 – Source contribution to the accumulation on the Tagliamento‘s mouth beaches.

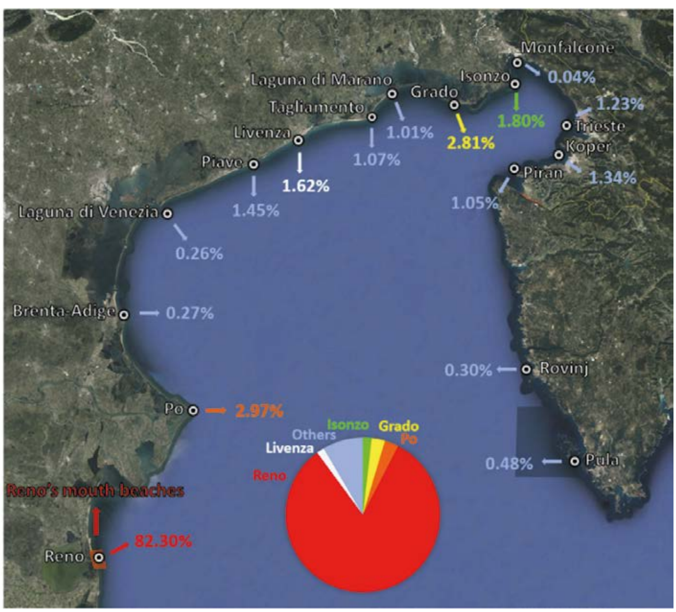


Figure 5 – Source contribution to the accumulation on the Reno‘s mouth beaches.

In adding the information coming from the satellite data source for the hot spot identification procedure, to understand the preliminary results of the investigation of a beach, we present the average spectral signatures, not atmospherically corrected, for two commonly types of surfaces: seawater and sand (see Figure 6a and Figure 6b). The seawater spectra are attended to decrease towards the SWIR bands and having the reflectance peak in the blue band, conversely sand reach its maximum values in the SWIR bands and the spectra has reflectance values typically an order of magnitude higher than seawater. It is worth to note that, at this stage, only the shape of the signature is relevant, not the absolute values of the reflectance.

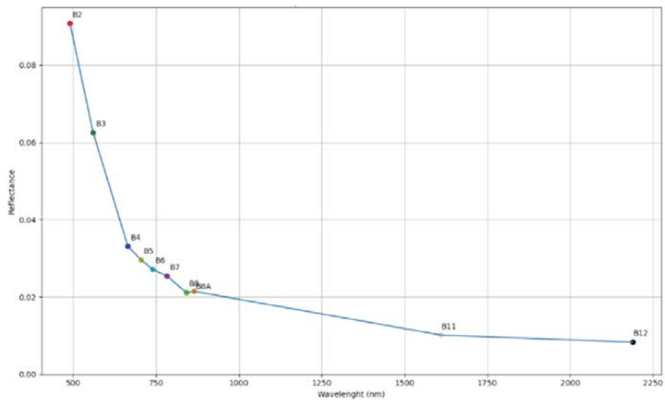


Figure 6a – Mean seawater spectra. The spectra have been collected averaging pixel values within three square areas of 100x100 pixel size located near shorelines of FVG Region at an average bathymetry of about 5 meters. This choice is motivated by the necessity of avoid open water areas but also not to be too much close to shores to avoid not homogeneous water coverage of sand due to tidal level or presence of sea foam.

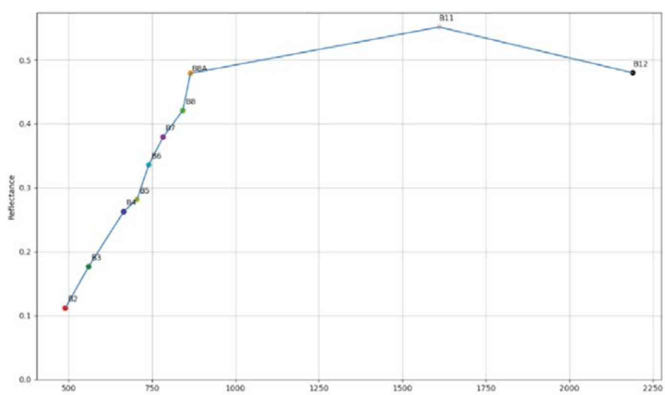


Figure 6b – Mean sand spectra. The spectra have been collected averaging pixel values within three square areas of 5x5 pixel size located along the sandy beach of Lignano town in the FVG Region. It has been verified by on-field proofs that the selected polygons where free of anthropic objects as umbrellas or deckchairs.

Model results have highlighted several marine litter hot spots along the North Adriatic Basin, so in applying the methodology we have selected one of such accumulation points to presents the catalogue of spectra that can be extracted when investigating an *open scenario* case study.

The beach we choose to study is part of the *"Tagliamento river mouth beaches"*. Here below in Figure 7 we report the 10 m spatial resolution RGB image of the study area and the corresponding Google Maps view.

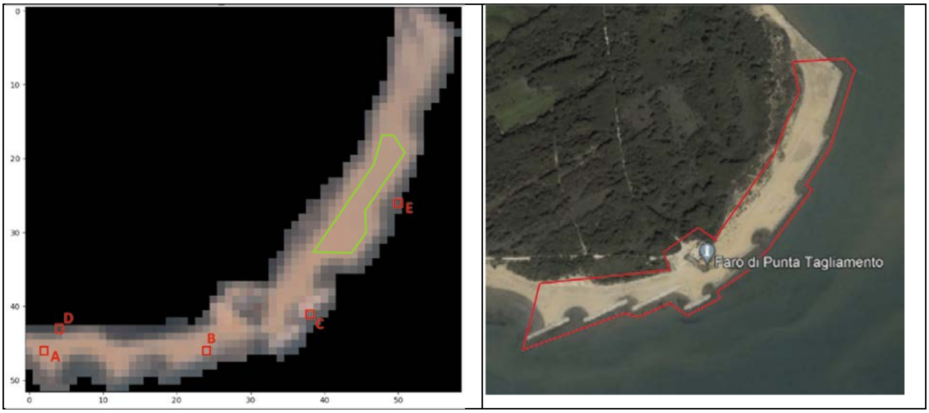
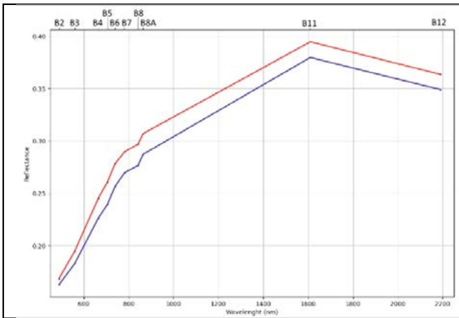
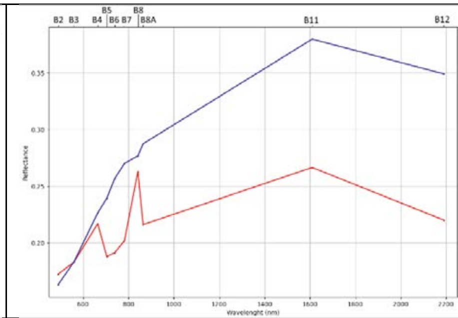


Figure 7 – The image on the left shows the RGB band composition of the study area we selected. The green polygon delimits the area chosen to calculate the average sand spectra; the red squares show the location of the sample of the selected spectra. The right picture is a screenshot from Google Maps of the same area of study.

The sequence of figures 8 presents a sample of the most representative spectra we have found in this polygon. All the spectra are compared with the *local* average sand spectra, Figure 6b, which is computed using pixels inside the green sub-polygon shown in Figure 7.

Discussion

The twofold approach to the marine litter hot spot identification is promising even if there are several weak points that are going to be considered to remove the uncertainties affecting the hot spots identification. So far, some fundamental results are already available. From summaries presented in Figure 4 and Figure 5, the greatest contributions are given by the nearest sources to the studied. Moreover, it can be noticed that the accumulation contributes follow the anticyclonic mean pattern of the Adriatic basin currents: i.e, the major contributes come from the eastward sources with respect to the target beach, in particular, this can be seen from the example of the Tagliamento's mouth beach. As far as the Reno's case is concerned, it can be noticed that the Grado source contribute is comparable to the Po source that is nearer to the point in study.

<table>
<tr><td>
</td><td>
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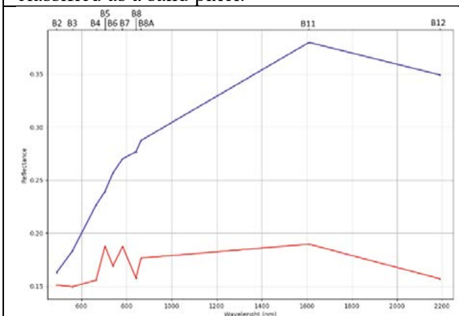
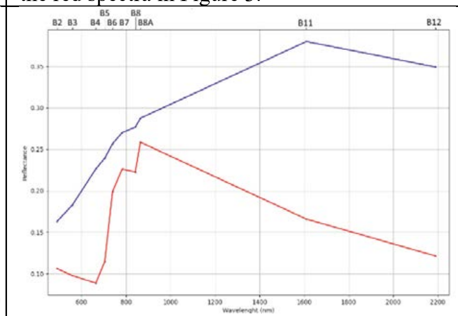
<tr><td>This pixel exhibits a spectra with a shape very close to the sand one, thus it can be easily classified as a sand pixel.</td><td>This spectra is an example of a rafted log signature, as can be deduced by comparison with the red spectra in Figure 3.</td></tr>
<tr><td>
</td><td>
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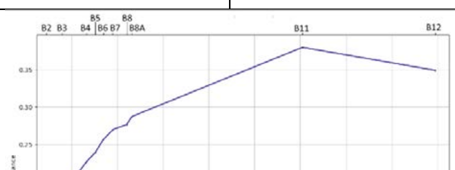
<tr><td>This spectra is an example of a rock signature, as can be deduced by comparison with the grey spectra in Figure 3. Moreover, visual comparison with the Google Maps image suggests this pixel could be mostly occupied by a breackwater.</td><td>Example of an unclear specral signature. Visual comparison with the Google Maps image suggests the pixel surface should be covered with vegetations, but the spectra doesn’t seem to resemble the shape expected from the literature.</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td colspan="2">Example of unclear signature with potential trend similar to plastics, however, the leak of in-situ formation of the beach at this lat/lon doesn’t allow to confrim the true nature of this spectral signature.</td></tr>
</table>

Figure 8 – We present a selection of pixel spectra that depicts the variety of shapes that can be found in an *open scenario* case of study class. In red is reported the average local sand spectra.

The dispersion simulation approach presents some not negligible limits: the most important is the low spatial resolution of the sea surface currents that led the LEs to be moved only by the wind field near the shorelines and in the lagoon waters. Moreover, there is the need to associate the correct refloat half-life parameter to the specific marine litter and to set the windage parameter according to the litter buoyancy; furthermore, the coast morphology has to be included, in order to better simulate the beaching behaviour. The above mentioned limits require another simulation code to applied and we consider suitable the PARCELS model [17]. Furthermore, to increase the sea currents availability and their resolution at the shore line and into the lagoons, a first attempt for the Friuli Venezia Giulia coasts is going to be done thanks to the oceanographic fields simulated by the ARPA FVG – SHYFEM hydrodynamic model. That improvement will allow to leverage the back trajectories to find shaded sources.

The huge and systematic amount of work required by satellite imagery post processing together with the complexity of the spectra signature identification, has put in evidence the need for an automatic algorithm to identify potential hotspot pixels, in Sentinel 2 imagery. To this end, a neural network framework is considered to work as a filter that will catch the suspicious pixels only, giving them a probability to be a polluted area. The training of the neural network is going to be based on the set of signatures collected thanks to the high and medium confidence analyses. Due to the trivial level of development of the spectra database, we are not still able to provide an interpretation of most of the potential signatures embedded in the available satellite imagery, although some relevant features can be identified thanks to the comparison with the literature.

Conclusion

The coupled approach to marine litter hot spots identification, that join information coming from the dynamic feature of the floating debris, which are moving in the sea due to sea currents and surface wind, and the remote sensing spectral signature for each pixel of the Earth surface satellite imagery has been proved to give good results.

The low spatial resolution of the satellite imagery and the limited number of bands, nowadays available from operational satellites, pose an important limit in the level of confidence of hot spot identification, Furthermore, there details of the marine litter journey that depends on physical effects poorly represented in most of the lagrangian numerical models that could be applied to the problem.

Anyway the experience presented in this paper stimulates improvements of the above described tools and in the use of the presented materials. Those improvements, which are going to be applied in the frame of the INTERREG IT-HR MARLESS project and beyond are promising.

Acknowledgments

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Measurement Techniques, for giving us the opportunity to share the results of our research during the Symposium.

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THE ENVIRONMENTAL FUNCTION ANALYSIS: A PROMISING TOOL TO EVALUATE THE COASTAL ZONE CONSERVATION POTENTIAL

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Abstract – In recent years, we have become aware of the concept that the complex dynamics that characterize coastal zone systems impose a close balance with the anthropogenic environment. Particularly, human activities and environmental resource exploitation are often responsible of changing the vocation of a coastal area. Moreover, recent studies demonstrated that coastal zones have a capacity to provide ecosystem goods and services; this capacity can be heavily modified by uncontrolled human activities. In the framework of Integrated Coastal Zone Management (ICZM), a multidisciplinary and issue-oriented system analysis can be helpful to understand the ecological and socio-economic system functioning, while a complete assessment of the environmental quality of the coastal area can be performed by means of Environmental Function Analysis (EFA) employing physical and biogeochemical indicators coupled with socioeconomic indicators.
This study reports and compares the application and usefulness of the EFA tool to discover the potential for conservation of two very different coastal areas located along the Campania Region (Southern Italy).
The first EFA site is located in the Volturno River Coastal Zone while the second EFA study site is located at the western end of the Sorrento Peninsula in the Bay of Naples.
Results demonstrated that EFA permits to effectively synthetize the information on coastal system functioning and on their potential for conservation or development.

Introduction

The Environmental Function Analysis (EFA) tool has been widely used to enhance coastal management plans [1, 6, 7, 9, 17, 19, 20, 21] and to assess land use conflicts in planning [11]. The EFA methodology is based on robust indicators to synthesize information on the environmental quality in coastal areas [8]. In this framework, a system of indicators and indices can be used to determine the quality of a coastal system and its potential for development by using a specific scoring system as described in [9]. In essence, the procedure describes the mixed and complex CZ system by following a Cartesian principle and dividing the coastal region into ecological and anthropic components identified by some specific features described by selected indicators [9].

This operational framework is developed on a matrix based on the principles of Ecosystem-Based Management (EBM) to describe the relationship between environmental

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functions and environmental characteristics [11]. Subsequently, EFA suitability was also demonstrated to assess the quality of coastal areas of Malta [20].

This study aims to assess the benefits of EFA methodology application comparing the potential for conservation and the potential for use of the Volturno River Coastal zone (central Tyrrhenian Sea – Italy) and of the Sorrento Peninsula Coastal Zone in the Bay of Naples.

These study areas were chosen because they represent two challenging decision-making contexts both characterized by protected areas coexisting with environmental disturbance and possible land-use conflicts [2, 3, 12, 14, 16]. The EFA application aimed to investigate the conservation potential and/or the potential for use detecting the possible anthropic influence and conflicts for use comparing environmental features and human features indicators.

Materials and Methods

The EFA's theoretical framework can be summarized into four main steps [2] as follows:

1) Definition of study area boundaries and selection of homogeneous land-use units within these boundaries. This is the first EFA fundamental step that allows depicting the study area merging geological, environmental and human features. This first step can be carried out by desktop study and literature data analysis.
2) Identification of characteristic parameters (indicators) for the study area, to describe and distinguish between the environmental and socio-economic components of that environment. In this study, based on the method of [9] later modified by [20], the application of the EFA methodology was tested by defining appropriate environmental and socio-economic components and selecting a set of relevant indicators.
3) Allocation of values to the parameters established in the previous step. Indicators are evaluated by means of the scoring process with a tripartite system. Single values are expressed qualitatively using a scale ranging from 1 (worst) to 3 (best), and are subsequently normalized and combined into synthetic indexes that help to obtain an integrated environmental and social value assessment [19,20].
4) Comparison of environmental (conservation) value with human (use/development potential) value to determine the potential management conflict. This is the last step of the EFA methodology, therefore the normalized values for each group of indicators are plotted into a conservation/use development matrix using a simple Cartesian space ranging between 0 and 1; the x coordinate expresses the development potential of the area, while the y axis returns the conservation value.

Results

1) Definition of study areas boundaries:

The Volturno River Coastal Zone (VRCZ) area extends onshore and offshore for 50 km^2 comprising the Volturno River mouth (Fig. 1-A). The boundaries of this unit were traced mainly considering the geological setting, coastal dynamic and human settlements. This coastal system is geographically confined landward by the Volturno plain, formed during the Quaternary, characterized by a flat topography (0-25 m a.s.l.) and constituted by alluvial deposits and anthropogenic filling deposits [2].

The Punta Campanella Coastal Zone (PCCZ) study area extends onshore and offshore for 7,5 km^2 including the Crapolla fjord (Fig. 1-B). The boundaries of this unit were traced following the geological features settings. Since, the Sorrento Peninsula is located along the west coast of southern Italy, it consists of a WNW trending calcareous ridge elongated between the Naples Bay and Salerno Bay [4,5,8,12].

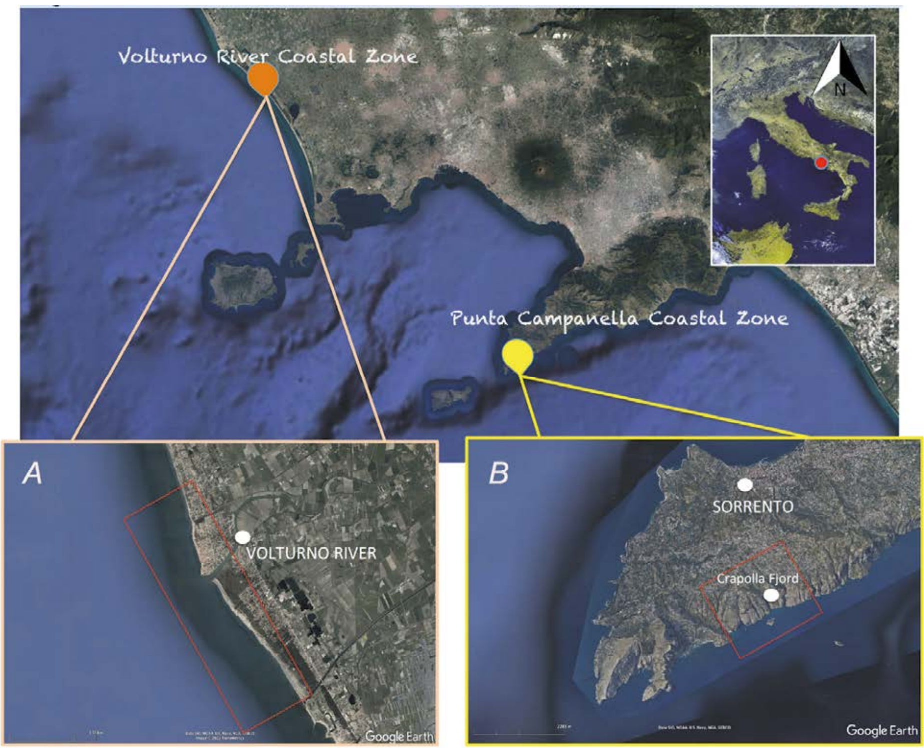

Figure 1 – Location and boundaries of the two EFA Study areas: A) "Volturno River Coastal Zone" (VRCZ) and B) "Punta Campanella Coastal Zone" PCCZ.

2) Identification of characteristic parameters (indicators):

The list of indicators used in this study area reported in Tables 1-2. Environmental features and human features have been explored using National Geodatabases and literature studies. The thematic maps have been visualized from the ISPRA data Portal (*Sistema Informativo di Carta della Natura*) and from the Regional Geoportal of the Campania Region (https://sit2.regione.campania.it/node last connection 01/06/2022).

Table 1 – List of indicators describing environmental features more details on indicators range values can be found in [1,19].

Environmental Features	Characteristic	Indicators
Coastal waters	Quality	Aesthetic Condition Microbiological Pollution
Fresh waters	Quantity	Supply (runoff)
	Quality	Ecological and Chemical pollution
Marine biota	Diversity	Biological diversity (Benthic foraminifera)
		Species of special interest
Terrestrial biota	Quality	Ecological Value
	Diversity	Species of special interest
Geological and topographic features	Quality	Size of bathing area
	Diversity	Lithological properties
Hazards	Coastal damage	Coastal erosion
		Coastline instability
		Subsidence
Resources	Landscape (Renewable)	Uniqueness

Table 2 – List of indicators describing human features.

Human Features	Characteristic	Indicators
Social values	Potential for use	Land use
		Population density (human pressure)
		Land consumption
		Cultural historic interest
		Accessibility
	Human well-being	Perception of the environmental quality
		Public recreation facilities

3) Allocation of values to indicators:

The allocation of values to indicators was based on thematic maps (showed in Figures 2, 3) and on literature data analysis for both the study areas the same indicators were evaluated. The indicators list for environmental features and human features is reported in Table 1-2, while the value ranges definition can be found in [1,20]. For the VRCZ the dataset is comprised between the years 2010-2013 (for more details see [16]), while for the PCCZ the full dataset is comprised between 2006-2012 references are reported in this study.

For the VRCZ (Fig. 2-A) a detailed classification of the environments through a geological-geomorphologic map is reported by [2,3]. Within the left bank of the Volturno delta there are several Natural Reserves such as the Site of Community Importance "Riserva Variconi", a good example of a morphological pristine site (EU Directive, Important Bird Area, Regional Nature Reserve - Ramsar site no. 1664 - SIC-IT8010028) (Fig. 2 B-C). The overall environmental status of the VRCZ as reported in [24] is intensively affected by human activities (Fig. 2-D), with a critical influence of intensive agricultural practices. Furthermore, due to the absence of a wastewater treatment plan, the bathing waters are frequently contaminated by organic pollution, and generally the marine coastal ecosystem can be classified between trophic and hypertrophic level, being strongly influenced by the river plume [14, 24].

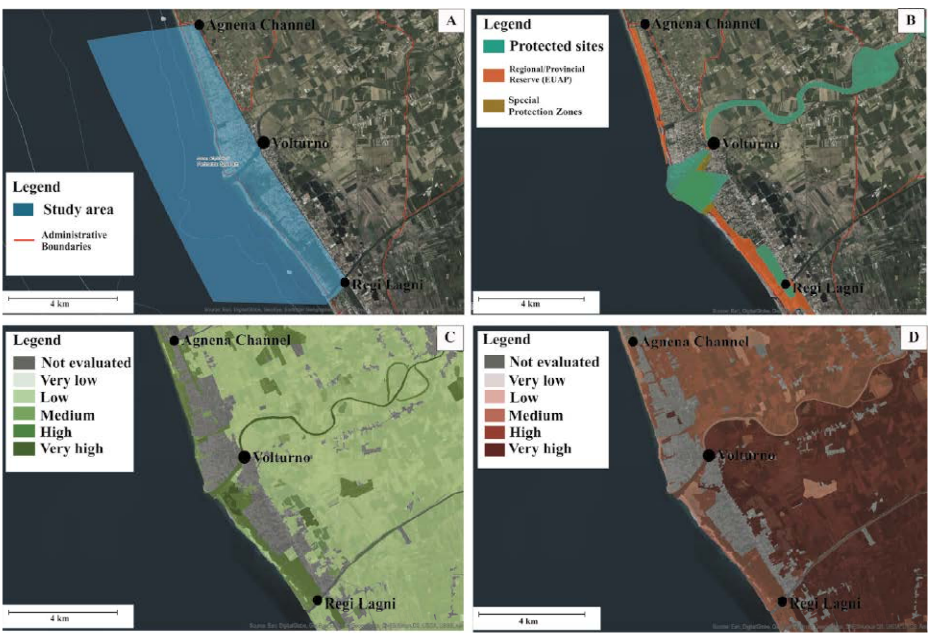

Figure 2 – Thematic maps for Volturno River Coastal Zone study site: A) Study area boundaries and bathymetry, B) Protected areas, C) Ecological value and D) Human Pressure (thematic data source Carta della Natura – ISPRA, modified from [16]).

In the PCCZ (Fig. 3-A) the coast is characterized by a steep fault scarp eroded and cut by gullies and ravines, moreover it is classified with hydrogeological constraints and high costal sensitivity [13]. Offshore the sea floor is characterized by coarse grained deposits close to the coast, passing to sandy clay and bioclastic sand moving offshore [4,5]. The continental shelf is narrow, steep and it is practically absent near Punta Campanella and Capo Sottile [4,12]. Since the coastal strip includes the Marine Protected Area of Punta Campanella (Fig. 3 B-C) the natural value of the area is classified as high [15, 22, 23]. Moreover, there is an ancient multi-level overlap of crops such as horticultural products and herbaceous crops, legumes, vineyards, fruit trees (Fig. 3-C). The Fjord of Crapolla, a narrow and deep crack in the rock, is characterized by archaeological findings [18]. It is categorized as cultural heritage site in the Sorrento Coast implying that this area is classified as high cultural value (Fig. 3-D). The vulnerability of shallow aquifer is high [10], while coastal water quality has been affected in the past by the presence of the Torca water treatment plan no longer operational.

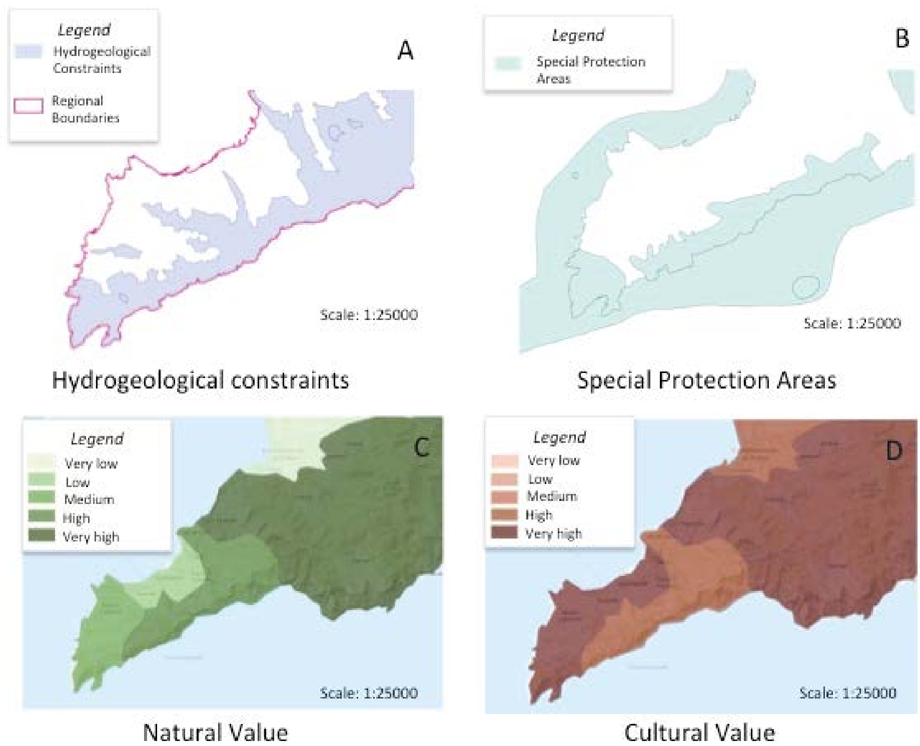

Figure 3 – Thematic maps for Punta Campanella study area: A) Hydrogeological constraints, B) Special Protection Areas, C) Natural Value, D) Cultural Value (thematic data sources: Geoportale Regione Campania and Carta della Natura ISPRA scale 1:25000).

4) Comparison of environmental (conservation) value with human (use/development potential)

Normalized values obtained for each group of EFA indicators are reported in figure 4. The histogram chart shows a comparison of values obtained for the VRCZ and for the PCCZ.

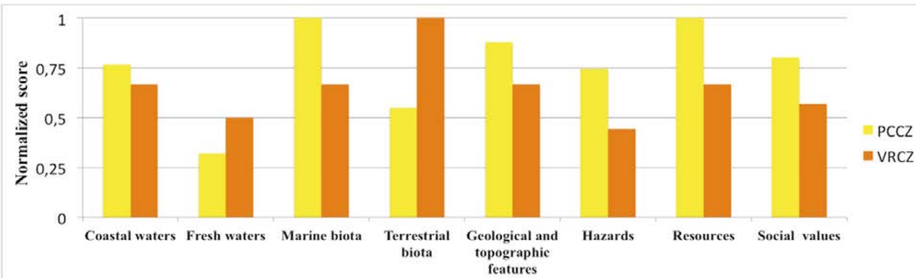

Figure 4 – Normalized values for Environmental and Human features (indicators are reported in Table 1) for Punta Campanella Coastal Zone (PCCZ) and Volturno River Coastal Zone (VRCZ).

The classification of potential for conservation versus the potential for use for the two study areas is reported in the EFA matrix showed in figure 5.

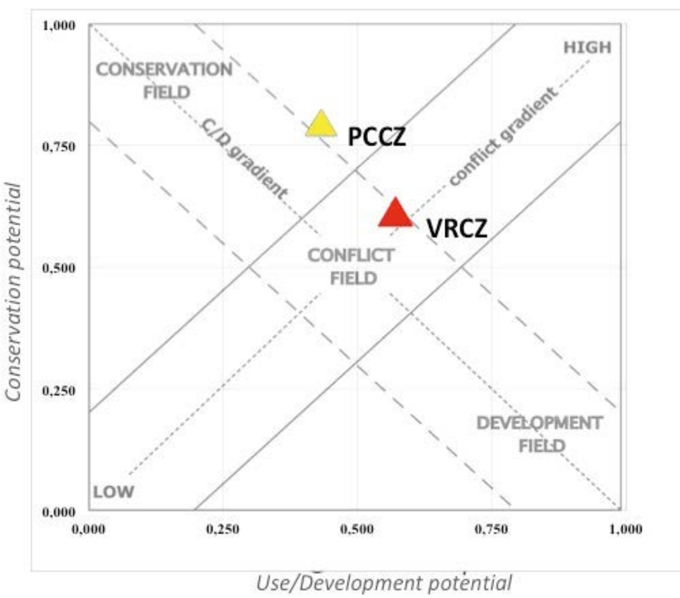

Figure 5 – Example of EFA matrix including the classification of the two study areas.

Discussion

The two EFA areas presented in this study are quite different for extension and for their geomorphological features. The first one is a river delta costal zone human impacted, while the second is a rocky coast characterized by cliffs and inaccessible areas where human settlements are scarce. Their similarity can be found in the presence of special protection areas on-land and also at sea in the case of the PCCZ. Comparing the normalized values of EFA indicators (Fig. 4), the marine biota is higher in the PCCZ than in the VRCZ, while for the terrestrial biota the situation is reversed. Coastal waters quality is comparable while resources and social values are higher for the PCCZ. The EFA matrix results (Fig. 5) showed that the EFA is a suitable methodology in order to detect conflicts for use recognizing the conservation potential versus the development potential. As a matter of fact, VRCZ resulted in a full conflict field despite the presence of a protected area testifying that dedicated management strategies should be improved. Conversely, the PCCZ was classified on the boundary of the conservation field testifying the prevalence of the conservation potential of the area respect to the development potential.

Conclusion

The two EFA results comparison presented in this study demonstrated the feasibility of EFA methodology in order to depict the potential for conservation and/or for development of two morphologically different coastal zones. This evaluation can be carried on easily including both inland and offshore areas leading to understand the complex relationships that characterize the coast zone functioning. The EFA can be easily applied in a wide range of case studies, a limit remains due to the availability of territorial data and open literature datasets.

Comprehensively, the EFA methodology permitted to detect if the management strategies implemented for conservation are effective or some corrective effort should be applied to shift towards the conservation field or to prevent conflicts.

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OLD LANDMARKS AND NEW FUNCTIONS. COASTAL ARCHITECTURES REDESIGN THE GEOGRAPHY OF THE COASTAL BELTS*

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Abstract – The geographical space should be conceived as a progressive and conscious construction, resulting from the interaction between individual and collective actions. If from the second post-war period and for the following twenty years the coastal space has maintained even a minimal break with the anthropized spaces, starting from the 1970s the rapid industrial development has increasingly occupied the coasts. These changes along the costal space can be understood referring to the 'maritime-coastal region', which are places between the land and the sea, profoundly different by the integration of resources. During the following years, the growing awareness of the economic importance of the sea and its immediate hinterland has generated further changes in the evaluation of the role of maritime spaces in the processes of territorial organization.
The chapter focuses its attention on one of the most symbolic maritime cultural assets: lighthouses. They are distributed along the European coastlines, responding to the same historical function, and evoking a common past.
A very interesting case is Galicia, a *finisterre* Spanish region. Its coast is rich in lighthouses and other architectural structures, which for a long time have been at the service of the navy, redefined with new economic and social functions. As a result, lighthouses and other cultural resources are considered as an expression of that system of signs that binds the territorial components. From a methodological point of view, the proposal uses a qualitative approach, with the aim to point out how lighthouses have become scenarios of new functions thus satisfying the needs of tourists with a high attractive potential. In reconstructing this evolutionary process, the proposal will go through the analysis of the new socio-cultural and economic dynamics which, always guided by an inner Mediterranean identity, are transforming the coasts and landscapes.

Introduction

Geographical space is a progressive and conscious construction defined by the relationships between geographical elements. In particular, the coastal space is a dynamic ecosystem in which natural and anthropogenic processes add up and interact, modifying their geomorphological, physical and biological characteristics.

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* While the paper is the result of a joint work, sections 1 is attributed to Donatella Privitera, sections 2 to Antonietta Ivona, sections 3 to Lucrezia Lopez. Conclusions are commons.

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Antonietta Ivona, Lucrezia Lopez, Donatella Privitera, *Old landmarks and new functions. Coastal architectures redesign the geography of the coastal belts,* pp. 244-252 © 2022 Author(s), CC BY-NC-SA 4.0, 10.36253/979-12-215-0030-1.22

Historically, coastal areas have been rich in unique seascapes, tangible artifacts, and intangible cultural heritage. All of them have been constantly threatened by the changing conditions of the sea and coast, both geophysical and socially constructed. They have also contributed to cultural transmission between people, goods and ideas. Today, cultural heritage plays a central role in the narratives of coastal regions and in their reorganization as places and/or containers of historical, cultural, social and economic safeguards.

The "maritime-coastal region" defined by Vallega [1] is useful for understanding changes in the coastal space; he defines it as a special region arranged on two environments, land and sea, which are profoundly different, but which establish integrated forms of employment and integration of resources. Over the years, the growing awareness of the economic importance of the sea and its immediate hinterland has generated continuous changes in the evaluation of the role of maritime spaces and in the processes of territorial organization. The "coastal belts" is a polyvalent concept, which assumes proportions commensurate with the phenomena, parameters and functions under study. More than two joint plans, the coastal areas and the coastal sea are linked by a network of relationships that thickens and becomes complex as human organization becomes more relational.

"Coastal and marine regions are gateways connecting land and sea, with unique landscapes and seascapes and related tangible and intangible cultural heritage, such as underwater and coastal antiquities, coastal archaeological sites, traditional material cultures such as fishing, maritime communities, and traditional gear and instruments. […] We define coastal and maritime cultural heritage as a set of tangibles and intangibles linked to human activities and interactions taking place within coastal and marine (geographical or cultural) areas in the past, the present, and imagined futures" [2] (p. 2).

Cultural heritage is therefore that part of the past that we select in the present for current purposes whether they are economic, cultural, political, or social. Human interaction with the sea in coastal areas has shaped the natural landscape; it has played a crucial role in forging the maritime and coastal cultural heritage. Over time, it has favored the promotion of a sense of identity and place attachment [3], [4], [5]. Currently, coastal areas still play a relevant role thanks to their variety of environmental, historical and cultural landscapes, but also for their character of transition and interface between the hinterland, the coast, and the sea. Perhaps, as Zunica [6] points out, it must be admitted that the thickness of the coastal strips is a polyvalent concept, which assumes proportions commensurate with different phenomena, parameters and functions. Historically, coastal regions have played the role of cultural transmission areas, where peoples, goods and ideas from abroad interact with the local and traditional ones. Besides the uniqueness of their landscapes, coastal areas are territories often associated only with leisure activities; consequently, they are commercialized and consumed. By the way, they also have a potential to assume a plurality of meanings and to become attractive areas of social interaction and collective interest. Nowadays, cultural heritage plays a central role in the narratives of coastal regions and in their reorganization as places and/or containers of historical, cultural, social and economic protection. In this sense, the definition of Maritime Cultural Heritage, refers to that cultural asset that witnesses the relationship between people and sea. This definition refers to all the cultural materials (in the water and on the nearby land) and intangible assets that are an expression of a water-based culture (saltwater and fresh water) that has anthropological, archaeological, historical, architectural, artistic, scientific or literary values or interests, among others [7]. Indeed, communities have become aware of the importance of these maritime heritage, not only to narrate their territorial identity, but also to plan a locally based sustainable development. According to Gillis [8], under the gaze of the tourist, coasts are considered places where human life was simple and picturesque.

The chapter advances the authors' understanding of how llighthouses could become resources for sustainable development on the social, economic, touristic and cultural levels. The study would help local governments with examples to enhance the historical resources to create a new identity that led to a sustainable development of a landscape, and to create networks with other comparable museums all over Europe to better exploit the touristic and cultural potential. The chapter suggests a systematic classification of lighthouse experiences with not traditional function and suggested some research propositions for further research. Public decision makers, maritime authorities and tourism operators may acknowledge the theoretical and practical contributions provided by this article and develop innovative escape experiences. The new functions of lighthouse such as tourism is an innovative and creative way to promote the sustainable development of waterfronts of port cities, giving more "energy" to these coastal and often rural areas [9].

Old landmarks and new functions - The symbolism of lighthouses

The architectural emergencies (lighthouses, towers, forts) that have presided over the coastal areas have undergone a continuous change in their value in use. From ancient symbols of the constant movement of people and goods that needed those garrisons to reach ports safely, today, after years of neglect, they are once again perceived as indispensable landing places. In short, tangible representations of man's eternal need to move from one place to another and, arriving there, mark the space with identity "objects".

Among the most evident coastal territorial signs are the lighthouses, which for a long time were the place of contact between the sea and the land, a connective element between two different but inextricably interconnected systems. The custom of accessing bonfires on the top of the hills in order to guide nocturnal navigation goes back to ancient times, as evidenced by the writings of travelers of the past and only in a subsequent phase did they begin to build towers on whose top fires were lit. The lighthouse of Alexandria in Egypt, built by Sostrato di Cnido (III century BC), considered one of the Seven Wonders of the world for its magnificence, became the prototype to be imitated. After all, the name of the island Φάρος, located at the mouth of the port where the building stood, ended up designating this type of artifact in many Romance languages. The resumption of commercial shipping during the Middle Ages represented a further incentive for the construction of new night markers. The Genoa Lantern built in 1128 is still today the tallest construction of this type in the Mediterranean; this medieval artifact represents better than others the power of the city at that time, so much so as to identify the city itself from an iconographic point of view.

The technical evolution of the building (always with a central plan), the technological evolution of fuel to light the fire and finally that of the use of lenses in order to amplify the light signal, have marked the historical evolution of this type of building. In a first phase, its construction spread to the Mediterranean area and then passed to northern Europe and the rest of the world, in relation to the increase in the importance of commercial traffic in those lands. Currently, with the appearance of satellite navigation for about fifty years, no more new lighthouses have been built; in many cases, the surviving ones have lost their maritime signaling role, so today they are solitary witnesses of the long past. It is therefore necessary to ask ourselves how to proceed with their conservation compatible with their structure, in the same way as any other testimony of the past.

Tourist use is certainly the most suitable one and in this sense it is possible to distinguish a ”tourism of lighthouses” where the building has a museum function that can be a documentation of the historical or environmental characteristics of the surrounding area, and a ”tourism in the lighthouses“ when the structure welcomes the receptive functions [10] or to inspire the design of dark tourism experiences because lighthouses do not always evoke positive feelings [9] (p. 63).

The conservation and re-use of cultural resources for tourism purposes, such as lighthouses, cannot take place in the same way everywhere. “While there is a logical set of steps to take, changes may need to be made to suit the conditions, needs, purposes and objectives of the place. These steps, or phases, are not mutually exclusive, as there is the possibility of some degree of overlap” [11] (p. 18). Consequently, the general success of the reuse of the lighthouses will depend on the contextualization of each of the initiatives and on the overall vision of the implementing bodies.

The main purpose of each conversion process must therefore be the recovery of the buildings from degradation to guarantee them a new use, activate the territorial economies and return it to the community, creating a solid opportunity for local development and a social well-being of the resident community.

In recent years, in the world and in Europe in particular, those lighthouses that have lost their original function have been objects of various initiatives aimed at promoting their architectural recovery and reuse for tourist and cultural purposes. In many cases, their light continues signaling activity and, even in this eventuality, the pertinent spaces (warehouses, guardian's house, etc.) could still host new uses.

For example, the Italian legislation on cultural heritage has introduced, for some years now, the concept of enhancement and use of cultural heritage by entrusting cultural assistance and hospitality services for the public to third parties. In this direction, in 2015 and in the other subsequent editions, the national project “Valore Paese” of the State Property Agency was launched. Its main aim was to promote the enhancement of the Italian public real estate assets through the cooperation between the tourism, art and culture, economic development and territorial cohesion. In this sense, the recovery of public assets owned by the State and local authorities has the possibility of being considered no longer only in terms of cost for the community, but also as a significant lever for territorial and social development, in a public-private partnership [12].

From the start of the project, new synergies have been created for the effective implementation of the project; for example, private entrepreneurs who request and obtain the concession for the use of lighthouses and other coastal structures and who will promote and use them will have to cooperate profitably with public administrations. New ways of entrusting cultural, hospitality and organizational assistance services were then prepared, also related to the establishment of mixed companies. The enhancement of lighthouses concerns the economic importance of the cultural heritage and the impacts it determines with its activities and services.

The Italian conversion of lighthouses and coastal structures has its respective in Spain, with the “Faros de España”. This project was presented in 2013 by the Ports of State and the Port Authorities, with the aim of enhancing the spaces of inactive lighthouses for the service. Its main aim was enhancing the development of activities other than maritime signaling, including hotel-type activities, as well as hostels or accommodation. According to this project, lighthouses can foster the development of cultural or similar activities of social interest, to allow them to be open to society and ensure their conservation in a sustainable and environmentally friendly way.

The "Faros de España" initiative, like the Italian one, focuses in a distinct way on promoting hotel-like development in lighthouses, but also includes projects in sectors other than tourism. Thus, this strategy guarantees and promotes responsible, sustainable and environmentally friendly conservation, sustaining the development of activities.

Another European example aimed at the recovery of the coastal building heritage is "Revive". It was created in 2016 by the Portuguese Government to recover and enhance historical heritage through tourism. The government recognized those artifacts as a strategic national asset, present throughout the national territory, and the importance of ensuring their preservation, valuation and disclosure as well as a wide access to their enjoyment. “Revive program” opens up properties to private investment to develop them as tourist attractions by concessioning through public tendering. State heritage properties are a very important part of the historical, cultural and social identity of a country, and make a rich and distinctive contribution to the attractiveness of a region and the development of tourism. (https://revive.turismodeportugal).

Lighthouses of Spain - Examples of Lighthouses as tourism product

Spain has 187 lighthouses; 55 of them are inhabited. Although, the signal technicians, former lighthouse keepers are not dedicated exclusively to the maintenance of their facilities, but rather they provide help to the port authorities. Their function can be considered in at least two respects. On the one hand, lighthouses are maritime signals to maintain their typically nautical value as an overall safety system for ships. On the other hand, lighthouses are territorial signs that require the conservation of their historical and technical heritage, as well as the development of complementary uses that revitalize them through the development of uses not related to maritime signaling.

These are the assumptions that favored the launch of the aforementioned state initiative “Faros de España” of the Ministry of Public Works and implemented through the public agency Puertos del Estado and the Port Authorities. It aims to diversifying the activities other than maritime signaling (including hotel-type businesses and rental homes and accommodation), as this could encourage the development of cultural or similar activities in the social interest and make lighthouses accessible to society. Moreover, it is important to ensure their conservation in a sustainable and ecological way. Thus, while Lighthouses will continue providing the marine aid to navigation (most of them have been doing for over 150 years), an effort is made to reuse the old lighthouse keepers' quarters with a similar residential and touristic functions.

The lighthouse will continue providing its service and these actions will be carried out, as is already being done in some cases, in the lighthouse’s ancillary spaces. An effort is being made to ensure lighthouses are more than just lighthouses by turning them into infrastructures that collaborate in improving our country’s tourism fabric, enhancing this industry’s competitiveness by attracting top-quality tourism.

Lighthouses and their public domain are assigned to the different Port Authorities, which oversee processing the applications to perform activities other than their marine signaling activities at lighthouses.

The activity will always be performed under an administrative concession for several years in accordance with the prevailing legal framework and the business plan. Apart from adapting the spaces to the new activity, the developer will generally have to carry out any refurbishment or consolidation work on said facilities, starting off from their current state of conservation. The public concession will always be granted by the Port Authority to which the lighthouse in question is assigned.

To date, the project promoted by Puertos del Estado - which now depends on the Ministry of Transport, Mobility and the Urban Agenda - is still in force, although for the moment even with little success. There are currently only three operating hotels in spanish lighthouses: Isla Pancha in Ribadeo, Lugo; Punta Cumplida, on the Canary Island of La Palma; and Lariño, A Coruña, en plena Costa da Morte; while the lighthouse the of Cabo Silleiro (Vigo) is currently in the planning stage for its transformation into a hotel [13]. Most of them are in inaccessible places, which is why those who know them best, the lighthouse keepers who have been taking care of their maintenance for decades, propose a more cultural and social use. An example of this is the Finisterre Lighthouse in Galicia which, in addition to its signaling function, it houses a cultural center. (Figure 1).

Figure 1 – The Finisterre Lighthouse - Galicia, Spain.
(Source: Ivona, Lopez, Privitera, 2022).

The Lighthouse has relevant historical and legendary connotations. constitutes a relevant signaling point in navigation along the Atlantic coasts. In fact, the most western lighthouse in Spain is the nearby Faro de Cabo de Touriñán. The original project consists of a main building (housing and warehouse), on one level, and ground floor rectangular for the service of three keepers. The tower elevation is of 17 m above the level of the site while the lamp rises

140.50 m above the level middle of the sea. Over the years, the residential building has risen and warehouse on two levels. It has an outstanding value for its historical, architectural interest (typology representative composition), technology, location and future viability. Can be easily visitable and integrated into a thematic network on the Lighthouses of Spain.

The Faro de Isla Pancha in Ribadeo, also in Galicia, is the first Spanish lighthouse transformed into a small hotel in 2017; it has 2 apartments and 8 beds. Since 1984 it was closed to the public for safety reasons (Figure 2). It was of extreme importance for the local economy, in addition to its role as conventional signage. It is a special situation because the original construction, close to a new Lighthouse consisting of a tower erected in 1983. The initial Lighthouse has therefore lost its function. The initial project consists of a main building (housing and warehouse), in a single height and square plan with a side of 11.30 m, planned for the service of two keepers, and a tower elevation of 8.80 m above the site level. The lamp stands 24 m above the level middle of the sea It has an outstanding value for its historical interest (Plan of 1847), architectural (representative composition typology), technological and for its future viability. It can be easily visited and be integrated into a thematic network on the Lighthouses of Spain [14].

Figure 2 – The Isla Pancha Lighthouse - Galicia, Spain.
(Source: Ivona, Lopez, Privitera, 2022).

Conclusions

The interest in the reuse of lighthouses as tourism accommodation is growing everywhere in Europe. As far as Spain is concerned, the great interest was not followed by an equal transformation of the projects in concrete cases. While in Italy the lighthouses transformed from maritime signals into structures with other uses (mainly hotels), in Spain, three lighthouses are currently operating for hotel use, plus another one under renovation. Probably the causes are to be found in the location of the 187 Spanish lighthouses, in many cases inaccessible or simply extremely far from other tourist attractions.

Lighthouses were restored and turned into a place of culture, tourism, sometimes research and higher education. But their main attractive role is directed to visitors, generating both domestic and international tourist flows and making a heritage a real resource for the area. Such an ongoing trend is evident, thus confirming the need to reposition these ancient artifacts, symbols of human movement and safety precautions, as tools to activate a model of sustainable development. In many cases, they could become the unique and unrepeatable element of the tourist offer precisely because of their positioning in exceptional landscape-backgrounds. In conclusion, the overall maritime and coastal cultural heritage is an important part of our cultural resources. Neglecting cultural resources leads to the loss of the identity associated with them; loss of tourist, recreational and educational opportunities; and, finally, loss of opportunities for social and cultural capital. Literature and practice show that only for a few years there has been an acknowledgment of the importance of coastal cultural heritage as an economic and social resource. In short, finally, the coastal garrisons are also or again transforming themselves into useful garrisons for the overall well-being of the local population if properly redesigned.

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WATER, HERITAGE, CITY: URBANIZED DELTAS ON THE LINE BETWEEN NATURE AND CULTURE

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Abstract – Deltas are unique dynamic environments, extremely rich in natural resources and cultural heritage, but also vulnerable to extreme events and environmental degradation. They are areas of complex transition between land and water, where the water lines take many different shapes: coasts and waterfronts, rivers, irrigation or drainage canals, and more. From an overview of the main issues identified for each type of water line in the context of spatial planning and design, a plurality of values, demands, and materials emerges, that flow into the project in an often-conflictual way. A recurring conflict is that between anthropocentric and ecocentric attitudes towards nature, which could be overcome through the introduction of an integrated and nonconflictual "environmental" approach. A case study from the Netherlands illustrates a paradigm shift in this sense, within the sectors of water management and heritage preservation. It also provides the basis to discuss the possible active roles, role heritage can play in the search for a new synergy between natural and human actions.

Introduction

Deltas are unique dynamic environments with respect to both natural and human activities. Since ancient times, they have attracted people and settlements because of the strategic position offered by river mouths and the abundance of natural resources. The formative power of the deltas has in fact generated the richest and most diverse ecosystems in these areas, while making them subject to rapid morphological variations due to the particular river, sea and wind dynamics. Consequently, while on one side a dense stratification of cultures has left a vast material and immaterial heritage, on the other side, as the process continues, an increased urbanization growth – with more than half of the world population already driven to these areas - threatens both ecosystems and heritage, as well as human activities and settlements. Dynamism here also means vulnerability, actually. Soil exploitation for urban land uses has dramatically reduced the ecosystems' ability to absorb the impacts of extreme events, and in the case of deltas has also undermined their formative power. Growing consciousness of issues such as rising sea level, subsidence, saltwater intrusion, extreme events, habitat loss, has been fostering new ideas to rethink the relationship between urbanization and the deltaic environment [22].

The first part of this contribution aims to show the complex conflictuality that emerges when urbanized water lines are addressed through planning and design, providing an overview of some key themes in urban and spatial regeneration theory and practice, linking them to three types of transition places that often coexist in delta areas – coast and waterfront, river, irrigated fields. In the second part, different attitudes to nature in the context

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of spatial planning and transformation will be associated to two opposed visions – anthropocentric and ecocentric discourses – in order to introduce a third possibility that may offer an integrated and nonconflictual approach. A case study from the Netherlands has been selected to illustrate a paradigm shift in this sense, aiming to also reconcile the Nature/Culture divide. In the last part, other insights from different contexts will be discussed as to the role heritage can play in such search for a new synergy between natural and human actions.

A complex transition: coasts and waterfronts

In terms of urban form, the interface between land and water assumes multiple shapes, hard to trace back to the idea of a single uniform line or waterfront. In delta regions, one or more river branches meet the sea, the ocean, a large inlet or a lagoon, with vast plain areas formed by the alluvial sediments. Among these, lowlands are often drained with huge infrastructural works, so that a network of canals for drainage and irrigation is added to this system of water lines. A variety of physical – spatial, urban, environmental – and cultural issues, widely connected with each other, meet on such borders. Some of these issues, that appear to be key themes in urban and spatial regeneration theory and practice, can be linked to three types of transition places – coast and waterfront, river, irrigated fields.

The abandonment of large areas previously accommodating ports or industries gave impulse to the first waterfront redevelopments in North America and Europe, starting with Baltimore in the Eighties. The rescue of these areas was primarily a matter of returning to the city parts that had long been landlocked, so that public space and its relation to water became a key theme [12]. As ports in Italy were never massively dismissed, unlike the international context, interventions mostly regarded the integration between port and city, city and landscape [26].

Culture and leisure were central to the first American experiments, which became models for overseas requalifications onwards, and are still present in today's practices. In fact, the circumstances leading to waterfront renovation processes is often a grand cultural o sports event, as in the case of the 1992 Olympic games in Barcelona or the 1998 Expo in Lisbon. The design, then, addresses the desire for an attractive image of the city. The waterfront becomes the façade of the global city, the scene of competition, creativity, and innovation [6]. Though literature tends to be quite celebrative about such renovations, some authors underline the risks of homologation and spectacularization within a global-oriented approach [13][14].

On the other hand, turning to the sea – and the people, product and information fluxes - more than the mainland is considered a distinctive feature of the maritime cities, which craft their identity in the combination of maritime and urban cultures. Some authors stress the importance of shaping the city from the point of view of the sea, too often forgotten nowadays due to contemporary transport habits [7]. Maritime identity has become key in the cases of Lisbon and Naples, where the most recent UNESCO guidelines for historic cities' management, the *Historic Urban Landscape Approach*, were adopted, redefining the concept of urban heritage and its relation to post-industrial areas and waterfronts [8].

The guidelines also aim to foster an integration different issues with sustainability. Urban coasts actually gather a mixture of often conflicting values, ranging from culture and identity to economy and production. Reconciling hard and soft values, hard and soft infrastructures, is one of the main challenges for maritime urban sustainability [13]. Another important challenge is that of climate-proofing the cities, which is increasingly present in urban policies but is still not well integrated into spatial planning, with some exceptions from Northern Europe and USA were sea level rise and extreme events are being addressed. It must be noticed, however, that the focus on resilience is often dealt with as a marketing operation, one more variation on the theme of competitivity [27].

On a broader scale, embracing territory and landscape, soil sealing, and ecosystem loss is one of the consequences of the building aggression of seaside destinations and coasts in general, where speculation and abusiveness have created vast areas of dispersed and de-structured urban land [12]. A relatively new strategy interprets the coastal line as a green/blue infrastructure, a concept which has been increasingly explored for rivers but still seems marginal in relation to coasts.

Rivers

Rivers have been considered biological corridors par excellence since the first studies on ecological networks, because of their inescapable continuity in contrast to the increasing ecological fragmentation. With the concept of green infrastructures, emphasis shifted from species and ecosystem preservation to the benefits they bestow. Rivers, with their linear shape, gain new meanings, as soft mobility infrastructures, green equipment for the urban space, cultural infrastructures, social relation spaces [12].

The river is interpreted on one side as a resource, on the other as a risk, with reference to unpredictable flooding or water pollution from industrial and civil plants [9]. The dualism leads to a conflict between what can be named a hydraulic landscape, focused on water dynamics control, and a hydric landscape, focused on the aesthetic dimension of water. At the same time, this same dualism explains the fluctuating relationship between the built environment and the riverside, which alternates osmotic and repulsive phases [2]. Despite the tendency towards a reconnection of cities and rivers, there is a persisting awareness decline, as the river is not perceived as a living and dynamic entity anymore, which points out the need for a renewed "hydraulic culture" [19].

Multiplicity of functions, complexity of hydraulic dynamics, linear extension of the rivers, etc. also raise the issue of management. If on one side large scale planning is needed, on the other an urge for a shared management and an engagement of multiple actors emerges at a local and supra-local level, within an increasingly multifunctional fluvial landscape. In this context, tools like the river contracts are growing in importance and are influencing institutional policies towards integrated and participative rather than sectorial projects. In this additional sense the river can be understood as a space or "structure of relations" [3].

Irrigated fields

Some tendencies observed for rivers and coasts are also shared with water landscapes which originally had an agricultural vocation and whose shape is determined by a widespread hydraulic infrastructure for irrigation and/or drainage.

The issue of dispersed urbanization is even more poignant in periurban and metropolitan areas grown – at least in Europe – out of the explosion of the city, which in turn was enhanced by the parallel loss of importance and viability of traditional agriculture [16]. In coastal and pre-coastal Mediterranean environments, this process has fostered abandonment, degradation, crop replacement, introduction of elements that are alien to the landscape, lack of interest from the institutions [20]. The relationship between urban and rural domains is blurred, and while the popularity of urban agriculture grows, agricultural soil is turned to urban uses. The previously rigid limits between city and farmland grow into vast indetermined border landscapes where uses mix but social and territorial dynamics are of urban or metropolitan kind [23].

On the other hand, during the last thirty/forty years, some opposing trends have emerged: a counter-exodus towards the countryside, an appreciation of landscape as a life quality driver and an instrument for spatial planning. Rural landscape is thus interpreted as part of a territorial strategy. On one side, the preservation of a functioning rural landscape is seen as a prerequisite for the achievement of environmental and economic sustainability, especially when strategies to encourage slow tourism are put into place. Historical paths, notably those along water lines, become tourist routes and green/blue infrastructures [5]. On the other side, the large urban voids generated as an externality of the urban explosion are now valued as opportunities to regenerate the surrounding urban areas and restructure the urban landscape at a territorial level. Seen from a metropolitan dimension, in fact, "rururban" space can turn into a new kind of public space if multifunctionality is implemented, as in the case of green infrastructures and agricultural parks [29]. Nutrition as a cultural issue has a key role in the idea of ecosystem multifunctionality, urban resilience, place reappropriation, and water gains new values in this sense, as a source of life. An interesting example was the rediscovery of water lines and the "water civilization" in the Lombardia region during Expo 2015 "Feeding the planet" hosted in Milan [30].

Figure 1 – Three water lines of the Tiber delta: the Ostia seafront, the Fiumicino river branch, a canal in the "rururban" area Piana del Sole.

Conflictual discourses

Given that water lines are places of conflicts between opposed values, views, cultural trends, even actors, it should be taken into consideration that any transformation or intervention implies a particular approach to the natural element, water, that can never be eliminated. Conflict here takes the shape of a dualism between ecocentric and anthropocentric attitudes towards nature. In the context of river management, Ventura et al. [31] proposed a conceptualization of the two dominant approaches, where the anthropocentric discourse interprets the river as a resource with the aim of increasing the material well-being of society, while the ecocentric discourse deals with an ideal natural state of the river, aiming to reach an ecological balance. On one side, the disciplines of water regulation treat the river as a controllable object without any context; on the other, those of fluvial ecology strive to return it to its original – though hypothetical – time and place. The uncompromising dualism, for the authors, makes it hard to solve conflict, as each identifies the other as the cause, and radicalization of its own principles as the solution. Conflict, instead, could be overcome through a third "environmental" discourse, where ecosystemic and anthropic realms form a complementary dualism.

Some of the main approaches to planning and design can be traced back to these models. Anthropocentric approaches like "sustainable management" or development consider nature as a resource to manage with caution, using the best available technology, which in turn is trusted as the solution to counter environmental degradation, especially climate change. And while "grey" solutions are still prioritized, definitions like Natural Capital or Ecosystem Services are used to mainstream sustainable management of nature [25]. Biophilic and regenerative approaches, on the other hand, consider nature as a biological need of human beings, and aim to bring it into the built environment prioritizing natural cycles and processes [18].

Finding a third way also implies striving to overcome the nature/culture divide and the dichotomies of modern times [17]. The splitting of domains and the reification of what was once a "cosmos" tied by sacred interrelations is often placed at the root of the environmental-aesthetic degradation taking place in our cities and landscapes [1]. Among those trying to shift towards a model where nature and culture are taken as one, is the landscape preservation sector. The two branches of UNESCO respectively responsible for natural and cultural heritage, IUCN and ICOMOS, are recognizing that landscape and its community are deeply tied and inseparable, and the protectionist paradigm must be overcome in favour of a synergy between conservation, management, and planning [4].

A paradigm shift in the Netherlands

From the standpoint of water management, a significant turn seems to have taken place since a few years. Following hurricane Katrina's disaster in New Orleans (2004), a discussion was initiated that has led, at least in some representative cases, to a move from an approach focused on hard infrastructures and containment to one that aims at working in synergy with nature instead of opposing it. In the USA and the Netherlands – whose experts traditionally contributed to water management knowledge dissemination – the "Dutch Dialogues" opened a debate on the efficacy and exportability of the Dutch model. The initiative was promoted by American architect D. Waggonner, P. Farmer from the American Planning Association (APA), and D. Morris from the Royal Netherlands Embassy. Later on, in the wake of the Dialogues, the APA started the "Delta Urbanism" research project [21], confirming the step taken from the old method "drain, dredge, reclaim", to a new one whose motto is "working together with water". The Rotterdam region implemented the "Room for the River" program (2005-2015) to reshape the shores, the canals, and the strategies to deal with river flooding, while New Orleans started the "Mississippi River Delta" project (Hein, 2020), based on the same principles, which also informed some years later the design of the winning project in New York's "Rebuild by Design" contest following hurricane Sandy (Pavia, 2019).

Meanwhile, another shift was occurring in the field of water heritage management and preservation. Beginning with the "Belvedere Memorandum" (1999), the material and immaterial heritage linked to the water management tradition was to be "preserved through planning". The strategy encouraged a dynamic approach, including creative reuse of existing heritage and construction of new structures based on a reinterpretation of historicised approaches [15]. Initiatives promoted from 2013 by ICOMOS Netherlands contributed to strengthening the ties between heritage and water management, and introduced heritage in climate resilience building, starting from the richness and vulnerability of delta areas. Outcomes of the first conference, "Protecting Deltas, Heritage Helps!", were synthetised in the Amsterdam Declaration [32], stating that a deep understanding of places and a conscious historic continuity with knowledge of the past are needed to live with water, and creative reuse can provide strategies for the future, as well as spatial quality and wellbeing in the present.

Human needs and nature's needs don't have to fight within flood management, since they can adjust to one each other, just like heritage preservation doesn't need to counter time, since continuity can accommodate desired and meaningful change as its prerequisite.

Figure 2 – Fort Vuren, part of the New Dutch Waterline defense system, whose restoration inaugurated the new approach to water heritage (credit: https://nederlandsglorie.nl/).

An active role for heritage

The experience and research line followed in the Netherlands, despite its openness to other contexts, remains tied to a very specific setting where the relationship to water has always been the backbone of national identity. One may wonder, then, how and to what extent heritage can contribute to reconstituting and strengthening the environmental balances within an anthropized landscape. In literature and in national policies attention is increasing towards community resilience, heritage community resilience – the virtuous circle initiated by collaborative care of heritage - and cultural resilience – the ability of a community to adapt thanks to the use, management, and maintenance of its biological and cultural resources [10].

However, beyond the positive mechanisms it activates in response to disasters, heritage plays a decisive role in the construction of the territory's everyday life, and therefore in the quest for wide-ranging long-term solutions to territorial imbalances and environmental degradation.

In the experience of the Landscape Observatory of Catalunya, the concept of heritage tends to blur with that of landscape [11]. Landscape, in turn, is conceived as an operational, integrative tool, through which physical, cultural, and spiritual issues can guide the transformation of the territory in compliance with the aspirations of inhabitants. The Observatory's method integrates natural and cultural features in the preparation of the landscape catalogues, which have the primary objective of integrating an articulated range of landscape values – aesthetic, natural, ecological, productive, of social use, historical, religious or spiritual, and symbolic - into spatial planning [24], also targeting global environmental issues from the standpoint of the social and cultural realm where they come from.

Landscape is also central as a democratic governance instrument within the approach developed by the Territorialist society in Italy. The eco-territorialist project aims at safeguarding and enhancing the human environment rather than nature *per se*, by building back the physical and cultural ties with the territory. It is the community that, in a bottom-up process, decides the rules, behaviours, cultures and techniques for dwelling and producing accordingly. Such a process is possible only if a virtuous circle is established in which the growth of "place consciousness" increases the community's identification with the "territorial heritage", which is in turn cared for, treated, and enhanced, to produce durable prosperity. Heritage, here, is meant in an even broader sense than in the Observatory's practice and is more actively involved in the process of territory-making. The concept of territorial heritage is close to that of a common good and is defined as an ensemble of elements, goods, and environmental, urban, rural, infrastructural and landscape systems which in their permanence and perception form a region's identity [19]. What matters, hence, is not only heritage as something given, but the process through which the community decides what should be valued or put into value in its own project for the future territory [28].

Figure 3 – Agroforestry mosaic in the plain below Capalbio, part of the landscape unit "Bassa Maremma e ripieni tufacei" in the landscape plan of Tuscany (photo by the author).

Conclusion

The previous lines have attempted to trace an overview on how water lines are being dealt with from the standpoint of spatial planning and what conflicts arise in the process. The conflict between Anthropos and Nature has come into focus, as well as some strategies that strive to overcome it. A key role of heritage has been identified and is currently under investigation in different contexts.

Cultures developed along water lines, especially in delta areas, have grown a heritage of techniques, of scientific and spiritual knowledge of the natural processes they had to deal with. In the XIX and XX centuries, faith in progress and in the possibility for mankind to break free from nature has too often erased what had been built and passed on from one generation to the other. Today, new opportunities can arise from the encounter of the recent urban and ecological disciplines with the reflections concerning the *longue-durée* structures the territory still preserves, considering historical processes a succession of phases, each with its own relationship between its pasts and its present time, rather than a linear path. It is hence necessary, since so many voices agree we are living in transition times – as to economy, environment, culture – to reconnect the urban and environmental evolution trajectories, while anchoring them to their material ground, the territory. Rediscovering the art of living with water means, on one side, becoming aware of possibility and risk, on the other, learning new and old strategies to coexist, to give sense and value to the environment that allows and permeates the life of the city itself.

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NATURE PROTECTION AND LOCAL DEVELOPMENT: A STUDY CONCERNING A NATURAL PARK LOCATED IN SARDINIA (ITALY)

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Abstract – As per Italian National law on natural protected areas (Law no. 394/1991), Regional natural parks can include inner land areas, rivers, lakes, and coastal areas having high natural and environmental values. Within a park, such areas define a homogeneous system based on natural characteristics and aspects of sites and on high-value views and landscapes, having also regards to cultural traditions of local communities.
Defining appropriate spatial planning tools for these areas is therefore of outmost importance. On the one hand, plans must guarantee protection and preservation of local natural values and of the ecological balance; on the other hand, plans should also promote social and economic development, by implementing planning processes aimed at valorizing the local identity. This problematic dichotomy deserves serious consideration because protected areas can border, or even include, agricultural plains, urban settlements, as well as tourism hotspots, subject to high anthropic pressures.
The eastern part of the Tepilora Regional Park, located in Sardinia (Italy), represent a relevant case study as a paragon of the question at stake.
It develops near the attractive village of Posada and includes the Rio Posada's (Posada River) environmental system, the River's estuary and the adjacent beach, an extended, flourishing and characteristic agricultural plain.
This study implements a knowledge-based planning methodology that starting from an in-depth study of the context, identifies a territorial system, consistent with the governance tools in force, characterized by sub-areas of a significant degree of internal homogeneity and, therefore, from a specific level of protection, which constitute the spatial reference for the definition of the constraints, of the permitted uses, of the intended public or private use, by virtue of the needs of protection and conservation of the resources present, in the Park.
The aim of the proposed methodology is to being effective in recognizing both expressed and unexpressed potentials of the Park spatial context, and it makes it possible to protect and enhance the Park's attitudes and identity through the definition of place-based planning strategies.

Introduction

The growing awareness about the importance of protecting the environment to ensure the ecological balance for present and future generations has led to a progressive expansion of the system of protected areas, on a national and international scale [3], which nowadays consists of heterogeneous landscapes, from those characterized by a high degree of naturalness to those most marked by anthropic action. This complexity is at the core of several

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multidisciplinary studies oriented to define integrated approaches to landscape planning and management, capable of combining nature conservation and local development needs [5,11].

According to the Italian Constitution and international agreements, Law no. 394/1991 (National law on natural protected areas) defines and classifies the protected natural areas. The Law represents the first comprehensive legislation which introduces a special protection and management regime for territories worthy of protection by virtue of their significant naturalistic and environmental values [4].

According to the VI update of the Official List of Protected Areas (2010), there are over 870 Protected Natural Areas in Italy [6]. More precisely, the terrestrial ones cover a surface of over 3 million hectares, that is about 10.5 % of the national territory [7].

The amount of recorded protected areas represents a significant result in ethical and moral point of view [2] and reveals a shared understanding of the environmental protection as a prerequisite to prevent loss of the soil resource and the ecosystem stability/balance, especially when involved in more effective green infrastructure projects [10], thus safeguarding primary values such as health, life, and biodiversity. At the same time, the date testifies an important economic and social goal as conservation policies, in the broader sense of protection and enhancement of natural and anthropic capital, actively contribute to increasing the country's levels of wealth and economic well-being [9]. In this regard, protected areas may represent an essential condition to promote endogenous model of sustainable development of the territories, also from the point of view of tourism, in line with the growing demand for slow tourism [1].

Regional natural parks constitute an important component of the nation's natural heritage, in qualitative and quantitative terms. Among the 871 Protected Natural Areas recorded in the Official List, 134 Protected Natural Areas fall into the category of Regional Natural Parks. The law establishes three mains cognitive, planning, regulatory and management tools through which to ensure the protection of their natural and environmental values: the regulation, which governs the activities permitted within the protected area; the planning scheme, which divides and regulates the territory according to the different degree of protection; the multi-year economic and social plan which promotes the sustainable development of local populations through compatible initiatives and activities.

In the Sardinia Region (Italy), Regional Law no. 31/1989 introduces the principles for the establishment and management of the protected areas, including natural parks. The four parks established to date differ in terms of geographical location, environmental and landscape characteristics, degrees of naturalness and anthropization, total surface, number of municipalities involved, presence of protected areas, including those of international level [8]. Nowadays, none of the four parks has yet adopted the main planning tool, i.e. the plan of the park, and, as a consequence, the regulation and the multiannual program of economic and social development, determining a general condition of delay in the definition of a regulatory framework for the natural heritage protection and in the proposal of development strategies aimed at ensuring the protection of natural and anthropic values and of their long-standing interrelations, according to the principles of integrated conservation.

Within this framework, the Tepilora Natural Park, located in north-eastern Sardinia, represents a relevant paragon to deal with the issue at stake [13].

The present study proposes a knowledge-based planning methodology that supports plan-making processes concerning natural parks for an effective conservation of the specific territorial reference units (homogeneous areas). The latter identify areas characterized by different degrees of naturalness, to which to assign different degrees of conservation. In this sense, the planning scheme of the Tepilora natural park is the result of the complex cognitive framework matured through specialized studies, field investigations and critical interpretations of the territory.

After a first introduction on the state of planning of natural parks in the Sardinian Region (paragraph 1), the paper analyzes the case study (paragraph 2) and proposes a planning methodology that supports plan-making processes concerning natural parks (paragraph 3). Finally, the authors discuss the expected results of the ongoing planning experience.

Area of study

The Tepilora Regional Natural Park, located in north-eastern Sardinia, can be considered a relevant case study for the definition of planning approaches and methods aimed at ensuring the protection of a territorial system characterized by different degrees of naturalness and heterogeneous values. These unique features, together with the geographical context, have also been stressed by the recent establishment of the Tepilora, Rio Posada and Montalbo Biosphere Reserve by UNESCO (June 2017), as part of the "Man and Biosphere (MAB)" program. The Biosphere Reserve brings together 17 municipalities of north-eastern Sardinia around the Tepilora park, which appears as its beating heart (Core zone MaB).

The Park covers an area of about 7877 ha, from the granite plateau of the Municipality of Bitti, to about 500 m above sea level, passing through the hilly area of the Municipality of Lodé, up to the plain of the Municipality of Torpé and the Coastal Municipality of Posada. For this reason, during the elaboration of the plan and according to the context analysis, three macro-areas have been recognized within the Park, which are characterized by a landscape and management homogeneity fully recognizable in relation to the territorial planning scheme drawn up (Fig. 1), which see in the Rio Posada (Posada River) the precious element of connection between sea and mountains.

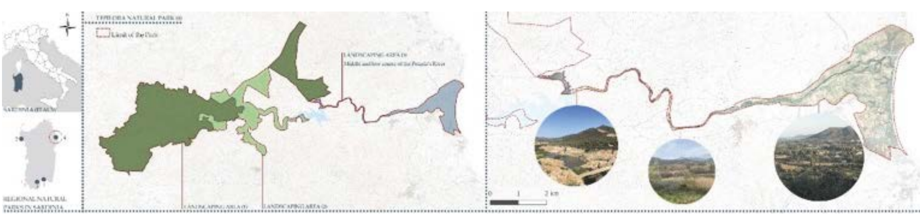

Figure 1 – The Tepilora regional natural Park and its landscaping areas. Author: Mara Ladu.

The first macro-area is identified with the mountain-forest landscape, where the character of the forest landscape prevails characterized by a high degree of naturalness, consisting of the state forests of Crastazza - Tepilora and Sos Littos - Sas Tumbas in the territory of Bitti and the state forest of Usinavà in Torpè.

The second macro-area is identified with the landscape of two enclaves located in the territory of Bitti and the hilly-forest landscape of the territory of Lodè.

The third macro-area takes the name of Medio e Basso Corso del Rio Posada (Middle and Lower Course of the Posada River) and is identified with the fluvial-agricultural and coastal landscape of the wetlands and the beach. The context is that of the alluvial agricultural plains of Torpè and Posada, served by a capillary irrigation network infrastructure that has allowed until now the development of intensive agricultural activity, where the artificial reservoir of Torpè represents an element of discontinuity between mountain areas and intermediate areas of the plains. It includes, in Torpé, the middle course of the Rio Posada and, in Posada, where it develops around the fortress of the ancient village, the flourishing agricultural plain, the beach, its dune system, where a mainly seasonal type of tourism has been consolidated, and finally the Ramsar area Foce del Rio Posada (Mouth of Posada River), recently established. This is an area of great landscape and naturalistic value, and represents the place where the Rio ends its path by rejoining the sea.

The diversity of landscapes of the park translates into a rich ecosystem variety (in terms of habitat and species), geomorphological, microclimatic and vegetational, also determined by historical and cultural factors. The downstream part of the park is characterized by an evident process of anthropization characterized by an important coexistence between natural habitats and agricultural areas and is also equipped with a recent and punctual planning tool, the Municipal Urban Plan (MUP). As will be illustrated in the next paragraph, the latter is the area of study assumed for the development and application of the proposed territorial planning methodology that is based on the reading and interpretation of the environmental context of the territory, in coherence, when possible, with the transformation processes in progress, and aimed at protecting and enhancing the complexity, identity and peculiarities of the territory.

Materials and Methods

The plan of the Tepilora Park consists in the conception of a territorial system divided into three macro-areas, each of which is divided into similar areas, characterized by the same degree of naturalness and protection, and further divided into Spatial reference units (SRU) that introduce further specific requirements. The methodological approach, developed and applied in the Middle and Lower Course of the Rio Posada is based on five main phases.

The first phase consists of the analysis of the territory and the identification of the structural components of the landscape. This phase is divided into: visits on site, diachronic reading of orthophotos, elaboration of environmental analysis, study of cartography and specialized plan reports. The last three define the Cognitive Framework (CF) of the Plan.

Visits on site are fundamental to investigate, from a qualitative point of view, the dynamics of the context, to build a visual idea of the study area and the consequences that design choices can have on it, on a human scale. The diachronic study of orthophotos shows the evolution of the study area, at a landscape scale. The structure of the CF was defined during the setting up of the Strategic Environmental Assessment (SEA). The SEA, in the case of the Tepilora Plan, plays a key role: it is integrated into the planning process [14] in the elaboration of the CF and of the Interpretative and Strategic Design Framework (IF-SD). In the definition of the latter, integration takes place by objectives and actions that are deduced in the drafting of the Environmental Report (ER). While with regard to the CF, the environmental analysis of the ER constitutes the complete cognitive basis of the state of the environment that allows to highlight the potential strengths, weaknesses, opportunities and risks that, summarized and collected in the SWOT analysis, represent the reference point of a sustainable planning rooted in the context to which it refers in strategic and spatial terms[1].

The analysis phase allows to identify the Rio Posada and the mouth system, the agricultural alluvial plain, the beach and the relief of Orvile, as structural components of the landscape. For each of these, a degree of anthropogenic transformation (low, medium and high) was assigned and at the same time, spatial correlation with the landscape systems highlighted by the specialized analyzes (phase I) was evaluated. The correlation assessment was then carried out, in terms of zoning and regulations, with the planning tools in force on the area of study: the MUP of Torpé and Posada (phase II) (table 1).

Table 1 – Excerpt referring the assessment of correlation between the structural components, the landscape systems, the level of anthropic transformation undergone by them and the planning tools in force on the study area.

Structural components of landscape	Landscape systems	Level of anthropogenic transformation	MUP of Posada	Correlation assessment
Rio Posada and mouth system of Rio Posada	- Artificial basins and rivers of the Termo-Meso-Mediterraneo Secco - Holocene lake sediments of the Dry Mediterranean Thermo-Meso	Low	H: safeguard zones	Yes
Agricultural Alluvial Plain (Posada)	- Thermo-Meso-Mediterranean Dry Alluvial Deposits - Intrusive and metamorphic substrates of the Dry Thermo-Meso-Mediterranean	High	- E: agricultural area - F: tourist-receptive area - G: areas for public services - S: services of general interest	Yes

The next step is to assign, for each type of urban area identified by the UP, a preliminary degree of protection (phase III), in line with the provisions of Law 394/1991: zone A, integral reserve; zone B, general reserve; zone C, protection areas; zone D, areas of economic and social promotion. The process of awarding the preliminary degree of protection took place following an assessment of consistency between the objectives, the intended uses, the prevailing categories of intervention identified by the MUP, and the level of protection provided by the protection zones referred to in the legislation on parks. Zones

[1] For further information, please refert to the SEA of the Tepilora Plan. The integration of the SEA into the planning process is also specifically the subject of Marras M.'s doctoral research, under the supervision of Prof. Zoppi C. and the co-supervision of Proff. Colavitti A.M. and Lai S.

A, B, C, D were then further divided into SRU (phase IV). The articulation in SRU represents a further degree of deepening, developed through the analysis of specialized studies, context and, in particular, carrying out a critical overlay mapping between cartography related to landscape systems, land cover, geology, vegetation and fauna. The perimeters of the areas identified in advance have therefore been subject to verification and, in some cases, redefinition of their degree of protection. In this way, although the zoning of MUP finds significant correspondence with the classification reported by the study on land cover, and highlights the invariants, the zoning of the Park Plan often does not coincide with that defined by the current MUP, as it implements a project that recognizes and reinforces the continuous and unitary character of systems that currently appear fragmented (Fig. 2).

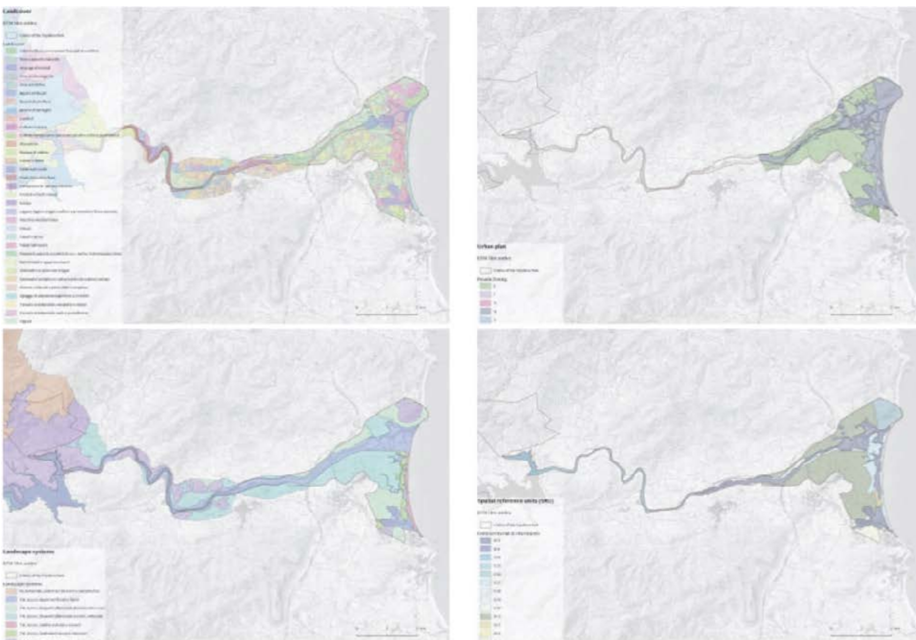

Figure 2 – Representation of the maps related to land use, the zoning of the urban planning tools in force in the area of study, the landscape systems, the SRU system introduced by the Tepilora Park Plan. Author: Martina Marras, based on the cartography drafted by the Planning Office.

The spatial taxonomy is accompanied by regulatory requirements defined in the Implementing Technical Standards (ITS). In the ITS, a more detailed definition of the general requirements relating to zones A, B, C, D is reported integrated for each SRU by further specifications that take into account the protection needs of species, animals and plants, and of the habitats present.

Phase V relates the system of actions that address the strategic framework of the plan objectives identified during the elaboration of the SEA, with the spatial system of the SRU highlighting the integration between the strategic plan and the regulatory device (Table 2).

Table 2 – Excerpt referring to some SRU about the correlation between the zoning introduced by the territorial planning of the Park of Tepilora, its strategic framework and the urban planning tool in force in the study area.

MUP zoning of Posada	Level of protection	SRU	Action of the plan
H - Water system and wetlands H - Habitat 43	B. General reserves	B15 Water system and wetlands of the Rio Posada	Interventions to improve the use of the environmental context of the Rio Posada Integrated conservation of the landscapes of coastal wetlands, river mouths and agricultural alluvial plains aimed at ensuring the balance between environmental protection needs and settlement development requirements Restoration and maintenance of riverbeds and sediment management (…)
…			
H - Beaches and dunes H - Area of tourist-environmental redevelopment	C. Conservation areas	C28- Beaches and dunes	Interventions to contain massive seaside tourism and to promote itinerant tourism in the various areas of the Park Actions to prevent the degradation and fragmentation of dune habitats Interventions aimed at the sustainable management of the coasts (…)
…			
E1 - Posada Gardens E1 - Area with sclerophyll vegetation, meadows and pasture E2 - Agricultural land E5 - Wooded areas and deciduous forests S2 - Services G - Services	D. Areas of economic and social promotion	UTR-D12-Posada Gardens	Launch of projects for the economic exploitation of products and services, direct and indirect, of agricultural and forestry systems Definition of measures for the reintroduction of traditional agricultural production on the territory Interventions in support of extensive and organic agriculture, favoring traditional cultivation methods and techniques Interventions to adapt and strengthen the irrigation network in the agricultural plain of the municipalities of Torpè and Posada (…)
…			

Results

The Plan of the Tepilora Park, in the macro-area of the Middle and Lower Course of the Rio Posada, which extends for about 955 hectares, that is 12 % of the entire Park, provides for the establishment of: n. 2 UTR of general oriented reserve (B), for an area of 217 hectares approx.; n. 7 UTR of protection areas, for an area of about 271 hectares; n. 4 UTR of economic and social promotion (D), for an area of 467 hectares approx. 48.9 % of the macro-area under study is represented by areas of economic and social promotion characterized by a considerable level of anthropogenic transformation deriving from agro-silvo-pastoral activity. The oriented reserve and conservation areas occupy an area equal to about 30 % of the entire extension of the macro-area and no integral reserve areas (A) are identified. The Plan assigns a high level of protection to the wet element of the Rio Posada water system, including it in zone B of general oriented reserve. Here the scientific and educational uses related to the dissemination of knowledge of the Park are allowed, as well as the activities of tourist, recreational and cultural fruition. These are allowed in compliance with the species and habitats present and with specific limitations relating to the means of use. The construction of new buildings and infrastructures is not allowed, with the exception of small buildings for the introduction of naturalistic observation activities. Protection zones (C) define a buffer zone between the wet element (B) and the agricultural plain (D). In the latter, the Plan identifies the area of economic and social promotion as the small urbanized portions present and the alluvial agricultural plain, recognizing a value that is also identity to the agricultural plot of cultivated fields and rural roads typical of the context. In these territories, the Plan allows sustainable anthropic activity aimed at enhancing pre-existing economic activities, also through the construction of new buildings related to the activities of running the fund and tourist-accommodation. At the same time, it introduces specific protection provisions for the most sensitive elements present in widespread form, including small streams and woodland formations.

Discussion and conclusions

The present study proposed a knowledge-based planning methodology which, starting from an identification of three similar macro-areas in the Park, allowed to define a further division of the territorial system into Spatial reference units (SRU) and to introduce different levels of protection according to the specific degree of naturalness recognized.

The study highlights how important it is for the planning process to develop in successive levels of plan design and in stages. The stages involve knowledge, interpretation and choices of plan. It is important to emphasize that the process of defining the Plan contains a subjective component, through which the planner projects into the plan his technical skills, his experience [12], but also his vision of the world. As explained in the previous paragraphs, the draft plan is developed starting from a general context, following a progressive degree of detail in the definition of a spatial articulation, in UTR, which is compared from a zoning and regulatory point of view with the pre-existing planning tools at an urban scale, in a gradual transition of scale that takes shape both in terms of planning and analysis. In the transition of scale, the study of the dynamics of the context is confirmed as fundamental, but also a subsequent skimming aimed at identifying the aspects considered fundamental so that the plan choices can be targeted and consistent with the objectives. In this macro-area, four main aspects have been identified, among the more than ten present: landscape systems, land cover, urban planning tools in force, flora and fauna. These have been chosen according to the area of study, that is a protected area, and according to the type of plan. In this way the planning process aimed at maintaining those natural elements which are specific to the landscape, protecting the species present, and their habitats, and evaluating the transformations already regulated by the local planning tools in force. The results also describe how the strategic vision, and the regulatory system can effectively contribute to the implementation of a virtuous local development, inside or outside the limit of the Park, identifying specific actions in favor of the integrated conservation of the coastal environment and, more in general, of the agricultural-fluvial landscape typical of the macro-area here examined.

In conclusion, the plan of the park becomes the planning tool capable of defining a regulatory framework based on the recognition of the place identity and its values, as well as of the expressed and unexpressed potential of the territorial context of the Park within a comprehensive conservation and enhancement strategy. Finally, the methodology is readily exportable to other spatial contexts, at different spatial scales, where conservation and development pressures should be adequately balanced as regards areas characterized by relevant values of nature and natural resources.

Acknowledgements

Marras M. and Ladu M. collaboratively designed this study and jointly wrote Section 2, Section 4 and Section 5. Individual contributions are as follows: M.L. wrote Section 1; M.M. wrote Section 3. All authors have read and agreed to the published version of the manuscript.

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LAND USE ANALYSIS AND COASTAL STRUCTURES: ADRIATIC COAST AS A CASE STUDY

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Abstract – Coastal areas are one of the most complex and vulnerable nature environments. Generally, these areas are densely populated, therefore pollution, habitat loss, coastal dynamics, and climate change make these areas prone to be vulnerable with a resulting high risk for the population who lives in those places. Moreover, these locations are often intensely anthropized and prone to intense transformative pressure that increases the exposure inducing a consequent increase in the risk of already compromised integrity of the ecosystems and their ecological function [21] For these reasons, the knowledge of the present mosaic of land use/cover might be an important instrument to analyze the morphodynamic processes and also, for the definition of the rules necessary for the sector planning (e.g., Coastal defense planning, water catchment planning). The main goal of the work is to analyze the current overview of land use at 1 km from the coastline investigating if there is a correlation with the deployment of coastal structures i.e., breakwaters, groins, etc. [18]. The study area has been defined using the concept of physiographic unit (i.e., the coastal area in which the sediment transport exchange with neighboring regions is zero) using the classification given by the Italian Institute for Environmental Protection and Research, ISPRA [8]. In this case, the coastal area between Conero Promontory to the north (Marche region) and that of Punta Aderci, to the south (Abruzzo region), with a total extension of approximately 200 km involving about 40 municipalities and 2 regions has been analyzed. The analysis has been carried out using the Copernicus Land Monitoring Services database products (i.e., land use) with high resolution [11]. Moreover, all coastal structures (groins, submerged and emerged breakwaters) have been surveyed using appropriate environmental, urban, and hydraulic indicators to identify a possible correlation or cause-to-cause relationship effect between the presence/absence of coastal defense, urban pressure, and soil use/cover mosaic. This procedure has made it possible to build an analytic picture of the analyzed physiographic units useful to identify critical areas with low permeability values and those in the opposite condition.

Introduction

Coastal areas represent one of the most inhabited and anthropized natural environments. Nowadays, about 40 % of the world's population lives in the coastal belt of 100 km, while 600 million people live in coastal areas with an altitude below 100 m above sea level, and for these reasons exposed to floods and seaquakes [10,15,17]. Good climate conditions together with greater accessibility to technological and transport services certainly influenced the highest population density. This fact is more evident in a country like Italy, in

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which the morphological aspect takes on a leading role in the geography of urban settlements. Flatlands, with the exclusion of the Po valley, regards essentially the coastal areas. The presence to the north of the Alps and the Apennines that crosses the peninsula from north to south, determine a limited presence of flatlands. In Italy, the municipalities overlooking the sea cover an area of about 42 600 km^2 (14 % of national soil), and people living there are over 16 500 000, about a third of the Italian population and corresponding to a population density of 400 inhab/km^2 twice the national value (200 inhab/km^2). The high anthropic pressure makes this system extremely vulnerable with significant losses of essential ecosystem services [6] and problems in the management of sandy beaches [13] where a large part of the touristic economies are concentrated [20]. This fact is even more true for the Adriatic coast, characterized mainly by long low, and sandy beaches alternating with rocky headlands only in some areas (e.g. Conero, Gargano e Punta Aderci). This geological conformation has led to the almost total disappearance of the original dune environment and its replacement with anthropic uses (agricultural, grazing, and urban) [21]. If the 1 km coastal belt is considered, today 65 % of this area is for agricultural (30 %) and urban (35 %) uses, the remainder has natural/semi-natural characters.

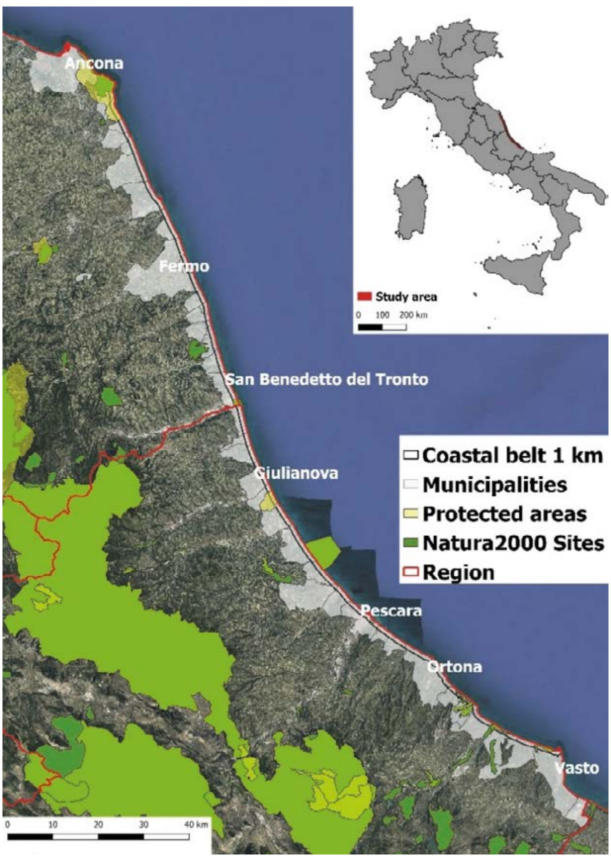

Figure 2 – Study area.

The Italian coasts have suffered in recent decades from important urbanization phenomena. In particular, the Adriatic coast, which is low and sandy coast, has suffered in recent decades from significant urbanization phenomena [21]. These transformations have profoundly altered the coastal dynamics, so much that there is a clear predominance of coastal erosion phenomena of predominantly anthropic origin. As reported by ISPRA [9], from 1950 to 1999, 46 % of low coasts have undergone changes of more than 25 meters, with stretches of coast in erosion superior to those in advance, the result is the loss of 5 km^2 of coastal soil. This has caused not only environmental and economic value loss [3,5] but also increased the risk of exposure to storms of housing, roads and railways to storms [2,13,16].

Nowadays, several projects related to these areas are focusing on both risk analysis (AnCoRa Project and SICoRA Project - https://www.regione.abruzzo.it/content/piano-di-difesa-della-costa) and integrated coastal zone management. This work focuses on the territory, corresponding to a physiographic unit [8], that extends from Monte Conero (municipality of Ancona) to the municipality of San Salvo in Chieti province. It consists of 200 km of coastline, equal to 14 % of the Adriatic coast, that involve 36 municipalities from 2 Regions (Marche and Abruzzo) (Figure 1). From a morphological and geological point of view, the beaches are sandy except for Conero and Punta Aderci promontories. In the considered municipalities, as derived from ISTAT data, over 780 000 people live there, 10 000 more than in the previous decade. The main variations are recognizable in almost the totality of Abruzzo municipalities, specifically in Vasto and Francavilla al Mare municipalities (just under 2000 more residents) and Montesilvano municipality which recorded an average annual increase of about 300 units. In the Marche region, the municipality of Civitanova Marche shows an increase of 1700 inhabitants. From an economic point of view, these areas are highly active, not only for the high concentration of services and infrastructures but also for their strong productive and tourist activity [4].

To better understand the importance of these areas for the local economies, the data on beach concessions have been analyzed. These data, updated to May 2021, come from the Ministry of Infrastructure and Transport website (http://www.dati.mit.gov.it/catalog/dataset).

In the studied coastal belt, there are more than 3300 concessions (about 17 per km), half of which were activated/renewed from 2012 onwards (450 is the maximum value recorded in 2014). The graph in Figure 2, shows the distribution percentage of the different types of state property concessions from 2012 to 2021. Over half of the concessions activated in the last decade concern recreational tourist uses and particularly, public and private bathing establishments, followed by those for various use (mooring points, renewable energy...) and productive and industrial uses. The analysis at the municipal level shows that San Benedetto del Tronto is the municipality with the higher number of concessions per km (just over 50) followed by the municipality of Alba Adriatica (about 30), while the remainder municipalities record values lower than 20 concessions/km. Therefore, not only the land-use change could have had an impact on the implementation of coastal defense but also on the growth of the number of beach concessions (Figure 2). The main aim of the present work is, on one hand, to identify a possible relationship between land-use changes and the system of the existing coastal defense [14] and on the other to assess how this system may have interacted with shoreline changes. The knowledge of these connections could reveal extremely important for the management of coastal belts.

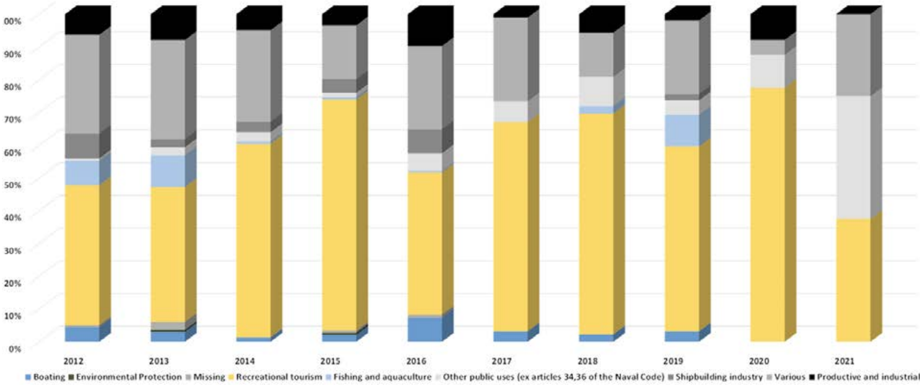

Figure 2 – Distribution percentage of state property concessions type from 2012 to 2021.

Materials and Methods

In this work, different kinds of data were used. Those on land use and land-use change (2012 -2018) are Coastal Zones. This high-resolution data (MMU 0.5 ha e MMW 10 m both for the status and the changes layers), is part of the European Project Copernicus-Land Monitoring Service (https://land.copernicus.eu/local/coastal-zones) with full European spatial coverage 10 km landward. In this work, the study area is the 1 km landward. This choice is motivated to the intense transformation of this area. The analysis of land-use changes was made at a municipal scale because, in the Italian planning landscape where strategic planning has a low cogency, municipalities are the main decision-making authorities on the transformations of territories [23,24]. Data on breakwaters and groins were digitalized, for both reference years, from Google Earth satellite images. Table 1 shows main parameters of used data. This allows assessing the shoreline coastal protection carried out during the investigated period.

Table 1 – Main parameters of used data.

Data	Reference Period	Data Source
Land use/Land Cover	2012-2018	Copernicus - Coastal Zones (https://land.copernicus.eu/local/coastal-zones)
Breakwaters and groins	2012-2018	Open street Map and Google earth pro (https://www.openstreetmap.org/)
Shoreline	2012-2018	Google earth pro
Buildings	2018	Italy Civil Protection (https://rischi.protezionecivile.gov.it/it/approfondimento/dataset-nazionale-degli-aggregati-strutturali-italiani)
State property concessions	2012-2018	Ministry of Sustainable Infrastructure and Mobility (https://dati.mit.gov.it/catalog/organization/m_inf)
Digital Terrain Model	2022	National Institute of Geophysics and Volcanology (https://tinitaly.pi.ingv.it/)

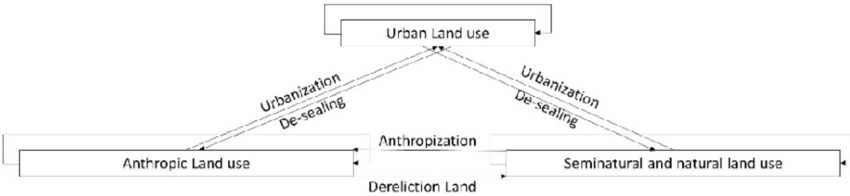

Figure 3 – Diagram of land-use transitions.

Coastal Zones legend is organized into 8 classes: 1: Urban; 2: Cropland; 3: Woodland and forest; 4: Grassland; 5: Heathland; 6: Open spaces with little or no vegetation; 7: Wetland; 8: Water. These categories have been grouped into three: Urban land use (1), Anthropic land use (2, 4), and Natural and semi-natural land use (3, 5, 6, 7, 8). This classification allows identifying land transformation drivers. As shown in Figure 3, "urbanization" consists of changes from any other land use to urban use that subtracts fertile soils and has direct negative impacts on environmental fragmentation, ecosystem services, climate, and hydrogeological effects [1, 7, 19].

In the abandonment process, a soil initially agricultural or for grazing regains natural aspects. In contrast, "anthropization" is the transformation from natural/semi-natural soil to agricultural or grazing land. Finally, "de-sealing" consists of the transformation from urban uses to agricultural/natural uses. Transformation from anthropic to natural uses has several positive consequences for example an increase in plant cover, a decrease in surface runoff, creation of new habitats [12, 25].

Moreover, to catch information about coastal dynamics, a diachronic analysis (considering only the sandy costs) based on the comparison of shorelines measured at different epochs has been performed. Consistently with the above (i.e., the observation period ranges between 2012 and 2018), the shorelines are referred to those periods. The digitalization has been performed using the historical images acquired by Google Earth Pro, appropriately georeferenced in Qgis. More in detail, the shoreline variation has been analyzed by considering the local variation (m) of the shoreline position between two different epochs ($\Delta S_{i,i+1}$). In order to compute $\Delta S_{i,i+1}$, the transversal direction to the shoreline and the (geographical) location of each i-th position needed to be evaluated.

In this case, sections have been drawn with a Δx of about 20 m (about 8800 sections in the 200 km of the physiographic unit extension). Figure 4 shows a sketch of the method used to evaluate the shoreline evolution.

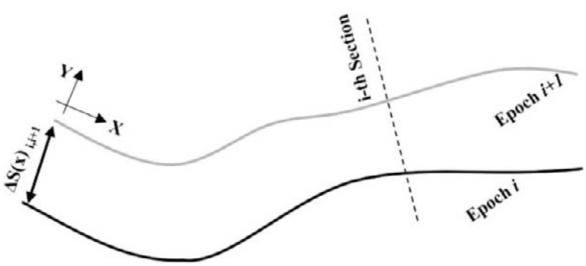

Figure 4 – Qualitative sketch of the method used for the study of the shoreline evolution.

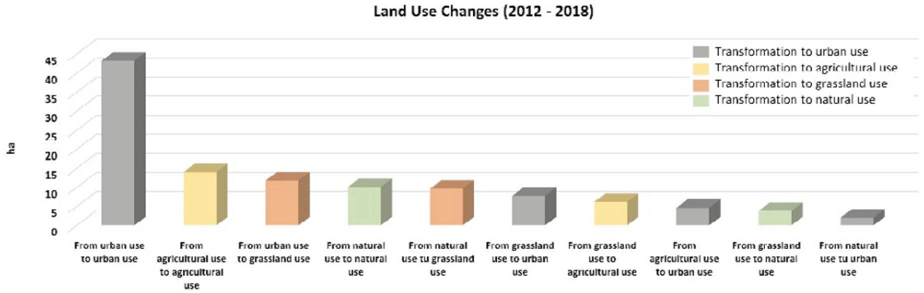

Figure 5 – Land use change occurred between 2012 and 2018 in the buffer of 1 km from the coastal line.

Results

Between 2012 and 2018 land use changes stand at 113 ha. The most extensive transformations are in the municipality of Giulianova (about 14 ha), Grottammare (12 ha), and Ancona (11 ha), while in 9 municipalities there is no change. Of these, the municipalities of Ortona, San Vito Chietino, and Rocca San Giovanni are in geographical continuity. Regarding the land-use change surface types, as shown in Figure 5, it results that 60 ha (53 % of the total) of 113 ha regard urbanization processes. Specifically, 45 ha are soil transitions within the urban soil category. More in detail, many areas that in 2012 were classified as "Construction sites" or "Land without current use" become "Dense or continuous urban fabric" or "Industrial, commercial, public units" to testify that, even if at different speeds, even now as in the past this transformation processes take place.

These processes are not virtuous urban regeneration/renovation phenomena but transformations that have completed urbanization processes started a few years before or that have converted green urban areas (Figure 6). The remaining 15 ha regard agricultural/natural

Figure 6 – Example of urban transformation with residential and receptive uses occurred between 2012 and 2018 in the study area.

soils. Abandonment phenomena have affected only 4 ha of the territory concentrated in the San Benedetto del Tronto municipality. There are also some passages to semi-natural soils on areas first used as a service for existing construction sites (about 12 ha). Anthropization processes consist essentially of "Vineyards, fruit trees and berry plantations" transformed into "Arable irrigated and non-irrigated land" for about 13 ha, and a further 9 ha from natural coverage (Sparse vegetation on sands, Sparse vegetation on rock) to "Semi-natural grassland", to witness the intensification of anthropic processes in the study area.

The intense transformative activity in the previous decades is confirmed by the reduced presence of the dune environment that today, is concentrated only in the border area between the municipalities of Vasto and San Salvo for a total area of 32 ha. In addition, it is important to point out the actual urbanization level which is equal to 43 %. This value is extremely high and much higher than the national one (10 %), with value peaks between 60 % and 80 % as shown in Figure 7. The morphology and lithology have had in the past and still have today a role of primary importance in orienting the transformative typologies along the Adriatic coast. The diagram in Figure 7 confirms this. Urbanization density below the study area average value is found especially in municipalities with rocky headlands, while in sandy sections this value rises significantly. The only exception is the southern sector of the Abruzzo's coast, where the presence of a Nature 2000 site has partially preserved the area.

The diagram in Figure 8 analyses the conditions detected along the study area. Specifically, it shows the percentage of free 200 m coastal belt (light blue bars), the percentage of length coast protected by breakwaters and groins (grey bars), the percentage of the coastal belt under environmental protection (Protected areas and Natura 200 sites, in green bars), the number of buildings in the 200 m of the coastal belt (table in shades of blue) and the number of beach concessions per km^2 (table in shades of red). The coastal sector from Ancona to Numana has the highest environmental protection level. From Porto Recanati to Martinsicuro the coastal belt free of urbanization is always lower than 40 % and the coastal protection, with a few exceptions, is always greater than 50 %, at the same time there are a few areas under environmental protection.

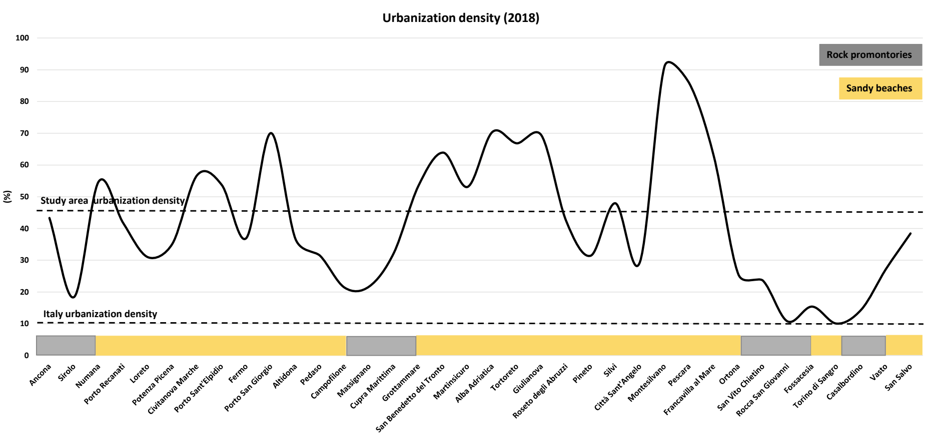

Figure 7 – Urban density in the section of the 1 km coastal belt for the study area.

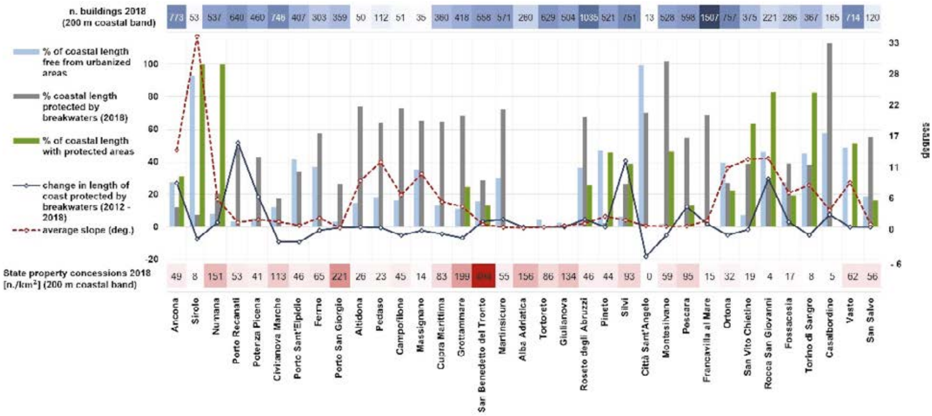

Figure 8 – Diagram of the coastal sector in the current condition.

The beach between the municipalities of Alba Adriatica and Giulianova has distinct characteristics from the other investigated sectors. As shown in the graph of Figure 7, in this littoral no groins or breakwaters are found, the coast is almost entirely urbanized (the territory is completely flat) and there is no protection from an environmental point of view. The sector from Roseto degli Abruzzi to Silvi has an environmental protection value higher than 20 % with large coastal sectors free from urbanization except for the municipality of Silvi, where one of the greatest increases in coastal protection was recorded. The territory portion from Montesilvano to Francavilla al Mare has the same urbanization condition as the previous coastal sector but with a substantial difference. Here, both environmental protection and coastal defense are significantly higher. The last sector from Ortona to San Salvo closes the considered physiographic unit. Here the morphological factor returns to be a limit for urban expansion but, at the same time a favorable element for the presence of ecological values evidenced by the percentage value of protected natural areas (always above 20 %). Beach concessions are limited if compared to the previous sectors. Only the municipalities of Vasto and San Salvo have comparable values with other coastal sectors. Also in this area, coastal defense assumes significant values (approximately 40 %) except for the municipality of Vasto. Here, more than half of the coastal perimeter remains free from urbanization and the free coastal belt coincides with the Special Protection Area "Punta Aderci - Punta della Penna". In line with the results obtained by a previous study [18] for the Abruzzo Region, the shoreline dynamics in the entire physiographic unit show an alternation of retreats and advance regardless of the presence of rigid protection structures. This well-balanced alternation between retreats and advances is confirmed by the shape of the frequency distribution of the ΔS (i-th sections) sample (≈ 8800 elements) that is not symmetric (skewness equal to 0.55) but not far from a normal distribution (kurtosis equal to 2.93). The mean and the median of the sample are about 0.6 m and 0.40 m respectively. This means that the advances tend to be slightly more than the retreats. The maximum and minimum ΔS values are 13 m and 12 m respectively, the 90th percentile is 3.5 m while the 10 % percentile is about -2 m. In this scenario, with extremely high values of coastal protection and no evidence of a positive or negative trend in coastal variations, a definite interpretation of the role of the rigid structure as a measure against coastal dynamics is difficult and certainly not without ambiguity, as long as the considered temporal interval is relatively short compared to the characteristic period of beach morphodynamics.

Discussion and Conclusions

The proposed work has shown how the dynamics of coastal settlement, albeit with reduced intensity compared to the recent past, continue to erode soils of ecologically fragile environments. The analyses have shown that 50 % of the transitions concerned transformations to urban use, which represents soil use with greater negative effects in environmental terms. It should be added that the data used, although of high resolution, fails to detect the sprinkling development [21] that characterizes the coastal belt (Figure 9).

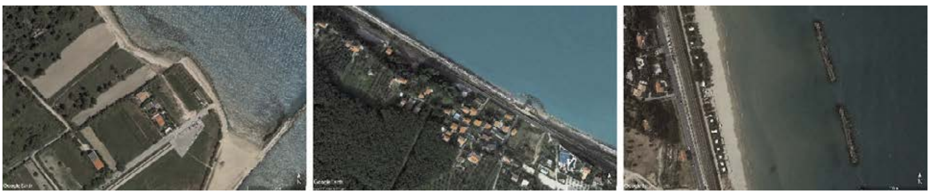

Figure 9 – Examples of building patterns along the investigated coastline not surveyed by Coastal Zones.

The strong economic energy and the weak mandatory local plans have encouraged the single building construction, due to their small size Coastal Zones do not identify them, despite this is a very-high-resolution data. For these reasons, the real phenomenon is of greater magnitude. If on one hand, there is an increase in the exposure of these areas, on the other hand, are more frequent technical and political actions trying to improve their resilience. Every year are several beach nourishment and new coastal defense systems to guarantee the operativity of the economic activities during the summer season. These types of interventions are part of the measures provided for in the coastal defense plans (updated in 2019 for the Abruzzo Region and in 2015 for the Marche Region). These plans, drawn up at the regional scale, address the problem of erosion risk and storm damage on the entire regional coastal to reduce hydraulic risk. The intervention areas concern the marine area and the overlooking sector of the beach/cliff. The combined analysis between protected areas (with rigid structures), and shoreline changes showed difficulty in assessing the role of the protection on the shoreline dynamics. The general pictures in the analyzed physiographic unit show a clear alternation between advances and retreat of the shoreline with a slight prevalence of advances. The area just behind the coastal area is still home to settlement interventions, an area that the urban planning tools often allocate to new building interventions. A previous study on the Romagna coast [24] shows that in the urban planning instruments of coastal municipalities, in the 1 km coastal belt, there are further 48 km^2 of land for urban functions not yet built. This fact underlines the importance to set up the planning tool mosaic of coastal municipalities belonging to the same physiographic unit (cPTM – Coastal Planning Tool Mosaic). The cPTM would allow to set up the settlement scenario and to be aware of the intended use in the 1 km coastal belt. Therefore, it would be simpler and more effective to implement actions of use changes, relocation, and transfer of land rights through the equalization mechanisms to safeguard coastal areas. Moreover, this solution allows economic saving in the long term because the above-mentioned interventions may not be necessary. The integration of cPTM with the risk scenarios provided by the Coastal Defense Plans is certainly an effective measure in the management and protection of this important ecosystem.

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PROTECTING VAGUEIRA (PORTUGAL) WATERFRONT: PRESERVING NATURAL, RECREATIONAL, RESIDENTIAL, AND COMMERCIAL FUNCTIONS

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Abstract – Vagueira is a Portuguese village located on the northwest coast of the country. The waterfront of the coastal settlement hosts relevant economic activities and the beach is well visited by tourists, hence concerning a diversity of assets of interest to protect. Nevertheless, it has been affected by a persistent trend of erosion, due to the prevailing deficit of coastal sediments in the littoral drift, and experienced overtopping and flooding events in the past. Consequently, the inefficiency of existing coastal defences (a longitudinal revetment along the waterfront and a groin located on its downdrift limit) to mitigate coastal hazards is being discussed.
The objective of this study is to determine if the deployment of a detached breakwater in front of Vagueira beach would help protect the coastal community and safeguard its natural services and general assets. For this purpose, elements at risk were assembled into uniform Land Use and Land Cover (LULC) classes, following the classification adopted in the COS2018 Portuguese map. The numerical modelling of the case study was made using the LTC shoreline evolution model, considering local hydrodynamic and topo-bathymetric conditions and historical sets of data. Thereafter, the LULC map was overlapped with LTC projections, in a GIS-based environment, to determine the future exposure to coastal erosion and flooding considering the situation of "do nothing" versus the breakwater deployment.
Results demonstrate that the construction of the breakwater can have a global positive performance, with benefits from halting land losses, increasing the emerged beach area and reducing flood risk. However, it is not a "one-size-fits-all" solution. Despite several configurations have been tested, the salient does not cover the whole extension of the waterfront and there is a negative impact on some LULC classes.

Introduction

By the end of the 21st century, erosion of sandy beaches and shoreline retreat may become predominant across the globe [1]. This is due to a diversity of natural and anthropic factors, mainly resulting in sediment deficit and sea-level rise. Particularly, the northwest coast of Portugal (see Figure 1a), which is characterized by sandy beaches with a typical northwest wave climate [2], had been undergoing a generalised sediment deficit caused by dam constructions, intense port activity, and the construction of hard coastal structures

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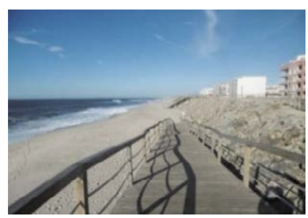
updrift. In Vagueira, the shoreline retreat averaged 4.4 m year^{-1} between 1958 and 2018 [3] and overtopping events in the urban settlement reached flooding extension approximately 50 m distant from the mean shoreline (see Figure 1b). According to mathematical modelling and recent observations [4], events with an average discharge greater than 1 ls^{-1}m^{-1}, that may cause damage to buildings located behind the defence [5], are estimated to occur two times every three years.

Nevertheless, Vagueira beach provides relevant recreational services (such as tourist-oriented activities) and regulating services (such as flood and erosion mitigation), that are of interest to be protected and maintained. In fact, the beach provides a natural defence to the forefront promenade which is occupied by several bars and restaurants, commercial establishments and residential buildings. In terms of tourism, the beach is well visited by inhabitants from the Center region of Portugal and also from Spain due to the proximity to the A25 highway [6]. In addition, Vagueira hosts an active community of artisanal fishing, which became also a tourist attraction.

Current coastal protection conditions of Vagueira include a longitudinal defence along the urban waterfront (see Figure 1c) and a groin located in its southern limit, which have demonstrated inefficiency to mitigate coastal hazards alone. Hence, although in Portugal detached breakwaters have not yet been applied for coastal protection, their effectiveness in controlling coastal erosion has been reported in successful case studies worldwide [7]. Therefore, the objective of this work is to investigate the efficiency of deploying a detached breakwater to help preserve Vagueira's natural and built capital by providing a wave shelter zone and promoting sand accretion.

a) Location.

b) Overtopping event (provided by: Municipality of Vagos).



c) View of the waterfront and the longitudinal defence.

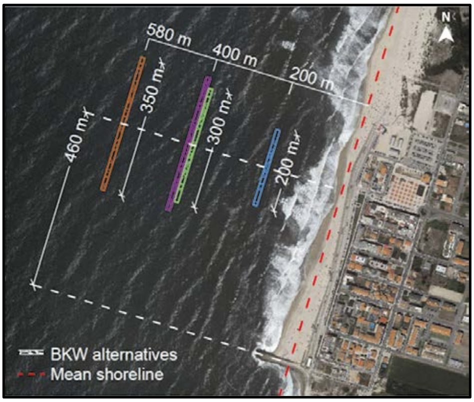
Figure 1 – Characterization of the case study.

Materials and methods

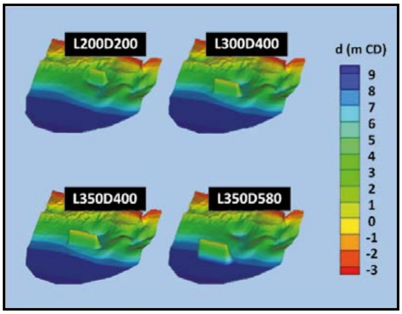
In order to find a solution for protecting Vagueira village and help secure the housing stock and the regular development of local economic activities, the performance of a detached breakwater was analysed. The analysis considered two distinct targets: i) reduce the risk of coastal flooding in the urban settlement and ii) mitigate coastal erosion of natural areas. For this, several alternatives for the detached breakwater were analysed.

The preliminary design of the new coastal structure comprised the test of several parameters within a suitable range of values. These tests were made through mathematical modelling and included criteria for the maximum value of the mean overtopping discharge and the number of overtopping events with discharges greater than certain thresholds. It was also analysed the sedimentary dynamics and the morphological evolution in the vicinity of the structure in the short and medium-term, under average hydrodynamic conditions.

This analysis allowed to conclude that a breakwater with a linear configuration, parallel to the shoreline, with seaward and landward slopes of 1:10 and 1:2 respectively, a crest width of 10 m and a cross-shore axis located 460 m north of Vagueira groin, is considered efficient to meet the targets proposed. The submersion level was fixed at 0.5 m below the mean level of the Low Perigean Spring Tide (= +0.84 m CD, Chart Datum) to avoid visual impact. In regard to the optimum dimensions and location, it was found that a structure with 300 m length (L) and 400 m distance (D) to the shoreline (configuration L300D400), constitutes the technical solution that best fulfils the objectives prioritized. The configuration L350D400 is concluded to be the second-best solution, so it is also considered relevant for the present analysis. In addition, the performance of L200D200 and L350D580 configurations, which represent extreme scenarios in terms of the structure' dimensions and detachment to the shoreline, are also analysed. Figure 2 depicts the final set of breakwater alternatives selected for further investigation.



a) Deployment area.



b) Configurations and local bathymetry [8].

Figure 2 – Alternative scenarios of a detached breakwater for coastal protection at Vagueira.

To assess the efficiency of each alternative, the following steps were completed. First, a comprehensive assessment of the case study to characterize its physical, social and environmental framework and define the modelling setup was made. From this, the model domain was considered centred on Vagueira beach, covering an area of 6×5.6 km^2, including the breakwater deployment zone and a wide vicinity to encompass the area of influence of the coastal structure.

Second, natural and artificial assets existing in the study domain were classified into uniform classes according to the nomenclature of the Portuguese Land Use and Land Cover (LULC) map, designated COS2018. This system follows a hierarchical classification that discriminates 4 levels of detail, the last one including 83 classes.

Third, LTC – *Long-Term Configuration* software [9, 10] was properly calibrated with local hydrodynamic and topo-bathymetric conditions and validated with historical data. This software allowed to forecast the evolution of the shoreline over time, for each scenario (*i.e.*, "do nothing" and "breakwater deployment"), relevant for the calculations of eroded areas. To predict flooded areas, the flooding extensions observed in the past were taken as a reference. Hence, the limit of the flooding area was considered displaced 50 m landward, parallel to the position of the shoreline previously projected.

Next, QGIS software (version 3.10.7-A Coruña) was applied to identify the exposure of each LULC to the coastal hazards (*i.e.*, flooding and erosion). The open-source software allowed managing and analysing georeferenced data, including overlapping the LTC shoreline projections in the LULC map to determine potentially flooded and eroded areas. It should be noted that for the flooding assessment only artificialized areas were considered and for the erosion assessment only natural areas. Hence, although some natural classes are expected to be flooded as well, they were not considered to be damaged. Similarly, artificialized areas were not admissible to be eroded as the retreat of the shoreline is limited by the existing longitudinal defence.

Finally, the performance of the breakwater alternative scenarios was assessed considering that it has positive benefits if results in areas gained or not eroded/not flooded by comparison with the scenario of "do nothing", and negative benefits if results in a worse situation. It should be noted that the "do nothing" scenario consists of the natural progression of the shoreline assuming the maintenance of the existing coastal structures.

In terms of beach areas, a distinction has been made: "Vagueira beach" (comprising an extension of 1.2 km centred in the urban settlement) was assessed separately from "other beach areas" existing in the model domain since the last does not provide recreational service (they are not usually sought by tourists). Also, since this study aimed to assess the performance of the breakwater in the medium-term, it was considered a time horizon of 20 years, for which annual values were interpolated from projections to years 5, 10, 15 and 20.

Results

Figure 3 depicts the LULC model produced for the case study, detailed at the second level of COS2018 nomenclature. According to this classification, it is possible to outline the spatial distribution of the LULC classes existing in the model domain: 56 % are coastal waters, 18 % are forests (mostly maritime pine on the east part of the map and invasive species alongside the beach), 15 % are temporary crops, 5 % is urban fabric (predominantly vertical near the waterfront) and 2 % are open spaces, which include the beach areas. The shoreline is always bordering 7.1 (beach) and 9.3 (ocean) LULC classes.

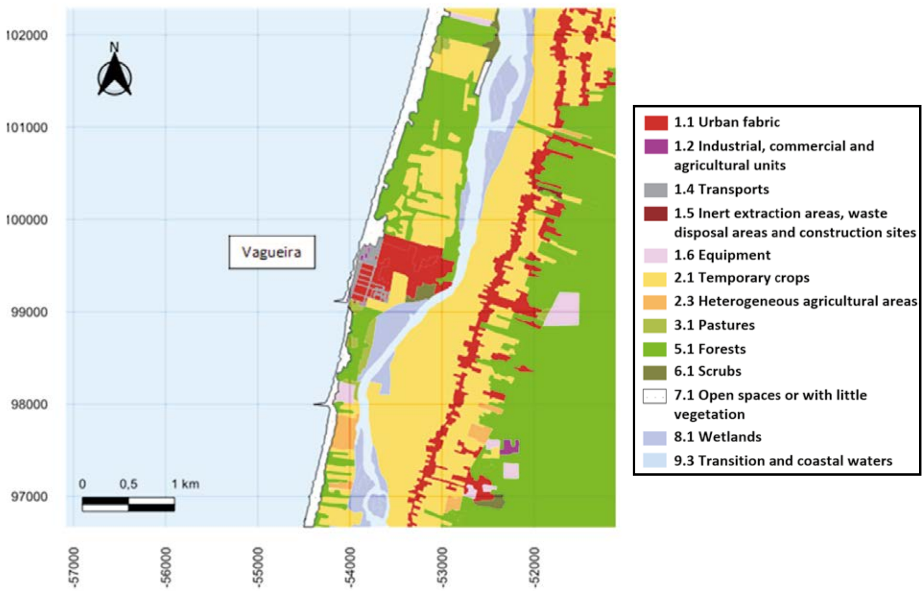


Figure 3 – Map of LULC classes existing in the model domain, according to the COS2018 nomenclature.

Table 1 summarizes 20-year LTC projections of flooded and eroded areas for each scenario, concluding that six LULC classes might be affected by these coastal phenomena. Namely, classes 1.1.1.1 (built-up fabric), 1.2.2.1 (commercial establishments), 1.4.1.1 (road network) and 1.6.2.2 (leisure equipment) are expected to have some areas flooded and classes 5.1.1.6 (forests) and 7.1.1.2 (beaches) are expected to have some areas eroded.

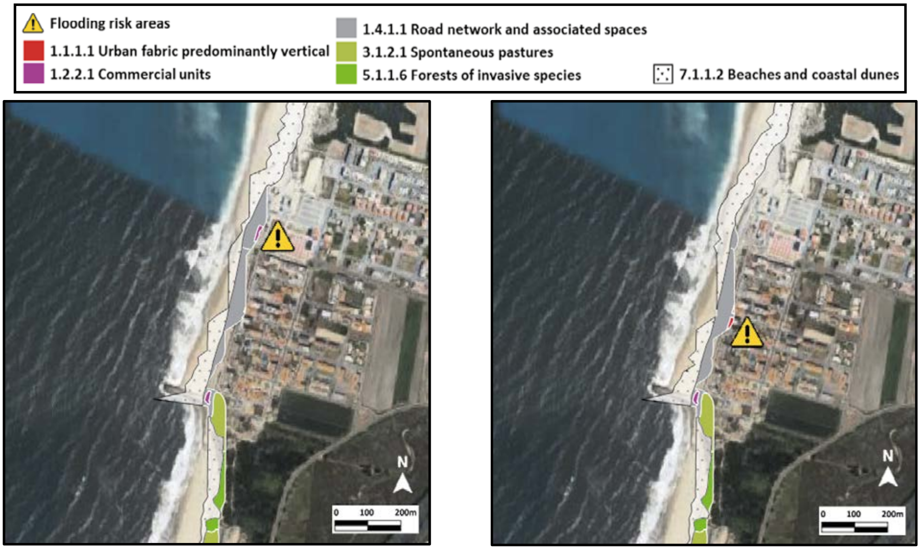
In terms of avoiding coastal flooding, the highest benefits of deploying the breakwater are perceived by the road network (class 1.4.1.1) and the commercial establishments (class 1.2.2.1) closer to the salient formed by the breakwater. As a trade-off, built-up fabric (class 1.1.1.1) is anticipated to be more impacted since there is an increase of erosion downdrift the salient, which reduces the beach width near the residential area. Finally, the leisure equipment affected (class 1.6.2.2) refers to a water park existing near a second groin located further south of Vagueira. The water park is expected to be similarly affected with or without the breakwater.

Table 1 – Areas of LULC classes exposed to coastal flooding and erosion (green cells represent benefits from the breakwater deployment, red cells represent an increase of flooded/eroded areas due to the breakwater).

Scenario	Year	Flooded areas (m^2)				Eroded areas (m^2)		
		1.1.1.1	1.2.2.1	1.4.1.1	1.6.2.2	5.1.1.6	7.1.1.2*	7.1.1.2**
Do nothing	5	0	1 149	16 705	140	0	10 226	56 055
	10	32	1 170	17 484	196	0	13 189	78 340
	15	33	1 172	17 635	216	35	12 529	87 938
	20	37	794	16 486	341	0	12 277	97 700
L200D200	5	39	487	15 560	140	0	7 342	56 059
	10	46	508	15 743	196	0	9 842	78 291
	15	48	534	15 841	218	34	9 358	87 893
	20	54	1 335	16 800	344	0	10 397	97 335
L300D400	5	46	389	13 500	140	0	3 623	56 036
	10	320	389	14 695	196	0	5 707	78 189
	15	358	389	14 030	216	32	4 668	87 895
	20	372	389	14 417	334	0	5 016	97 289
L350D400	5	296	389	14 793	140	0	4 402	56 009
	10	348	389	15 126	196	0	6 899	78 302
	15	372	389	14 418	214	32	6 415	87 872
	20	368	389	14 391	342	0	7 264	97 237
L350D580	5	45	389	13 703	140	0	2 458	56 320
	10	300	389	14 097	192	0	3 424	78 465
	15	334	389	14 002	227	38	3 148	88 034
	20	355	389	13 928	338	0	3 546	97 603

[1.1.1.1 Continuous built-up fabric predominantly vertical; 1.2.2.1 Commercial establishments; 1.4.1.1 Road network and associated spaces; 1.6.2.2 Leisure equipment; 5.1.1.6 Forests of invasive species; 7.1.1.2 Beaches and coastal dunes (*Vagueira beach; **Other beach areas)].

Support illustrations depicting the flooding extension expected for the reference scenario and scenario L300D400 by the year 20 are presented in Figure 4. The triangle warning signs highlight the transference of risk with the breakwater deployment from the new sheltered zone (accretion of sediments promotes higher protection, particularly for commercial units painted purple) to immediately south (increase of erosion downdrift the salient promotes extension of flooded areas, particularly affecting the urban fabric painted red).



a) "Do nothing". b) L300D400.

Figure 4 – Flooding extension and LULC classes affected at year 20 of simulations.

In what concerns coastal erosion, the columns of "eroded areas" in Table 1 represent in fact net erosion, *i.e.*, the sum of erosion (preponderant) and accretion. This is because it is predicted the maintenance of a generalized erosional trend, in spite of the occurrence of punctual accretion. Regarding the 7.1.1.2 class, it is predictable to lose around 10 ha of beach area by the last year of the simulation (11 % at Vagueira beach and 89 % in other beach areas) if no intervention is made. The detached breakwater scenarios have a residual impact in other beach areas but can reduce more significantly the areas lost by coastal erosion in front of Vagueira. It is also noticeable the positive impact proportional to the increment of length and distance: scenario L350D580 is expected to represent a beach loss in Vagueira of only 3 546 m^2 by the year 20 which is significantly lower than 12 277 m^2 lost without it; scenario L200D200 would still represent losses of 10 397 m^2 in the same year. Finally, the forests (class 5.1.1.6) are expected to be little affected in any scenario since they are further away from the breakwater influence zone.

Figure 5a illustrates the position of the initial shoreline (SL) and the corresponding initial area of Vagueira beach (in striped blue hatch). The boundary that limits Vagueira beach comprises an extension of 1.2 km alongshore and encloses the area typically occupied by beach tourists, representing 16 % of class 7.1.1.2. Other beach areas existing in the model domain represent the remaining 84 % (see Figure 3). Figures 5b to 5f illustrate erosion and accretion areas for each scenario, at the end of 20-year simulations, where it is noticeable the salient formed in each breakwater scenario. According to these results, it is possible to conclude that the detached breakwater scenarios reduce erosion areas between 6 % to 27 % and increase accretion areas by 2 000 m^2 to 5 300 m^2 within the Vagueira beach domain.

Globally, scenario L200D200 is the least efficient in preventing flooding (particularly, classes 1.2.2.1 and 1.4.1.1) and erosion (particularly, class 7.1.1.2*).

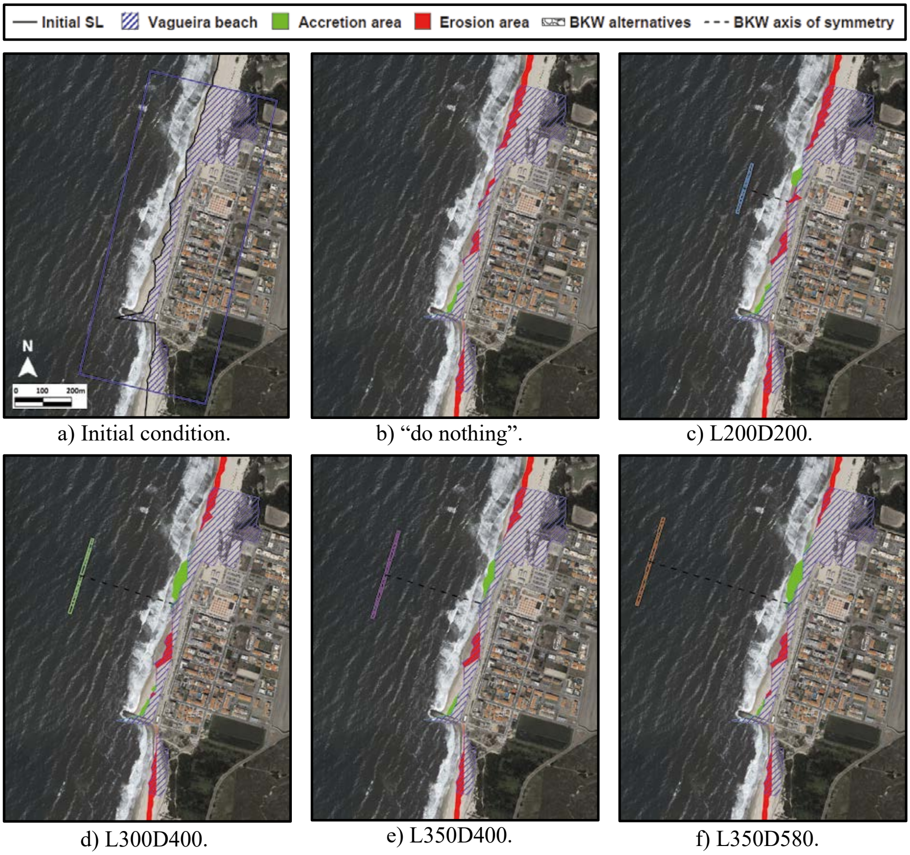


Figure 5 – a) Initial shoreline and delimitation of the initial area of Vagueira beach; b) to f) Expected erosion and accretion areas (class 7.1.1.2) at year 20 of simulations.

Discussion

The results of the present study are mainly driven by the accuracy of the numerical model used to forecast the beach response, which determines the performance of the detached breakwater in protecting Vagueira village and its natural and built capital. Although numerous computational tools exist for this purpose, all rely on simplifying assumptions. This study applied the LTC model since it is an in-house software which has already reported its accuracy in a recent study [4] that compared 15-year simulations made in the past with the real evolution of the shoreline in a coastal stretch near Vagueira.

On the other hand, this work has analysed the impact of the detached breakwater alone. However, the Portuguese Environmental Agency, which is the entity responsible for the coastal management in Portugal, has increasingly been performing artificial nourishments along the west coast. These interventions can significantly alter the forecasted morphodynamical balance and add greater benefits to the breakwater performance. Thus, additional scenarios combining beach nourishments with the detached breakwater deployment should be further investigated. In addition, to prevent the increase of erosion in front of the residential zone, scenarios for a segmented breakwater should also be simulated.

Conclusions

The objective of this work was to investigate the efficiency of deploying a detached breakwater in front of Vagueira beach, to help preserve Vagueira's natural and built capital and respective services. For this, two distinct targets were proposed: i) reduce the risk of coastal flooding in the urban settlement and ii) mitigate coastal erosion of natural areas. The numerical modelling of the case study was made in LTC software, which allowed forecasting the beach response for each scenario ("do nothing" and breakwater deployment - considering alternative lengths [L] and distances to the shoreline [D]). Complementarily, the classification of land use and land cover classes existing in the study area helped link the projections of the coastal morphodynamics with assets and services expected to be affected.

According to the simulations, the deployment of the detached breakwater is expected to promote the formation of a salient (*i.e.*, increase of the beach width) updrift its cross-shore axis of symmetry and, consequently, the increase of erosion downdrift, since no sediments were added to the system. This morphological response of the beach helps reduce the extension of flooding at the road network and commercial establishments in case of overtopping occurrence. As a trade-off, the residential area is anticipated to be more impacted since it is located downdrift the salient. The leisure equipment observed southern in the model domain and other natural areas are expected to be similarly affected with or without breakwater because they are further away from the influence zone of the coastal structure. Finally, in what concerns the recreational service that the Vagueira beach provides, it is expected to benefit from the breakwater deployment since all structural configurations analysed result in less net erosion than if no intervention was made.

Results demonstrate that there is no "one-size-fits-all" solution and future coastal management strategies must take this into account. Irrespectively of the punctual benefits and disadvantages detailed, it was noticeable a proportional relationship between the increment of the breakwater length and distance in relation to its global performance, founding out that scenario L350D580 is the one that best fits the goals proposed, followed by L300D400, and scenario L200D200 is the least efficient.

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THE TERRITORIAL ORGANIZATION OF THE AMALFI COAST: NATURE AND MAN'S INTERVENTION

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Abstract – The Amalfi Coast is characterized by jagged mountain ridges and valleys that include streams and plunges into the sea with steep cliffs, here and there interrupted by short sandy coasts. The coastal and inland towns contribute to the beauty of the landscape, rich in historical and artistic evidence from the Middle Ages. In fact, the celebrated landscape is largely the work of the intense work carried out by the inhabitants between the 10th and 13th centuries, when they shaped the steep slopes with terracing, which made the development of agriculture possible. At the same time, urban agglomerations expanded, almost unique examples of adaptation to difficult environmental conditions. A multitude of mule and pedestrian streets ran through the area, constituting the direction for urban expansion and ensuring connections between the various centers and with the neighboring Salerno and Neapolitan areas. The study aims to analyze the natural and anthropogenic components of the whole, today threatened by geological instability and by the growing demands related to traffic and mass tourism.

Headings

The Amalfi Coast corresponds to the southern part of the Sorrento Peninsula, extending between Positano and Vietri sul mare, the Lattari mountains, a branch of the Campania Apennines, the province of Naples and the valley of the Sarno river. The extremely inaccessible territory is closed behind by rugged mountain peaks and overlooks the sea with high cliffs, interspersed with deep valleys in which torrential streams flow, coming from the rear hills, which often flow into the sea with spectacular effects, like the Schiatro in the fjord of Furore.

The impassable environment was transformed into a hospitable context between the tenth and thirteenth centuries, by means of a capillary work of steeply sloping soil that led to the formation of flat terraces consisting of narrow strips of land contained by dry stone walls, which allowed the “miracle of agriculture”. The work also represented an organic control system for the land and water, captured and destined for irrigation [23]. The terracing technique was also adopted for the layout of the buildings which, resting on a lower level and adhering to the rear rocky bank, develop in height, acquiring greater thickness, as the retraction of the slope allows the expansion of the pose. A dense network of roads, mostly stairways, was traced to serve the possessions, constituting the backbone for the urban settlements, in the full fusion of the natural landscape with the built. The centuries-old isolation in which the coast lived up to the nineteenth century has preserved much of its original, exceptional naturalistic and environmental characteristics, which in 1997 benefited it from being included in the UNESCO World Heritage List.

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The naturalistic and environmental peculiarities

The area in question, with its terraced landscape [2, 8, 9, 13, 14, 24], has strong similarities with the_Cinque Terre of Liguria, inscribed in the World Heritage list with similar reasons [10, 15]. Renowned tourist destination at an international level, is generally associated with the maritime sector, with scenic coasts, rich in enchanting views, with small coves, remains of defense towers and charming towns, full of historical stratifications and grandiose emergencies. architectural civil and religious, mostly medieval, intact or in a state of ruin. The urban space is characterized by the soaring of extrados vaults, bell towers and domes, often adorned with polychrome stone inlays and colored majolica elements, crowned by the hills behind with their rugged profile and the lemon groves on the terraces.

Equally enchanting are the inland areas, where the different streams generate lush valleys, with picturesque waterfalls and rare specimens of flora and fauna. The Valleys of the Mills and Ironworks in Amalfi, the Dragone di Atrani, the Sambuco-Reginna di Minori and the Reginna Maior between Maiori and Tramonti are unique, high-quality environments that have been immortalized by Italian and foreign artists since the 19th century. Their charm is enhanced by important evidence of industrial archeology, such as mills and paper mills, which exploited the driving force of water, which have now disappeared or are in ruins.

A significant component of the landscape, which has gone unnoticed and only recently the subject of systematic surveys, is linked to the karst nature of the soil which generates many caves along the rocky walls, in inaccessible and often inaccessible places, the most imposing ones reported since the past for their naturalistic peculiarities. Used by man, thanks to the insertion and completion with masonry elements, they compose articulated systems, derived from the inseparable union between the cavity and the built parts, which are configured, at times, as autonomous organisms, which replicate the language of *sub divo* architecture, simply implanted in the cave that protects them, in other cases, as complements or closures of the same. Over time subject to significant increases and variations in use, they are largely threatened by abandonment, by abusive occupations, landslides, slopes and various phenomena, or by the isolation resulting from the cancellation of the ancient road connections [3].

So far, attention has been focused almost exclusively on episodes of a religious nature, associated with the hermit cult, especially the work of Greek monks, present on the Coast between the 9th and 10th centuries [5].

Figure 1 – The Amalfi Coast (Google Earth).
Figure 2 – Amalfi and Atrani from the west. Up Pogerola, Pontone, Ravello.

Figure 3 – Maiori, S. Maria de Olearia.
Figure 4 – Amalfi from the sea.

Some cases are famous, such as S. Maria de Olearia, installed inside a large cave, near Maiori, with a composite structure including the monastic residence and three superimposed chapels, decorated with important frescoes [1].

Recent inventory campaigns have significantly expanded the field, highlighting that the use of caves was not only for worship purposes, but involved all aspects of daily life, in which the housing function merged with the productive and zootechnical one, often gathered in very small spaces. The destination of the rock heritage for civilian uses highlights a new aspect of the Coast, already observed in other Italian areas [4], namely that the local populations of peasants, breeders and shepherds also exploited the caves for the needs of daily life [20].

The streets and urban settlements

It has been anticipated that the road network was the connective element of the whole, ensuring internal communications and pushing towards the Neapolitan and Sorrento area, the Agro Nocerino-Sarnese and the Salerno area. The impervious paths, which can only be covered on foot or by mule, took place with a hierarchical role: the main ones exploited as far as possible the less steep lines and welcomed the secondary ones, almost always steeply sloping stairways, which cut perpendicularly the slope, leading to the mountain areas and the sea, branching off into paths serving homes and crops.

The entire system of routes in the western sector of the coast was grafted on the Via Maestra dei Villaggi, a veritable monument due to its architectural, environmental and landscape features. Starting from Amalfi, with a succession of steps and rare flat sections, it crossed the seaside villages of Pastena, Lone and Vettica Minore, of which it constituted the backbone. Then climbing towards Tovere, it reached the Agerola plateau with an impervious zigzag trend, up to the Neapolitan side.

The network remained almost unscathed until the first half of the nineteenth century, when the construction of driveways completely subverted the way of traveling with the trend on the edge of the coasts, tunnels, hairpin bends, viaducts and bridgesnecessary to overcome reliefs, differences in heig ht and frequent valleys, overlapping or flanking the ancient routes [22].

Figure 5 – Atrani.

Figure 6 – Cetara.

The main roads today are the state road 163 of the Amalfi Coast “The most beautiful road in Italy” and the regional road 366 of Agerola, which greatly affected the original structure, with profound and irreversible upheavals in some of the towns crossed. The first, which runs from east to west along the entire coast, joined, in the first half of the 19th century, Amalfi with Vietri and, in the last quarter, with Positano and Meta di Sorrento; at the same time as this last stretch, the other was begun, directed from Amalfi to the Agerolino plateau and from here to Castellammare di Stabia, which ended only around 1930 [22].

Between the end of the nineteenth century and the first half of the twentieth century, connections were opened with the centers of the interior (from Atrani to Ravello and Scala, from Maiori to Tramonti), which, meeting on the Valico di Chiunzi, proceed towards the Agro Nocerino. In the last half century, where possible, the conversion of the old pedestrian road into a rolling stock has been undertaken. Despite the multiple alterations of the topography, produced over the centuries by natural events, such as landslides and floods, or by the aforementioned nineteenth-twentieth century works, it is still possible to read the primitive road development, up to the modern phases [22].

None of the coastal towns have origins prior to the Middle Ages. The territory, isolated from the rear areas and accessible only by sea, hosted some villas in Roman times - of which conspicuous remains were discovered in Minori, Positano, Amalfi and Tramonti - from which would come the large amount of bare materials - columns, capitals, urns, tombstones, etc. - extensively reused in subsequent factories.

The various villages are located both on the coast and in inland areas, at different heights and with different characteristics. Famous for their exceptional architectural and panoramic peculiarities, in reality, they are the result of ingenious adaptations to difficult territorial constraints and of the maximum exploitation of the scarce resources available. Originally it is the same settlement typology: a small nucleus of houses around a church, overlooking a road that forms its backbone and, extending itself, acts as a link with similar neighboring centers. Amalfi - the capital of the ancient maritime republic - is the main city. Located almost in the center of the coast, it marks a clear difference in layout between the towns that rise to the west and to the east. The former - Conca dei Marini, Furore, Praiano and Positano - are located high up, above rocky walls that plunge into the sea. Instead, Amalfi and those on the eastern side - Atrani, Maiori, Minori, Cetara - up to Vietri, arrange themselves at the mouth of streams, overlooking the beach and occupying the same sides of the valley in which the waters flow [21].

Thus sets of valley floors are configured, crossed by a stream, today covered becoming the main road, with the buildings arranged on the lateral slopes, reachable by stairways, sometimes with a frightening inclination and dark underpasses. The organization is conditioned above all by the width of the gorge in which they are located: narrow in Atrani - the bed of the Dragone stream being little more than a furrow - dilated in Maiori, where the course of the Reginna widens as it descends from Tramonti. The scarcity of space gives rise to a suggestive compactness of the inhabited areas, arranged on the terraces which, overlapping, often create a continuous curtain of white and sunny complexes facing the most favorable exposure with panoramic loggias. In the form of the building, we find the common characteristics of the Mediterranean countries - terraces, extrados vaults, domes, polychrome decorations - which refer to the Byzantine and Islamic traditions, introduced thanks to the intense trade exchanges with the Near East, North Africa and Spain. Amalfi summarizes all the characteristics of the eastern maritime centers. Overlooking the beach divided by the Canneto outlet, it is enclosed to the east by Monte Aureo, crowned by the medieval tower of the Ziro and ending at the sea in the Capo di Atrani, equipped with the tower called "Saracena", and to the west by impassable and rugged overhanging [12].

The dense urban fabric of Amalfi, assimilated to that of the Islamic countries, with which the city had relations since the 10th century [7], also remains in the municipalities that follow one another to the east. In fact, we find it on a smaller scale in the contiguous Atrani, compressed between Monte Aureo - in whose elevated sector there are rocky chapels and large natural cavities - and Monte Civita, on whose offshoot to the sea you can see the collegiate church of S. Maria Maddalena, on the site where at the time of the Duchy was the fortress of S. Sofia. Unfortunately, the state road, running with a multi-span viaduct, raised on the beach in the first half of the nineteenth century, irremediably occluded the view to the sea [22].

Continuing on, you will find the towns of Minori and Maiori, located in the valley crossed by the Reginna minor and Reginna maior rivers respectively. The coast, particularly extended in Maiori, is enclosed on each side by a promontory, with the viceregal towers of Mezzacapo, incorporated into the castle of the same name, guarding both shores, "Paradiso", west of Minori, and "Normanna" to east of Maiori [17].

The original center is located on the slopes that flank the central flat sector,

Figure 7 – Maiori, plan.
Figure 8 – Vietri sul mare.

crossed by the torrent covered in the nineteenth century, on which the ancient pedestrian streets coming from the small suburbs converge which, due to the elevated position and the rugged orography, retain much of their plant. On the downstream area, parallel to the beach runs the state road that formed the route for subsequent settlements, favoring, especially after the 1954 flood, a predominantly speculative building [21].

Cetara winds sinuously into the gorge defined by the stream, covered in the urban stretch, which flows into the beach, dominated to the east by the imposing Angevin tower, increased in the viceregal age. On the two sides of the watercourse, there are the ancient nuclei, the eastern one between the defensive garrison and the church of S. Pietro, the western one with a sparse texture, gathers around the former convent of the minor friars, today City Hall. Vietri sul mare, on the eastern edge of the coast, occupies a particular position on a sort of plateau, contained by high walls that plunge into the sea and into the Molina stream, at the mouth of which is the Marina hamlet, protected by the towers of Albori and Crestarella. The picturesque initial set, perched in the elevated area and dotted with domes, bell towers and buildings decorated with refined Baroque stuccoes, has expanded disorderly towards the valley in a compact aggregate that covers the entire slope.

In the area west of Amalfi, the complete variation of the urban topography is immediately perceived. Beyond the deep depression that closes the city on this side, its five hamlets extend, Pastena, Lone and Vettica Minore, which overlook the sea above high cliffs, Tovere and Pogerola, on the internal reliefs.

With the exception of the latter, reachable by a path that goes up the ravine or from the city center, the others take place mainly along the so-called Via Maestra dei Villaggi and on the transversal and parallel minors that converge there, denoting a linear organization, typical of this sector [6].

The same condition is found in Conca dei Marini, closed to the north by high rocky walls, to the south by overhanging cliffs and to the east and west by deep gorges.

Figure 9 – The coast from Amalfi to Conca dei Marini.

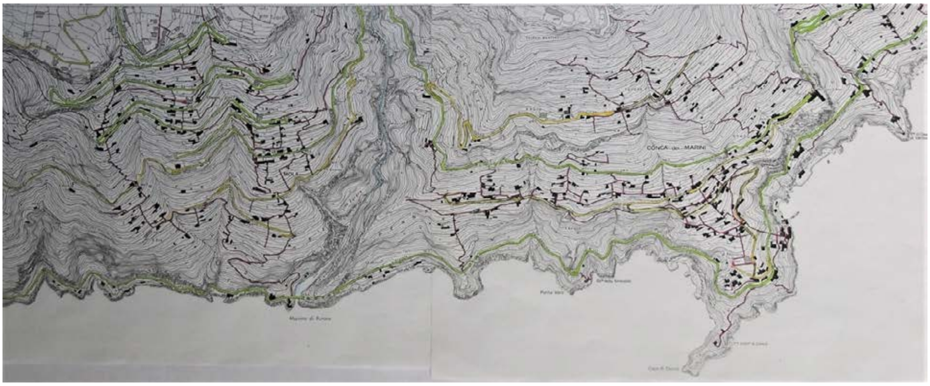

Figure 10 – Furore, Conca dei Marini, Tovere, plan.

Here, in the hospitable areas, small scattered agglomerations and a tiny nucleus were formed near the natural harbor, up to the mid-nineteenth century among the few sheltered landings near Amalfi. The buildings were arranged along the edges of the road - today made suitable for vehicles - which, following the slope, completely crosses the municipal territory from east to west, welcoming from the mountain and valley tiring stairways and touching the three parishes around which they settled in the Middle Ages the urban centers, reaching the border with Furore. About halfway there is the only open space, from which the connection with the larger nucleus started, extended on the promontory of the "Vreca, from where it branched off towards Capo di Conca, with the viceregal tower, and towards the Marina [21].

Furore extends to the west, beyond the deep valley where the Schiatro torrent, which flows into the famous fjord, on which, at the end of the nineteenth century, the bold single-span bridge of today's SS. 163. The soil, which rises from the sea up to the Agerola plateau (about 600 m) has a strong steepness, which makes it extremely difficult to travel, with few buildings arranged in a complex manner on the slope [16]. Despite the upheavals brought about by the Amalfi-Agerola, which cuts it with repeated, pronounced hairpin bends, it is possible to recognize the distribution in small groups, which is associated with that of the last century, set along the road and in the immediate vicinity.

Praiano and Positano fall into a different typology, being distributed on the slope in a not very compact way, by overlapping alignments served by stepped connections, which cut the level curves at 90°.

The first is made up of Praiano and Vettica Maggiore, which occupy the two sides of the promontory that ends at the sea with Capo Sottile, so they face east and west respectively. Praiano, at a higher altitude, is just lapped downstream by the SS. 163, along which the recent expansions line up, and crossed by a road that leads to the square in front of the parish church of S. Luca. A similar organization is found in Vettica Maggiore, located up to the limit of the eminent coastal cliffs. The village, at the center of which is the church of S. Gennaro, is entirely penetrated by the state road [21].

Positano develops along the gully that acts as the main road.

Figure 11 – Vettica Maggiore.

Figure 12 – Positano.

The eastern side, which descends to the "Spiaggia Grande", is gentle, the opposite occupies the sides of the hill that rises between the central beach and that of Fornillo, extending to the top. The primitive structure, even if it is not disturbed by the state road, which surrounds it upstream with a sinuous trend, however, appears to have changed due to the enlargement of some old tracks. Despite this, the ancient road network is still identifiable, which features longitudinal main roads, connected by orthogonal secondary roads that go up the ridges, serving the residences which, leaning against the rocky bank, constantly change orientation [21].

The inland towns, Scala, Ravello and Tramonti, are made up of nuclei scattered over very large territories, at different altitudes.

Scala extends on the ridge overlooking the Dragone valley from the west. It consists of a main aggregate, pertaining to the former cathedral of San Lorenzo, and several hamlets that are arranged longitudinally from north to south, on roads that follow the contour lines, with buildings upstream and downstream. Today connected to the provincial road, in the past it was reachable only through the winding climbs from Atrani and the northern area of Amalfi. The latter comes to Pontone, whose very sloping ground exploits a winding system around the ridge, on whose southern limit the imposing and spectacular ruins of S. Eustachio. From here a steep flight of steps, continuing north, goes to the other villages. The environment is very suggestive, due to the presence of churches and palaces of medieval origin, some still adorned with stone inlays, and Arab baths [18].

Ravello, located on the opposite side of the valley, reflects a different condition, with nuclei aligned on the edges of the roads going from north to south and on the long tiers, perpendicular to the level curves, which go north or descend east, up to the sea. The largest inhabited area extends over a tapered plateau, on the top of a massive rocky spur emerging between the Sambuco and Dragone valleys, in whose almost vertical walls there are interesting karst phenomena that give rise to numerous caves. Gathered around the former cathedral, it is famous for the presence of religious artistic emergencies and medieval palaces, among the most important on the coast - such as the well-known Villa Rufolo - which stand out with their size inside the center. It retains the original structure with an elongated oval shape, with exclusively pedestrian streets, which ends on the sheer wall on which Villa Cimbrone is located. The context is characterized by the widespread presence of structures in which inlays, bare elements, Arab baths, are preserved.

Figure 13 – Ravello.

Tramonti extends into the Reginna basin, north of Maiori, on a vast territory, in which steep parts alternate with others of moderate slope, with a complex and atypical aggregation. It consists of thirteen hamlets, which go from south to north on the two sides of the valley where the river flows with its tributaries, composing small villages around a church, exploiting more or less flat areas and connected by a dense network of streets, today, made almost entirely suitable for vehicles. Running from an altitude of 150 m a.s.l. of Pucara at 650 m of the Chiunzi pass, has extremely varied landscapes, from almost maritime to mountainous, with woods that take over as you go upwards [19].

As can be deduced from these notes, the conservation of the traditional environment of the Amalfi Coast cannot ignore the enhancement of all its components, both natural and attributable to human intervention, which has created a unique whole, shaping terraces, implanting cities of great architectural and artistic value in difficult and inhospitable sites, generating a panorama celebrated all over the world. These characteristics were the basis of recognition in the UNESCO Heritage List (criterion I, IV, V, Integrity and Authenticity), as values to be passed on to future generations [11].

Figure 14 – Amalfi, Scala, Ravello, plan.
Figure 15 – Tramonti to Pucara at Polvica, plan.

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ATMOSPHERIC AGENTS AND SPATIAL PLANNING. CASE STUDY OF THE MUNICIPALITY OF ROSIGNANO MARITTIMO IN TUSCANY

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Abstract – In recent years, the municipality of Rosignano Marittimo in Tuscany has been repeatedly affected by more and more intense weather phenomena, which have caused damage to people and urban settlements along the coast. Extreme weather events such as intense downpours, floods, whirlwinds and powerful sea storms, together with critical issues due to ongoing coastal erosion, highlight a number of problems.
The Council administration has recently participated in the ADAPT European project, a Program of transborder cooperation between Interregional Maritime Italy and France - 2014 - 2020, aimed at defining a local Climatic Profile and a Plan of Adaptation to Climatic changes. At the same time, the editing staff of the municipal structural plan has started a method investigation in coherence with the regional Tuscan law no. 65/2014 on the governance of the territory, with the scope of finding answers to some of the critical issues investigated. However, the topic of climatic change expresses deep profiles of uncertainty, due to potential long term climatic response times, as compared to possible actions to be taken today. The evolutionary framework of the coastal belt produces a dynamic definition of a coastline to which the continuous delimitation even of areas of maritime state property assets, correlates in the making. Therefore, the dynamism of the coastline immersed in uncertain flows of atmospheric agents raises a fundamental question to the delimitation of state property areas, on which the political decision maker is called upon to express himself through a territorial planning setup.
The physical definition of the coastal system and the management definition of same are topics that are treated in the present paper, that sets the goal of defining a possible methodological approach through the presentation of the case study for territorial planning in coastal areas, able to define a flexible cognitive framework, by means of which to distinguish strategies in the short and long term, for planning and managing of maritime state property assets.

Introduction: a glance at Gaia

It was in 1979 that James Lovelock began to outline the hypothesis that the Earth could be considered living, governed by large, self-correcting homeostatic cycles. Lovelock calls his hypothesis Gaia, in honour of *Gaia* of the Greeks, because «in the minds of men of antiquity, the Earth has always been the generator and the nurse par excellence [...] and the concept of "Mother Earth" is a category of the spirit that still persists in the great religions.»[4] For Lovelock, the word Gaia «serves to denote [the] hypothesis that the biosphere is a self-regulating entity, that it establishes the material conditions necessary for its own survival and

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that living matter does not remain passive in the face of what threats its existence.» [4]

In summary, his hypothesis takes into account a number of key aspects, including: «(1) [...] the tendency [of Gaia] to optimise conditions for all life on Earth. [...] 2) [That Gaia has] vital organs within it, as well as others that exist in abundance particularly on its periphery and that can be used. [...] 3) [That Gaia's] responses to worsening changes [must] obey the rules of cybernetics, in which time constant and ring gain are important factors» [4].

The Gaia hypothesis has had mixed fortunes, seen by some as an indemonstrable para-scientific hypothesis. Until recently, scientific and philosophical debate, also linked to the concepts of the Anthropocene and the New Climate Regime, brought it back to the forefront, for example, with the anthropologist of science Bruno Latour [3]. It was precisely in analysing climate mutations, that, Latour began to reflect on the irruption «of this monster, half hurricane, half Leviathan, with a bizarre name, "Cosmocolossus", until I soon merged it into an equally controversial figure I had conceived while reading James Lovelock, the figure of Gaia. I could no longer escape: I had to understand what was coming at me in the rather distressing form of a force that was at once mythical, scientific, political and, probably, also religious» [3]. It is with Lovelock that Latour becomes familiar with the concept of Gaia, as a living planet with an atmosphere in chemical disequilibrium. If this is the case, says the anthropologist, the Earth must have some sort of *agency* «that allows it to maintain, or recover, over billions of years, a state of affairs durable enough to counter the perturbations introduced by external events - the increasing brightness of the Sun, asteroid bombardments, volcanic eruptions» [3]. After a substantial treatment of the subject, which we certainly cannot summarise here, it becomes necessary for Latour to think that the current human inhabitants of the Earth (the Terrans) must overcome their old conceptions of their relationship with Nature, to become aware that they are immersed in Gaia insofar as «the two sides share the same fragility, the same cruelty, the same uncertainty about their destiny. They are powers that cannot be dominated and cannot dominate» [3]. This is why the anthropologist emphasises that a new paradigm should push us «to get rid of the expressions "modern", "nature" and even "ecology", [...to] "move from the Ancient to the New». [3].

Another philosophical horizon is opened by Timothy Morton in outlining the realm of *hyperobjects*[1]. *Hyperobjects* are increasingly emerging in the framework of philosophical reflection as «entities that become visible only by resorting to post-Humean statistical causality» [5]. Among them, Morton puts climate and other recently discovered entities «that make us reflect on our place on Earth and in the cosmos. Perhaps this is the key point: hyperobjects force us to reconsider the fundamental ideas we have about what it means to exist, what the Earth is, what society is» [5]. The emerging *hyperobjects* are a new test of man's positioning within his own world. After the Copernican revolution, which removed man from the centre of the universe, the downgrading of man as a divine creation due to Darwin, the ousting of man from the centre of psychic activity thanks to Freud, etc., it is now

[1] Access to hyperobjects does not occur by travelling a distance, through some transparent medium: the hyperobjects are here, right here, in my social and experiential space. They look at me menacingly like faces pressed against a window pane: and it is precisely their proximity that threatens me. [...] Every day global warming burns the skin of the back of my neck causing me itching, discomfort, a vague sense of apprehension. Evolution unfolds in my genome because my cells are constantly dividing and mutating, because my body clones itself every time one of my sperm fertilises an egg. As I reach out to grab the iPhone charger attached to the dashboard, I break into evolution, into the extended phenotype that certainly does not end at the edge of my skin, but extends into all the spaces that my 'being-human' has colonised.[5]

the *hyperobjects* that pose new problems. In fact, for Morton, «ecological thinking that reasons about hyperobjects does not conceive of individuals as embedded in a nebulous global system, nor, on the contrary, does it theorise about an entity larger than individuals that moulds itself from time to time into individual forms. Hyperobjects stimulate *irreductionist* thinking because they pose scalar dilemmas to which it is not possible to respond by establishing ontotheologically what is more real - the ecosystem, the world, the environment or, instead, the individual» [5].

From a historical point of view, the recent IPCC report (2021) exposes weather changes in every region of the Globe and the entire climatic system without precedents, and is irreversible, in hundreds or thousands of years. The report highlighting human influence on the climate both past and future, contributes to fundamental decision processes for limiting ongoing climatic change, at this stage only possible through a rapid and constant reduction of carbon dioxide (CO2) emissions and other greenhouse effect gases. Today, deciding to reduce climate altering gases on a large scale would mean sure benefits on air quality in the short term, but we would have to wait another 20 to 30 years to see global temperatures stabilize. Differently, the rise in temperature, even by only 1,5°C, would mean changes in water cycles, with heavy rains and flooding on the one hand, and severe drought in several regions, on the other. Coastal areas will be characterized by a continuous rise in sea level with more frequent coastal flooding in a much reduced time scan of events.

In Italy, a new climatic model was presented in 2018, with the variation of level of the Mediterranean, which was the result of a study by a group of ENEA researchers, in collaboration with the MIT of Boston. Its aim was to map coastal areas that risk flooding, as well as planning the territory and making it safe. The studies presented foresee that there will be a loss of tens of square kilometers in Italy's coastal areas by the end of the century, with receding beaches and agricultural areas, where half of the Italian population is concentrated.

Dealing with the problems of the new climate regime, even at the local level, poses a not inconsiderable philosophical and epistemological problematic horizon.

Materials and Methods

Gaia's theory prompts reflection on the feedbacks that are now evident even at the local level. This article brings together the in-depth studies developed on the coastal reality of the municipality of Rosignano Marittimo[2], for an area relating to the coastal strip from Caletta to the sea mouth of the industrial canal of the Solvay Chimica Italia S.p.A. plant.

The municipal administration has recently participated in the European project ADAPT[3], a cross-border cooperation programme between Italy Maritime Interregional and France - 2014 - 2020, aimed at defining a Local Climate Profile and a Climate Change Adaptation Plan. At the same time, the drafting of the Municipal Structural Plan started a methodological investigation[4], consistent with the Tuscan Regional Law 65/2014 on the government of the territory, with the aim of finding answers to some of the critical issues investigated.

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[2] The research area falls within the Municipality of Rosignano Marittimo (LI), located in the central part of the Tuscan coast, in the Province of Livorno.

[3] http://www.comune.rosignano.livorno.it/site5/pages/home.php?idpadre=36878

[4] Research Coordinator: Prof. Saragosa C. Title: "*Lo studio dello Statuto del Territorio del Comune di*

A first body of studies[5] essentially concerns the definition of the local climate change profile, with particular attention to the variation of rainfall in relation to the future values assumed by the climate indices in the RCP4.5 and RCP8.5 emission scenarios. On the one hand, the work identified the cumulative annual rainfall as a 30-year average with reference to the processing of the indicative values provided by the ISPRA and PNACC studies and the estimates derived from local trends. While on the other hand it assessed the drought phenomenon over time, through the analysis of the maximum number of consecutive dry days per year, by means of the historical elaboration of the average spatialisation between the different measuring stations, with reference to the 2015 ISPRA studies. The analyses performed made it possible to define the rainfall heights of maximum rainfall over time, through Gumbel statistical analysis. In relation to the different studies used to define the local RCP6 and RCP8.5 scenarios, the sea level in future projections was estimated.

A second body of studies is aimed at characterising the vulnerability of the territory through the assessment of the impacts that climate change may generate on urban settlements consistent with the IPCC (2014) definition [2]. The study based on remotely sensed data (LiDAR, high-resolution remote sensing imagery, and from the LANDSAT 8 platform) prepared a methodology [1] for estimating current ground temperatures and future climate projections.

A third body of studies carried out a series of analyses with the aim of providing quantitative information on the evolution of erosion processes[6] that affected the portion of the coastline under investigation in the period between January 2010 and September 2018. To this end, multi-temporal analyses were conducted by studying aerial photos, optical images and satellite radar using PhotoMonitoringTM techniques for the identification and analysis of the geomorphological evolution of the coastline falling within the study area.

A fourth body of studies concerns the analysis of the hydrographic network in relation to rainfall events with the relative hydraulic hazards and 30- and 200-year return times, estimated by law[7].

A fifth body of studies analyses the five meteorological events that have produced significant damage to the area under study over the last eight years, due to the development and transit of tornadoes[8], identified according to two distinct groups of phenomena.

Rosignano come fondamento della redazione del nuovo Piano Strutturale L.R. 65/2014". University of Florence - Department of Architecture DiDAlabs - Laboratory Plans and Projects for the City and the Territory - Research Group: Prof. Saragosa C., arch. Chiti M., arch. Tiffany Geti, urb. Rossi M., urb. Bartali L., urb. Miccio A., urb. Tanganelli A., urb. Iacometti F., urb. Montoro G., urb. Rossi G.

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[6] Title: "*Analisi geomorfologica mediante tecniche di telerilevamento dei processi di erosione costiera lungo la linea litoranea tra Rosignano Solvay e La Mazzanta a supporto degli studi del Piano Strutturale del Comune di Rosignano Marittimo (LI)*", NHAZCA S.r.l., Spin off di Sapienza Università di Roma. Prof. Mazzanti P., PhD Romeo S. Referring to 2019.

[7] Title: "*Studio idrogeologico preliminare al nuovo Piano strutturale*". Edited by Myricae srl, Geotecno Studio Associato, Chiarini Associati. Referring to 2019.

[8] Title: "*Analisi degli eventi con trombe d'aria su Rosignano (LI)*". Edited by Consorzio LaMMA – Laboratorio di Monitoraggio e Modellistica Ambientale per lo sviluppo sostenibile, Area della Ricerca CNR. Referring to 2021.

Results

Gaia's Feedback

Studies on the variation of rainfall in climate change show a projection of a contraction of time-concentrated weather events. The climate change we are currently seeing the effects of, therefore, does not involve a substantial variation in the amount of rainfall over the year, but a concentration in particularly intense events. This variation has a relationship with the modelling of the terrain and the existing hydraulic reticulum, which was formed under totally different rainfall conditions and is therefore capable of disposing of different meteorological phenomena. Already, the hydraulic reticulum entered into distress at a 30- or 200-year probability interval. With the variation of rainfall and its concentration in particularly intense events, the entire system, characterised by the modelling of the soils, if not redefined quickly, will enter into crisis, producing critical phenomena, even of considerable danger, that will be difficult to manage with simple prevention and civil protection.

A second analysis concerns the variation in temperature over time with particular reference to the perception of heat on the ground. Here, too, there is a substantial variation in environmental conditions over time. The variation can in fact change the habitability of entire parts of the city, which tend to become excessively hot over time, profoundly affecting living comfort. Entire public areas, used to perform various urban functions, may, as conditions currently stand, be unfit for any use for most of the daytime hours, especially in the summer season.

One of the most important feedbacks, due to climate change, is the rising sea level. The rise results in the ingress of sea water into the parts of the land located at lower altitudes and therefore particularly into the sandy parts of the coast. This phenomenon is intimately linked to what is happening with the problems of coastal erosion due to changes in sea currents and the reduction of solid contributions to the sea due to the use of riverbed materials and other works that interrupt the transport of solid materials. In reality, the coastal strip is

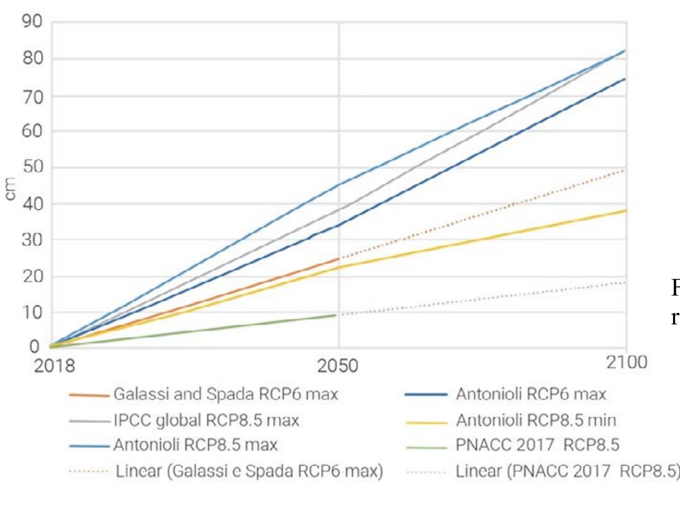

Figure 1 – Sea level rise analysis.

an important resource for the reality we are trying to study. In this very limited strip of land, partly sandy, partly rocky, all the seaside tourist activity takes place, which feeds a substantial local economy. The loss of this coastal strip, which constitutes the vital seaside tourist park, will entail the necessary revision of the tourist economy that has been produced over time. A tourist economy whose foundations are based not so much on specialised enterprise as on the complex management of the existing built heritage.

More difficult to correlate with climate change, are calamitous events that have occurred recently in the area. These were a series of tornadoes that hit the coast, causing damage to both building structures and street vegetation. Many residential structures and some sports facilities were blown over, and many of the vegetation furnishings, mostly consisting of pine trees of a certain age and therefore size, were felled. Both the building materials and the large trees that were felled produced events that bordered on tragedy.

The morphological features of soils and the answer to hydraulic cycles

The events, summarised in the previous paragraph, have a violent impact on the pre-existing morphological system. If the forms that occur in the various territorial realities are forged over time for the correct flow management, at the moment in which the flows (of matter and energy) change in their quality and quantity, the shapes may become inadequate to respond to the necessary flow management work. Their inadequacy may lead to an alteration of the sense of well-being felt in inhabiting them or, more seriously, they may represent an obstacle to the flow and potentially even become lethally dangerous.

In the first case, by example only, the reduction in the surface area of coastal areas, especially sandy ones, may lead to the abandonment of the coast's use for tourism purposes, reducing the economy linked to hospitality, whether professional (hotel structures, catering establishments, loisir services) or in second homes (much of the existing building stock in the area under study is destined for hospitality, especially during the summer period). Again in the first case, the variation in ground temperatures can generate urban areas, under the current morphological and material conditions, that are difficult to use for a large part of the population (especially the somewhat elderly); in fact, heat islands are formed that can poorly guarantee the well-being necessary to carry out many activities.

In the second case, again as an example, the situation can even become lethal. Let us think of the inability of the existing hydraulic system to handle very intense punctual meteorological phenomena, producing more and more floods that, at least in the local situation we are studying, with buildings also subjected to levels below the water flow level, can have dramatic effects. Or let us think of the vegetal furnishings that, also taking into account their ageing, are subjected to phenomena linked to previously unknown winds, are literally eradicated, ruining them to the ground in a way that is sometimes catastrophic for things and people.

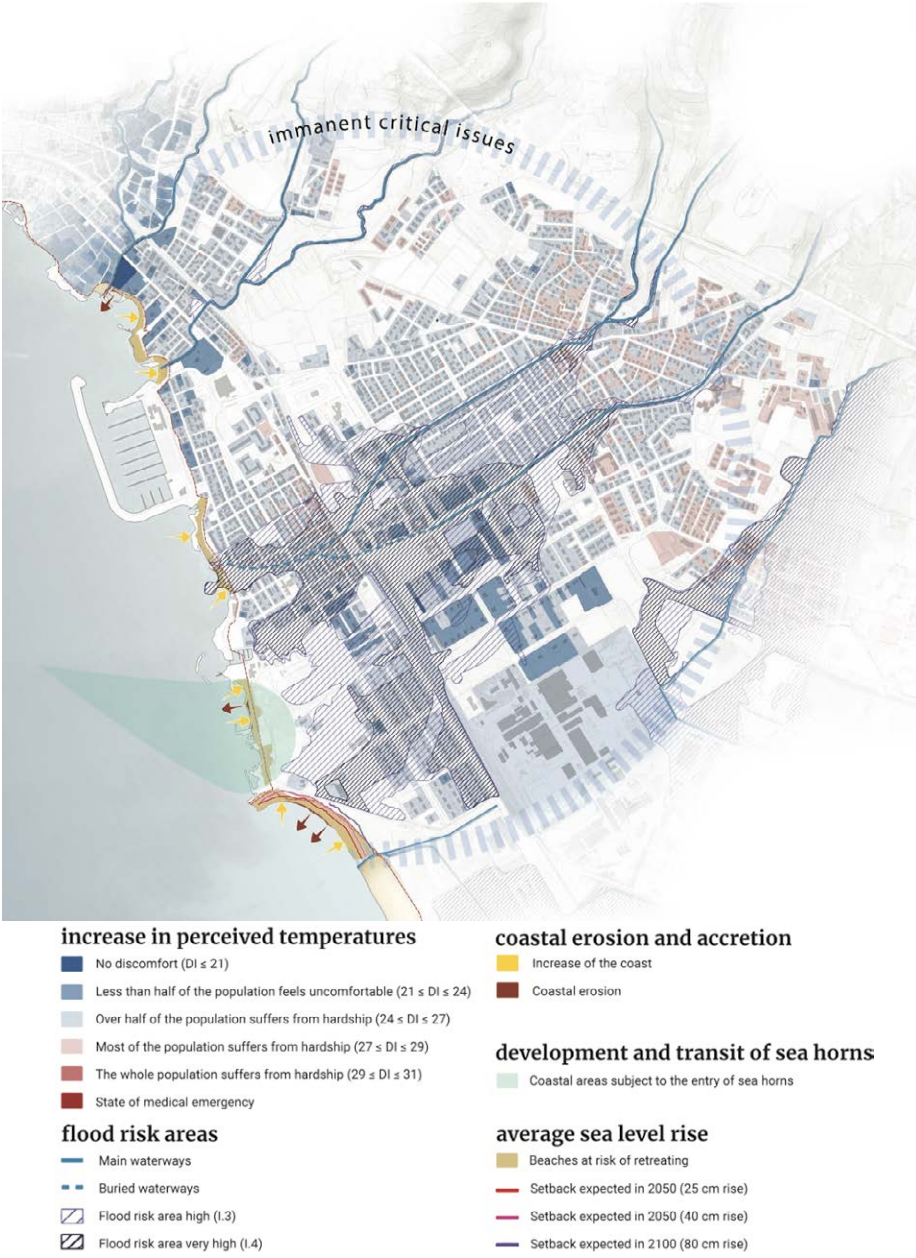

Figure 2 – Immanent critical issues: perceived temperatures (discomfort index), flood risk area, coastal accretion and erosion, sea level rise.

Immanent criticalities, settlement pattern and climate change resilience issues

Unfortunately, the morphological conditions of the hydraulic network and human settlement have evolved over time under completely different environmental conditions. This entails a difficult adaptation, being mostly rigid structures, to the changed conditions. In this context, the re-configuration of space becomes necessary, driving even urban planning to be challenged with innovative interventions to modify physical structures and the existing vegetation system of significant magnitude.

It will be necessary, for example, to re-organise the entire hydraulic system that has stratified over time. The hydraulic network, in fact, will not be (and was not even under the meteorological conditions of the past) able to manage rainfall flows that are significantly different in quality and quantity from those currently being experienced. It will be necessary, therefore, to act by modifying the hydrographical structure, both with lamination basins designed to slow down the flow of water, but also, at times, with the overall re-designing of the network so as to, if possible, increase or deviate the flow that involves the most compact human settlement areas.

The vegetation apparatus, which enriches our cities, will have to be substantially revised, both to avoid, as we have seen, the abatement due to high-energy events (tornadoes) that occur on the coast more and more frequently, and to combat, as far as possible, the growth of heat islands that are increasingly present in this phase of climate change. Vegetation is undoubtedly an effective regulator of ground temperature, although its arrangement must find perceptive relations with the deep identity of the urban configured space, composed of squares, streets, blocks, buildings with their own relational needs. On the other hand, it is also with the reconfiguration of the urban built environment that positive effects can be achieved in controlling ground temperatures. The reorganisation of the built space could take place with systems that provide shade, such as covered pathways, arcades, building protection systems, etc. A different organisation of urban water management could also play an interesting role, with systems for conserving the flowing water resource and its reuse with respect to the possibility of cooling the built environment.

Moreover, town planning must be confronted with socio-economic aspects, for example in the case under study, in the definition of a new model of tourist reception and in the redefinition of the relationship between man and the resources of the system related to bathing, which will see their significant changes. The problem now becomes particularly interesting, given that the management of state-owned maritime areas will have to be reviewed with the application of the new regulatory apparatuses linked to the decrees on competition in application of European Union directives. In this case, it is a matter of finding a functional balance between reception and use of the coast and the sea, which must in any case envisage an overall reorganisation of the system and of the ways of using the resource, which will appear increasingly varied and limited in size over time.

Conclusion

As, albeit in extreme synthesis, has become evident, the studies that have been prepared for the coastal reality of Rosignano Marittimo show that climate change is no longer just a process distant from local perception, but that on the contrary it has significant effects right in the various territories: the feedbacks from the biosphere take on consequences that were previously unimaginable. From this process, it is necessary to set up a series of activities to modify the forms that constitute the settlement patterns in order to adapt these morphologies towards the modified flows generated by climate change. The operations are substantial and are declined by the concept of urban regeneration. It is therefore not just a matter of managing the emergency, but activating a process of settlement system reconfiguration.

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A NEW PROPOSAL FOR A STRATEGIC AND RESILIENT REGENERATION PLAN FOR SEASIDE WATERFRONTS. AN ADRIATIC CASE: RICCIONE

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Abstract – Affected by the increasing violence of the effects of climate change and the neglected awareness of unavoidable sustainable planning, the border areas between sea and land face recurring emergencies and worsening natural risks. That special environment along the coastline, sometimes still enveloped by wilderness, sometimes strongly marked by urbanisation, is threatened by the sea level increasing and the progressive coastal erosion with irreversible injuries. Consequently, several different and innovative strategies must be arranged to compensate for the effects of change and ensure a future for these territories.
The case study concerns Riccione, an Adriatic city and a seaside resort, which presents an easily recognizable and remarkable typological model for urban structure, consolidated economic organisation, social relationships, and an appreciable balance between people needs and the natural resources. In this context, the research attempts to propose a new territorial strategy to innovate the regeneration process based on new resilience conditions. The approach suggests local actions at the local level (planning and traditional procedures and innovative interventions aimed at a spatial-functional requalification of the whole waterfront system), but also at the territorial level (embedding urban elements and natural coastal components, economic issues and environmental needs).

The weakest spot in the coastline system

As in the past, once again the coast shows itself as an extraordinary place where natural processes and human actions manifest their changes and interactions. In a most evident and dramatic way, the coast is constantly affected by land consumptions for urbanisation, industrialization, and infrastructure development; even in the same time protected coastal reservation areas increase and a stronger attention is paid to surviving marine natural areas. If sudden and very violent storm surges as well as the silent but constant erosion of the shores alarmed communities pushing for new attempts to control coastal natural hazards, the devastation of inlands and the effects of a hydrogeological instability spill excess water and mud toward the coast warning about the weakness of this environment.

Everything makes the coast a weak but resilient demarcation between an advancing system and another forced to retreat, from time to time confusing which realms is really next to surrender and remarking how the coast is a changing environment that only at alternating periods, with more or less long laps seems to find forms of stability.

Along the coast line, in fact, the natural morphologies are temporary; and all the processes of use of this very particular context appear transitory, as well as the settlement

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systems that have followed one another over time: like footprints on the shoreline, no form can be said to be definitive and lasting.

Consequently, the coastline environment, sometimes still wrapped in wilderness, sometimes strongly marked by urbanisation, threatened by the increase in sea level and the progressive erosion of the coast with irreversible injuries, requires a number of different and innovative strategies to compensate for the effects of change and ensure a future for these territories.

Very strategic cores of this complex coastal, the seaside resorts over the past years changed from simply touristic locations or attractive holiday destinations in large and intensive urban settlements, marked by composite economic organization based on mixed and different activities: A complex 'sea vacation machine' with very high environmental impacts, though with very high incomes for tour operators and local stakeholders: It is easy (maybe cynical but not misleading) to suppose that degradation of the basic resources of this powerful economy is the real trigger of new sensitivity for the protection and safeguarding of the coastal environment. Anyway, just in the urban centres of the coastline we could recognize the most environmentally impactful settlement and at the same time one of its weakest spots, for they are exposed not only to uncertain tourism flows and trends (as we recorded during the pandemic), but also to the already known degradation processes of the urban settlements (congestion, land consumption, urban quality levels decreasing, facilities obsolescence) and to the extreme natural events such as coastal storms, floods, and landslides, as well as longer-term risks of coastal erosion and sea level rise.

According to these remarks, the following considerations attempt to outline a proposal for a planning strategy to ensure sustainable and resilient development for large urban seaside resorts. In fact, the paper is intended to present an innovative focus on the coastline topic, moving from the analysis of the seaside waterfront's peculiar features but refusing the current separation of border areas (seashore, beach, promenade, and buildings overlooking the seaside) from the rest of the urban organisation. The waterfront is not intended as a borderline, but rather as a complex and integrated urban border area, with potential regeneration characteristics that are also strategic to trigger a redesign of the entire urban settlement.

A new policy for an 'inter-relational' coastal territory aware of the waterfront as a multitude of anthropogenic functions and landscape morphologies will be the key to understand in a single regeneration action all the complexity of a coastal seafront. This will be the first step towards defining a new city-beach-sea relationship.

The paper remarks the need for a methodological approach concerning coastal areas, taking into account all the issues emerged in the survey (i.e. relationships and urban features shaped by the touristic vocation, sandy shores as a well-identified space in the city, the related symbolic value, etc.). These elements are crucial for the development of a strategic planning led to empower a resilient urban-coastal landscape, ensure the economic development of a seaside resort well matched with the natural environment, cultural heritage and social identity matrix.

A peculiar context and local coastal issues

To develop a new strategy for a sustainable approach for a large and urban seaside resort, we focused on one of the most important sites on the Romagna coastline, Riccione, in the ‘Adriatic riviera’: One of the best known destinations of international tourism in northern Italy. Although we are talking about one of the most developed “sea vacation machines” (for its high-quality beach infrastructures, the potent set of attractive resources, the best holiday accommodation organisation supported by very comfortable private and public facilities), the area tackles the same threats as the whole Italian coast does.

The case study involves the Adriatic city of Riccione, a seaside settlement that presents an easily recognizable and analyzable typological pattern in the peculiar, urban, and social relationship between human needs and natural space. The look at Riccione represents the choice of analysing a ‘mature’ context, with consolidated urban characters and in progressive evolution to the ecological, social and economic conditions: a territorial ‘coring’ to understand in detail which new strategies and actions to put in place.

In fact, Riccione, even if its seaside economy started at the beginning of the last century, developed mainly in the 1950s when it became one of the most organized resorts of the “riviera romagnola”: Very requested destination for many Italian families, tasting the effect of post-war economic success, increasing salaries, when seaside vacations became a middle-class status symbol more than a healthcare factor. The success drove an urban development which, though in moderate forms, enlarged the urbanised areas, sieged the seaboard and limited the beach extents, converted natural areas in built-up neighbourhoods for quite 60 km from Ravenna to Gabicce. This stretched urban organisation has seemed in a fragile environment balance, which today is now close to risk for multiple factors, largely attributable to the effects of climate change.

The first consequence of this fragility can be identified in the damage caused by the extreme events that injury the Italian coasts, with risks of natural disasters and the prospect of a constant worsening of the intensity with which the phenomena strikes. These concern both catastrophic events, such as hurricanes, tornadoes, and cloudbursts capable in a few hours of destroying kilometres of coastline causing serious damage to beach facilities, and a gradual increase in wave energy that may become significant in the future.

For this reason, one of the greatest risks that may affect the waterfront is being gradually 'erased' by coastal erosion and sea level rise. For many years now, sandy coastal areas have been subject to shoreline retreat, through a more or less violent action depending on regional geomorphological contexts [1]. The causes are found not only in the gradual melting of the glaciers that raise the sea level, but also in the destruction of the dune cordon and the construction of ports. But that is not all; in fact there is also the problem of salt rising along the rivers, which would lead to very serious events even inland, starting with the territories closest to river mouths.

Then, geodynamic forecasts show how the sea level gradually rises and there are territories that are more subject to subsidence, as the cases identified between the Po Delta and the north Romagna coast, also due to massive extraction of gas from the soil [6]. The environmental pressure due to climate change is accentuated by the excessive (and unplanned) use of coastal areas that were ‘invaded’ by mass tourism. The almost complete saturation of the land guaranteed a rich economic return, but the original character of the sites was lost, transforming the green cities into a compact expanse of residences and hotels [6].

So it is a combination of anthropic and climatic actions that influence the state of coastal environments: while the effects of global warming have led to a consequent increase in surface water temperature, as well as marked fluctuations in sea level [1], unplanned land consumption near the coast increases the severity of damage.

For years, there has been a succession of plans that deal with the problem of coastal erosion, proposing solutions and operations aimed at safeguarding and defending sandy sediments through beach nourishment, beach restoration, construction of winter barriers to protect both beach facilities and the sediment volume of the beach.

In this regard, sand dunes and the extension of submerged erosion barriers are interventions that, while protecting beaches from erosion risk, are mechanical and artificial in nature, so they still cause an impact, although controlled, on the land [8].

These actions are provisional; in fact, they aim to maintain the natural and socio-economic multifunctionality of the complex coastal system [1]. The problem of coastal protection meets other problematic issues in the application of European legislation on beach concessions that recently has been at the centre of a lively political debate and a clash among operators. The social and environmental dynamism that characterizes coastal areas, combined with their high physical vulnerability, draws attention to the need for a unitary policy that is attentive to future prospects and capable of holding together a constantly changing system, on which insist not only landscape values but cultural and economic values that need to be preserved.

An urban planning focused on coastal areas, in addition to being a fundamental prerequisite for a correct management of interventions, would have the task of regulating economic activities and protecting the territory of the land-sea interface, guaranteeing its tourist development and environmental sustainability [5]: such as the management of sandy shores, which remain stuck in rather obsolete instruments, whose most innovative content appears to be due only to the spatial organization imposed by the current epidemiological situation, rather than proposing new layouts and new forms of arrangement and use, which take environmental issues, which could lead the project for the 'beach space' [2] towards a qualitative rethinking of its functional structure, so that the entire waterfront could be translated into a shared process of spatial-functional regeneration, capable of connecting according to a plurality of relationships, city and coast.

The analysis of the case study

The case study involves the Adriatic city of Riccione, a seaside settlement that presents an easily recognizable and analyzable typological pattern in the peculiar, urban, and social relationship between human needs and natural space.

Riccione represents the opportunity to analyze a ‘mature’ context, with consolidated urban characteristics and a settlement in progressive ecological, social and economic evolution: a territorial ‘coring’ to understand in detail which new strategies and actions to implement. In this context, which we could easily describe as a paradigmatic ‘Adriatic seaside typology’, the research attempted a proposal for a territorial strategy, for a possible innovation of the regeneration process marked by the identification of new conditions of resilience, translated into design guidelines and actions that can enhance a spatial functional redevelopment of the whole waterfront system, linking a plurality of urban and coastal relationships.

Moreover, innovation is already taking place in the administrative field through the adaptation of the current urban structural plan into a new PUG (*Piano Urbanistico Generale*) as imposed by the new Emilia-Romagna Regional Planning Act n. 24/2017, through which a strategic framework marked on increasing resilience by mitigating hydrogeological risks and increasing soil permeability, economic growth, qualification of public spaces and the natural environment will be territorialized.

The real challenge will be to be able to use the new tool as a possibility to work on the urban edges of the city-beach boundary (which falls under the current 'Piano degli Arenili'): important lines of union and hinge, between two territorial parts and two social and economic realities that look at each other and interrelate exchangeably within the complex and unique system of the seaside waterfront.

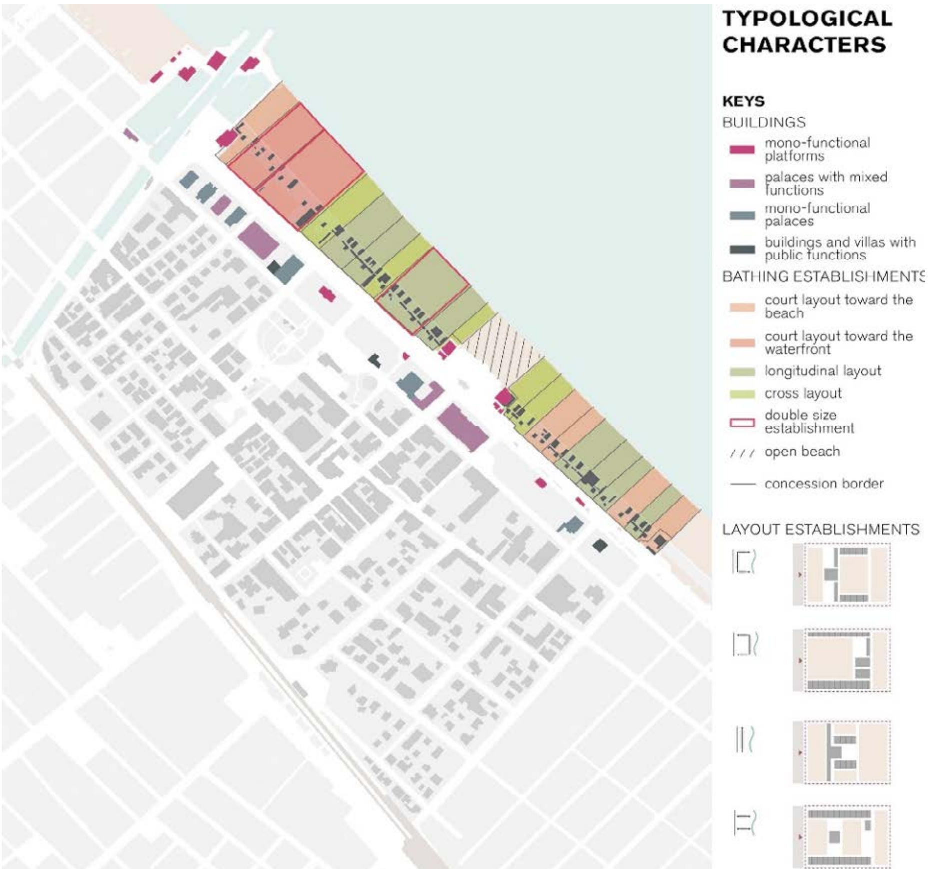

Figure 1 – The typological characters of the waterfront of the Ceccarini district.

Furthermore, an urban planning focused on coastal areas, which is a fundamental prerequisite for proper management of interventions, would have the task of regulating economic activities and protecting the land-sea interface territory, ensuring its tourist development and environmental sustainability [5].

In fact, the integration between the organization of the beachfront and the urban section behind it pushes for a rethinking in a concerted and synergistic way between the two areas that are generally managed with different philosophies and tools, and it is also with this additional spirit that the research on Riccione's seafront could be fielded.

Through in-depth reflections on the potentialities and criticalities of Riccione's beach-coastal system and in detail those of the Ceccarini district, the specific study area of the following research, it was possible to detect all the complex urban-economic relations that are established between waterfront and city. Relevant spatial and functional components were highlighted, which led to the formulation of an abacus of typological situations (Fig. 1) that are valid as a basis for the study of other seaside territorial realities. This particular study was carried out through the identification of the succession along the waterfront area of the various morphological and functional types and the identification of the different sizes, arrangements and functional types found along the strip of establishments and along the strip of public and private buildings facing the waterfront.

This analysis has resulted in a proposal for the regeneration of the morphological system of the seaside waterfront through the drafting of guidelines whose objective can be identified in the intent to give a direction to the transformation of the coastal-seashore waterfront toward the construction of a 'hybrid' space where adaptation actions and regeneration actions, having as their object urban and natural space, fit into a single resilient design system, always considering the risks generated by the processes induced by the current climate change, conditions from which coasts and shorelines are not spared.

From this perspective, the rethinking of the system of coastal planning in terms of adaptation to climate change is seen as an opportunity to introduce new processes of redevelopment of land-sea spaces, and to draw up programs voted to ensure transformations for a better urban quality, a urban regeneration of neighbourhood, a social and economic as far-reaching and medium-long term.

The need to define a programmatic methodology approach to the theme of coastal territories regeneration is imperative to take all those specific aspects that pertain to the sphere of 'seaside' (see the urban relations and characters shaped by the tourist vocation of the place and the sandy shores as a well-identified space of the city); a decisive characteristic in the choice and development of a strategic design study that has the intention of restoring to the urban-coastal, a resilient landscape associated with a settlement and tourism model in contact with the natural environment, without denying its historical and social matrix.

A strategy for Riccione's seaside waterfront

The strategy, drawn for an area of Riccione's territory, Ceccarini district, is made up of a large set of actions that contribute together to the formation of a new coastal bathing landscape integrated spatially and functionally with urban settlement.

The structure of the guidelines (fig. 2) is based on the construction of a diagram in which the main strategies are followed, like corollaries, by increasingly specific actions:

a) four thematic fields that are based on the recognition of the waterfront as an 'identity place' for the city;

b) two strategic objectives that represent the main lines of action to which all interventions at different scales refer;
c) general strategic lines that identify specific local actions.

The division between general strategies and local actions allowed the purpose of specific solutions for the case study and, on the other hand, the extent of the strategic vision. This last step is part of the need to propose a large-scale strategy, in which all the specific actions on an urban scale converge, representing an attempt to respond to the "substantial fragmentation of the coastal system" [9] that has often marked the intervention methodology on the waterfront, excluding it from integrated considerations or territorial plans.

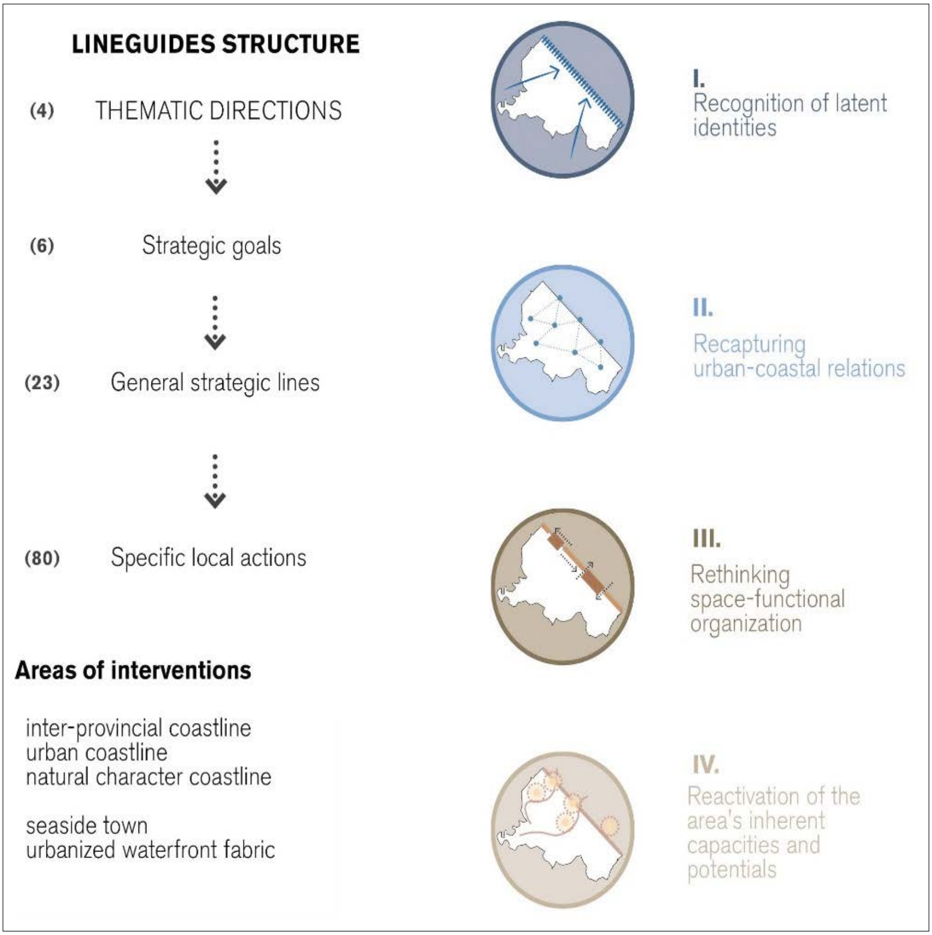

Figure 2 – The structure of the guidelines.

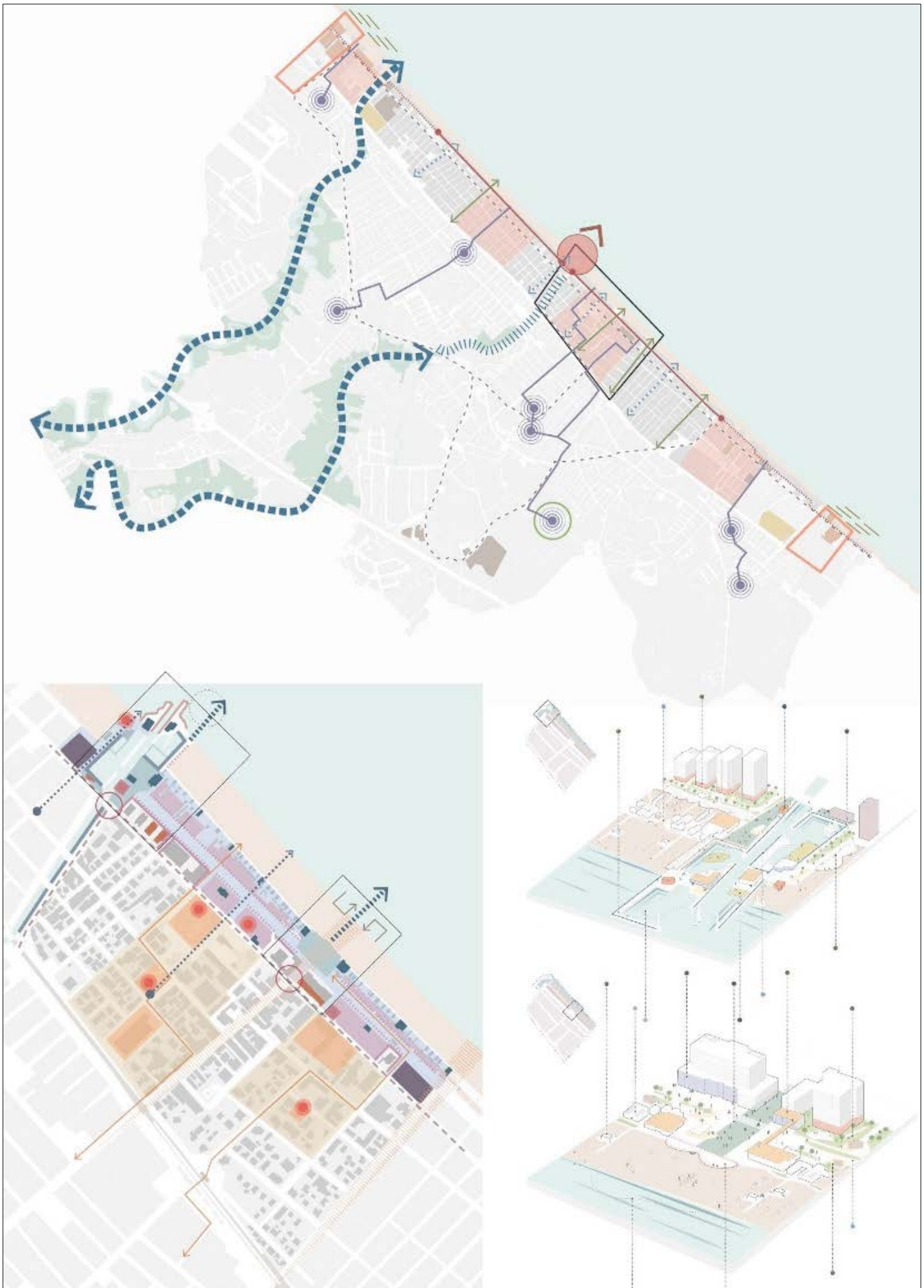

Figure 3 – Strategic visions: Identification of some spatial strategies based on the structure of the identified guidelines.

Conclusions

In the whole proposal, actions aimed at building an urban landscape capable of facing future environmental challenges are not left in the background (see the objective "Reactivation of the capacities and potentials" objective). According to the vulnerabilities and critical aspects identified in the analysis of the Italian coastal system, the strategies are divided between the restoration of natural coastal defense systems (localized measures aimed at containing erosion as a consequence of the effects of climate change, which are already present in scientific documents approved at both the regional [7] and supraregional [4] levels) and the enhancement of the built heritage in relation to the preservation of the unbuilt.

Thus, the need to propose interventions for environmental restoration, improving resilience and adaptive capacity of the territory through the exploitation of natural resources and limitedly invasive actions is taken into account while respecting the coastal landscape.

Finally, thanks to the translation of the guidelines into graphic maps, it is possible to identify two strategic visions for the regeneration of Riccione's seaside waterfront (fig. 3) and the Ceccarini district that highlight the inter-relationship between the different thematic lines of intervention, from the strengthening of natural and infrastructural land-sea connections, to the rethinking of the spatial and functional organization of the built and unbuilt areas of the waterfront and the bathing spaces.

This is particularly emphasized as a strategic element of integration between the inner urban fabric – the city – and the 'natural' coastal system – the beach; a relationship that is not only physical or social and economic but also psychological and perceptual, for which the waterfront is the knot of the multiple relationships that can be recognized between the urban environment and the natural system, and that should guide a place-based urban regeneration.

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DEVELOPMENT OF A SUSTAINABLE ACCESSIBILITY MODEL FOR THE MARINE PROTECTED AREA GAIOLA UNDERWATER PARK, IN NAPLES, ITALY

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Abstract – The Marine Protected Area (MPA) Gaiola Underwater Park was instituted in 2002 for the preservation of the urban coastal area of extreme importance both for natural and archaeological aspects. Due to the urban context where the MPA is located, the anthropic pressure on the site has always been high and it has always undermined the preservation of the cultural and environmental heritage of the site itself. Particularly, the public beach in the General Reserve Zone B has always been impacted by great problems of overcrowding that have always undermined a safe and sustainable use of the area. During the recent Covid-19 crisis, the problems related to the overcrowding of the Park became even more urgent. In May 2020, the safety problems highlighted by the pandemic, drove the Manager Authority attention to change the paradigm of management of the MPA and to study a new model of accessibility that allowed to keep a safe environment, a more respectful preservation of the environmental and cultural heritage of the Park and, at the same time, a safer and more enjoyable experience for bathers and visitors. On the occasion of the July 2020 reopening, after the lockdown, a protocol that guaranteed the place's security and sustainable fruition, based on the regulation of users' access and zero waste strategy, was developed. Since the first year of its application, this new fruition model of the area has been able to reduce up to eliminate all the atavistic criticality connected to the exasperated overcrowding of the area, finding at the same time a high approval rating among the users due to the recovered decency and livability of the area. This work aims to show and discuss the results of the application of the new fruition model, obtained from the analysis of the data collected through field monitoring, questionnaires, user interviews and online reviews.

Introduction

The Gaiola Underwater Park, with a marine surface of 41 hectares, extends for almost 2 km along the coast of Posillipo in the City of Naples between the Trentaremi Bay and the Borgo of Marechiaro. Established by the Interministerial Decree 07/08/2002, it is at the same time a Marine Protected Area and a Cultural Site referred to in the art. 101 of the Legislative Decree 22/01/2004, n. 42 "Code of Cultural Heritage and Landscapes". In fact, the Park preserves under its water not only a precious biodiversity [4], but also part of the I century B.C. Roman Villa called Pausilypon [1], whose maritime structures are partially or totally submerged due to the volcano-tectonic phenomenon of bradyseism [2, 3].

Considering that the metropolitan area of Naples is one of the most densely populated in Europe, with almost 3 million inhabitants, the Gaiola Underwater Park is subjected to a constant anthropic pressure that reaches its peak during the bathing season

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(from May to September). In fact, in the General Reserve Zone B, the Park hosts a public bathing area, immediately adjacent to the Integral Reserve Zone A, where the exasperated overcrowding during summer had always represented one of the most critical aspect both for bathers' safety and for the cultural and natural heritage's preservation.

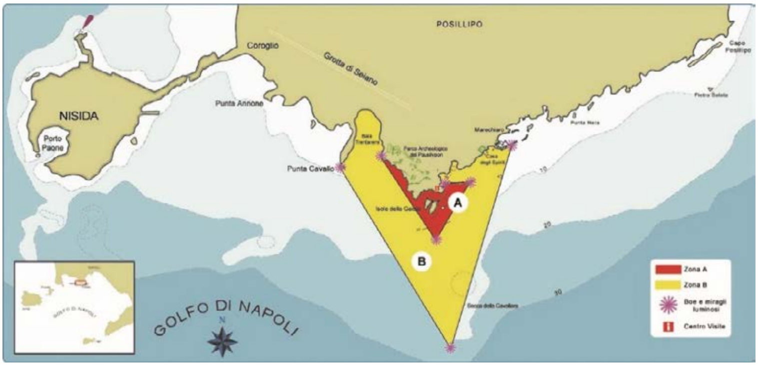

Figure 1 – Map of the MPA Gaiola Underwater Park.

During the years, the lack in regulation in this area had encouraged the development of problems related to lawlessness, public order and environmental impact, with negative effects on the livability of the place for bathers and on the Park's touristic and cultural development. In fact, besides the limited space available (almost 500 m^2), until 2019 the area had always been subjected to an average turnout that varied from 800 to 1200 people per day, with peaks of more than 2000 people.

The sudden super-saturation of the space often forced bathers to reach and stay in dangerous and unusable places, exponentially increasing the risk of accidents.

In addition, these problems related to public security were exasperated both by the inborn difficulties for means of rescue to reach the area, that is located at the end of a long pedestrian stair, and by the lack of appropriate hard shoulders and evacuation routes.

Figure 2 – Overcrowding in the public bathing area in the B Zone in past years.

Figure 3 – Overcrowding in the public bathing area in the B Zone in 2019 and safety problems.

This situation was aggravated also by the wild stop of vehicles that regularly prevented the approach of means of rescue, besides the no-parking zone and limited traffic zone.

Along with the problems related to public safety and security, due to such a mass of people, there was the increasingly alarming environmental impact on the Park's delicate coastal and marine ecosystem and historical and archaeological heritage, considering also that the area lacks a public service of collection and disposal of waste produced by bathers. During the summer season, bathers in the public bathing area only produced on average almost 100 kg of waste per day, many of which were dispersed in the environment and at sea.

Regarding the archaeological preservation of the site, it is important to mention that the public bathing area is located where there is the submerged Ancient Roman harbor of the Imperial Villa, that is an area rich in archaeological finds that, with such overcrowding, were vulnerable and at risk of theft.


Figure 4 – Waste dispersal on land and at sea (before 2020).

During the years, the continuation of such chaotic condition and decay had submitted the MPA to a permanent state of emergency for environmental, archaeological and safety issues, encouraging the development of problems related to widespread illegality, public order and wrong usage of the territory.

In 2020, the sanitary emergency brought out the previously discussed atavistic problems and in order to open the Park again to the public – since, as a cultural site, it had been closed following the national dispositions - the regulations issued by the Government for

COVID-19's contention led to the adoption of a security protocol to ensure compliance with the guidelines established for Natural Parks, Cultural Sites and public beaches. At the invitation of MITE (Italian Ecological Transition Ministry) and MIC (Italian Culture Ministry) and in agreement with the Manager Authority, the Municipality of Naples and the Port Authority, a protocol that guaranteed the place's security and sustainable fruition regulating the access and the modalities of fruition of the public bathing area inside the Park was developed. The adoption of this regulation immediately led to exceptional results in terms of livability, safety and security, decency and environmental sustainability, eliminating all the atavistic problems related to the exasperated overcrowding, including widespread illegality and problems of public order.

Thanks to the results obtained in 2020 confirmed also by the widespread support from the same users of the area, on request of MITE and MIC, the protocol of access' regulation was maintained also in 2021 in order to guarantee the basic condition of public safety and a better archaeological and environmental preservation of the area, in line with the statutory aims of the Park.

Materials and Methods

The Protocol for a safe and sustainable fruition of the public bathing area in the B Zone of the Park was developed considering 4 main objectives:

- to guarantee the safe fruition of the area for bathers and visitors;
- to eliminate the production and dispersion of waste in the environment;
- to improve livability and enjoyment in the area for the users;
- to improve people knowledge and awareness toward the environmental and cultural value of the Park.

In order to reach these objectives, the access to the public bathing area has been regulated through an online booking system with a clear and intuitive two-language interface on the institutional web site of the Marine Protected Area: https://www.areamarinaprotettagaiola.it/prenotazione. On the same webpage, it is shown the Regulation for the fruition of the area, that includes the norms of access, environmental preservation and, during the pandemic emergency, the anti-COVID19 measures. The entire Regulation is also printed on the ticket of access of each booked bather.

On the basis of the available surface of the area (500 m^2) and of the sanitary emergency's trends, the number of accesses to the area has been enhanced from 75 people in 2020, to 100 in 2021 and 200 in 2022 (after the Covid-19 emergency).

In order to enhance and diversify the possibility of fruition of the protected area, two turns of access have been established: one in the morning (9:00 a.m. - 1:00 p.m.) and one in the afternoon (2:00 p.m. - 6:00 p.m.), with a total of 400 people per day in 2022.

In the Regulation for the sustainable fruition, among the norms for the environmental preservation of the area, it is included the Zero Waste Strategy that establishes the ban on the introduction of non-returnable bottles and single-use materials in order to reduce to nil the production and dispersal of waste in the environment. At the same time, the area has been cleaned up by the accumulation of waste and various objects that illegally occupied the state area, limiting the available space for bathing. Finally, hard shoulders for rescue and for the inflow and outflow of users have been realized.

In 2021, thanks also to users' suggestions, the online booking system was improved, introducing the limit of 2 reservations per week for each bather and the possibility to delete autonomously the reservation. This led to a greater turnover of users in the public area. In addition, it was introduced a penalty that consisted on the impossibility to reserve for the following 2 weeks for those that reserved but did not use their reservation without deleting it. This unfair practice (ghost booking) was very common in 2020, going to reduce up to 20 % the number of daily available places for users. Already in the first two weeks since the opening of the Park in 2021, the number of deleted bookings amounted to 756, in comparison with the scarce 11 in 2020. Both in 2020 and 2021, it was developed a monitoring plan for the innovative model of fruition based on sample interviews, questionnaires and the analysis of the spontaneous reviews left by the users on the online platform of the Park and independent online platforms, such as Tripadvisor.

The main objective of this study is the analysis of the strengths and weaknesses of this sustainable fruition model of the area that - for the second year, in 2021 - tried to combine public fruition, safety and security, environmental sustainability and preservation of the cultural heritage.

Results

The data in the following work have been collected not only through field monitoring, questionnaires and interviews supplied to users, but also through the online booking system. The data that better explains the difference in fruition from the past is density, defined as the number of people/m^2.

As Figure 5 shows, the difference between the data collected in 2020-2021 and in the previous years (2018-2019) is really evident. In the previous years the maximum density amounted to 1,13 - 1,49 p/m^2. By contrast in 2020, the maximum density was between 0,16 e 0,13 p/m^2 and in 2021, between 0,19 e 0,24 p/m^2.

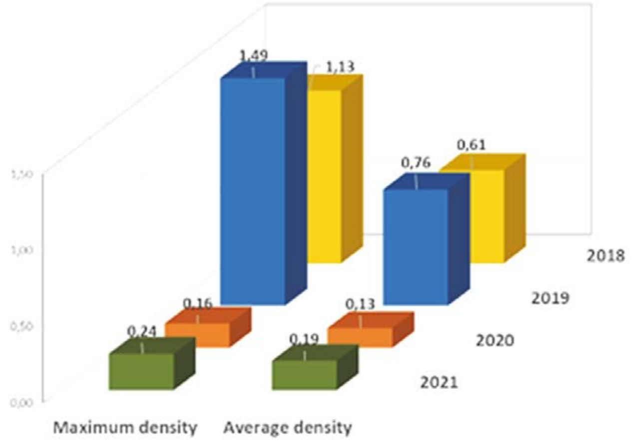

Figure 5 – Comparison: average and maximum density from 2018 to 2021.

The available space, that in the previous years varied from 0,67m^2 to 0,88m^2 per person, reached 4,20 m^2 in 2021, as shown in Figure 6 (A), going to considerably reduce the overcrowding of the previous years, ensuring the proper interpersonal distance in 2020 with direct improvements in livability and security of the public place.

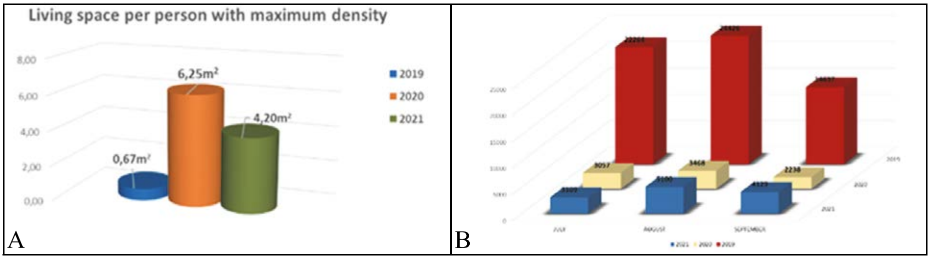

Figure 6 – Comparison 2019-2020-2021 between living space per person (A) and turnout per months (B).

Figure 6 (B) shows the turnout of users in July, August and September in 2019, 2020 e 2021 (only these 3 months have been considered since, due to anti-COVID 19 measures, in 2020 the Park opened on the 3rd of July). It is really interesting the data showed in Figure 7, related to the comparison between the density of bathers in the different coastal bathing areas near to the Park, in 2016 and 2020. Paradoxically, it is possible to notice that, in 2016, the Park, that represents the most important area along the coast from a biological and archaeological perspective and that is the most difficult area to be reached from means of rescue, had the highest level of bathers' density with respect to the other bathing sites along the coast. In 2020, the data related to the Marine Protected Area was clearly lower than the other coastal sites (only few private beaches had a density lower than Gaiola).

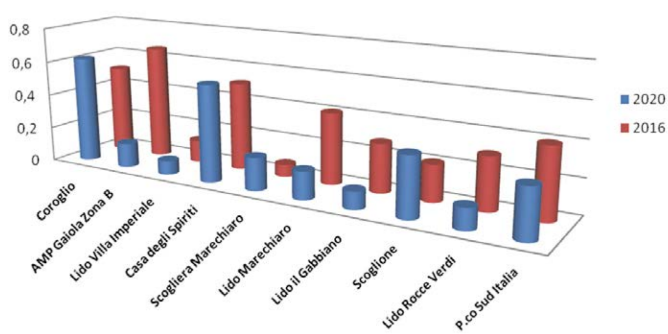

Figure 7 – Density comparison among the other coastal bathing sites in 2016 and 2020.

In relation with the statutory aims of the Marine Protected Area, the most interesting data, consequential to the adoption of the sustainable fruition model, is the one related to the elimination of waste production and dispersion in the environment. As Figure 8 shows, the data exceeds expectations, above all if compared with the previous years, when the kilos of waste produced and dispersed in the environment, both on land and at sea, were out of control with more than 3 tons of waste per month.

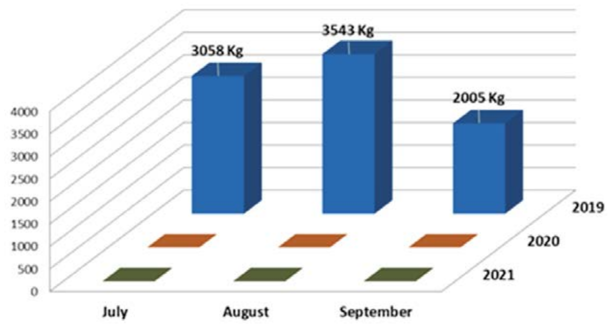

Figure 8 – Waste production per month in 2019, 2020 e 2021.

This situation was exacerbated by the permanent overcrowding in the area and by the lack of a public service for cleaning, completely in contrast with the Park's statutory aims for the environmental preservation and the basic measures for public hygiene.

The introduction of the sustainable fruition model, with the ban to introduce non-returnable bottles and one-way packaging, has reduced to nil the production of waste in the area, following the "Zero Waste" strategy, in line with the statutory aims of the Park and the MITE's campaign "Plastic Free".

Through the anonymous questionnaires supplied to bathers, it has been possible to collect data related to the degree of satisfaction of the site after the introduction of the new model of fruition. In particular, the questions have been divided between habitual users (61 % of the survey participants), that have been able to compare the actual situation with the past, and new users (39 % of the survey participants), that visited the Park for their first time evaluating the actual condition, without being influenced by the comparison with the previous years.

Figure 9 (A) shows the answers of the habitual users in 2021 in comparison with previous years considering 4 parameters: general satisfaction, cleanliness and decency, livability and security. The results exceed expectations, since all the parameters analyzed reach almost 100 % of perceived amelioration. The same result has been detected also from the new users, since more than 90 % of the survey participants has rated "excellent" or "good" (Figure 9 – B).

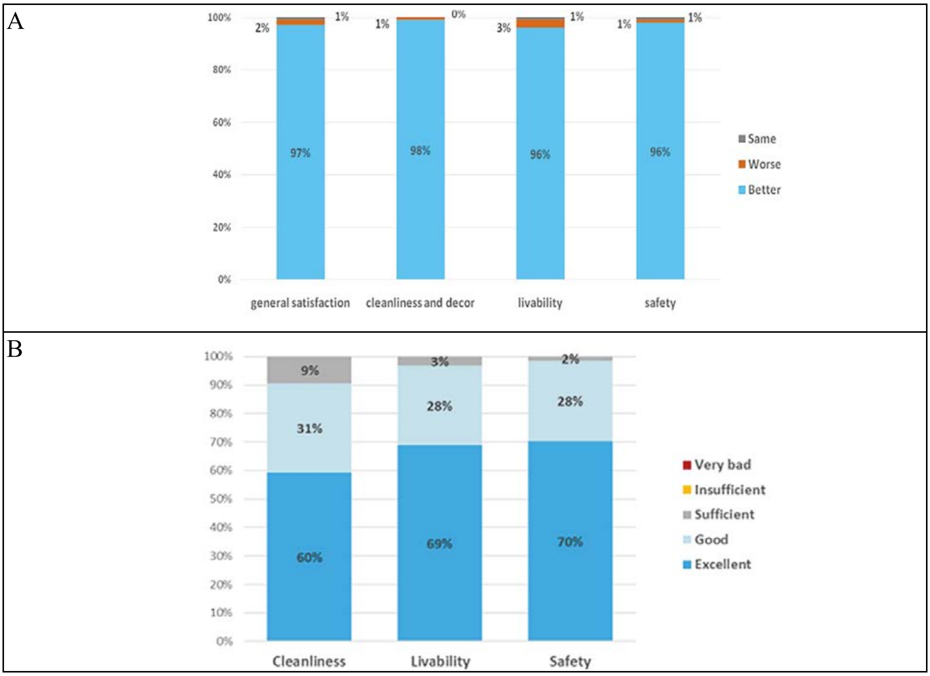

Figure 9 – Index of satisfaction of habitual users (A) and new users (B).

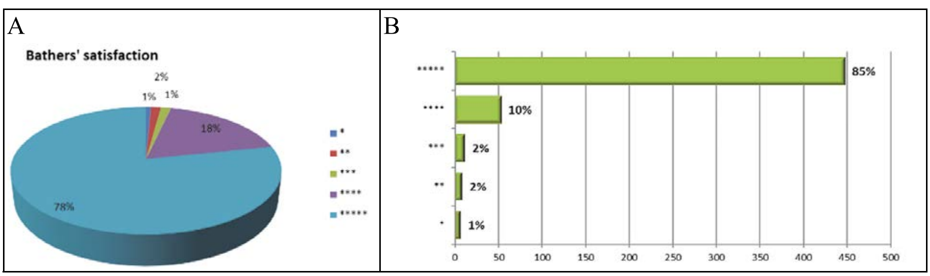

Figure 10 – Index of users' satisfaction from the online reviews left on the Park's website (A) and on Tripadvisor (B).

The bathers' absolute satisfaction of the new conditions of livability, enjoyment and decency of the area is proved also by the analysis of the online reviews left on the online platform of the Park (Figure 10 - A) and on Tripadvisor (Figure 10 – B), that are not influenced by the presence of the interviewer.

A very interesting data is the increasing awareness and perception in bathers of being in a Marine Protected Area with respect to the past, as represented in Figure 11. This is due to the fact that users, at the moment of the online reservation, visit the website of the Park, improving their knowledge on the environmental, archaeological and normative issues that characterized the Park and their awareness of going to dive in a Marine Protected Area. The same improvement is visible also in the awareness of being in a very important archaeological site.

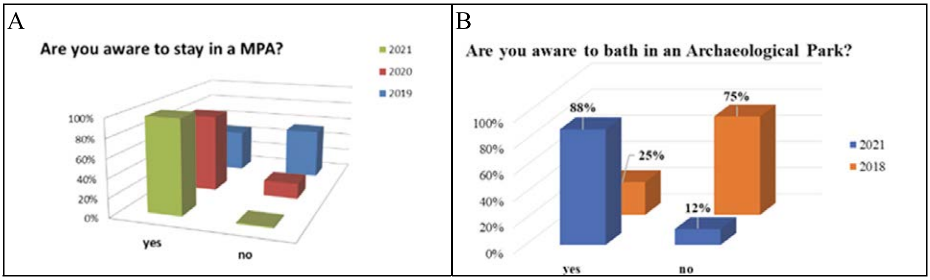

Figure 11 – Answers to the question on the awareness of being in a MPA (A) and in an Archaeological Site (B) in the years.

Discussion

From the results previously exposed, it is evident that all the criticalities detected in the previous years related to the overcrowding in the bathing area have been reduced to nil thanks to the adoption of the new model of sustainable fruition of the area and the limitation of access to the public bathing area inside the Park. The necessity to limit people turnout, urgently required by the pandemic emergency, has made it even more evident the problems related to the lack of safety and security and preservation that characterized the area before 2019, triggering actions in order to solve them. The overcrowding in such a small area, lacking in evacuation routes, hard shoulders and characterized by serious difficulties of access for means of rescue, exacerbated also by the constant congestion in the narrow street due to uncontrolled parking, has always represented a persistent problem for bathers and visitors' security, independently from COVID-19. To this are added also serious problems of environmental decay, waste dispersal and risks for the natural and archaeological heritage that avoid to reach the statutory aims for the Park's preservation and safeguard of the cultural and environmental heritage. The situation was exacerbated by the lack of an ordinary cleaning service and garbage collection along with the illegal occupation of the state area with boats and various objects then abandoned in the area. During the years, all these issues have provoked a continuous and inexorable deterioration of the area, increasing problems of criminality and public order. The limitation of access and the online reservation system have reduced to nil not only the problem of overcrowding in the bathing area but also the traffic congestion in the narrow street at the entrance of the Park that in the past regularly prevented the transit of the means of rescue.

The regulation of access along with the ordinary service of management and surveillance through specially trained staff, since the access' gate of the Park, have restored, for the second year, decency and livability in the area, preventing the resurgence of illegal activities and illegal occupation of the area.

Data show that both new and habitual users strongly and equally perceive the amelioration in livability, decency, security and enjoyment of the area, expressing great satisfaction toward the new model of sustainable fruition of the Park. The majority of users (97 %) in 2021, confirming the 2020's data, sustain and support the efforts to improve the quality of public fruition of the area and ask for the maintenance of the access' regulation for the future, even after COVID-19 emergency (Figure 12).

All the indicators analyzed demonstrate the radical reduction, almost to nil, of all the main criticalities that in the past represented not only an obstacle to the obtainment of the statutory aims of the Park but also a serious problem for the security and livability of the area, as perceived by the same users.

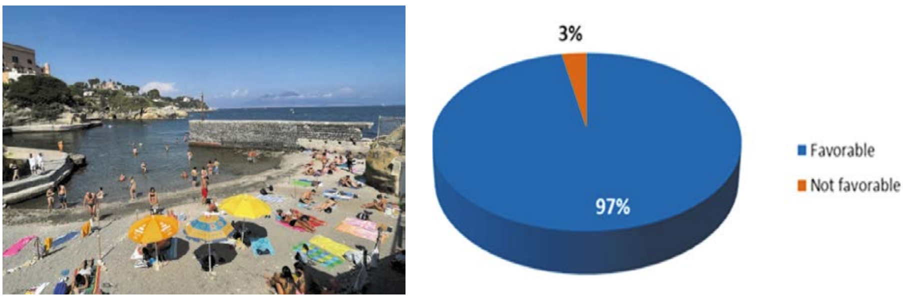

Figure 12 – Users favorable to the limitation of access even after Covid.

Conclusion

In conclusion, it is possible to affirm that the modality of access to the Gaiola Underwater Park following the model of sustainable fruition adopted since 2020, has managed - after 18 years - to solve all the criticalities related to the fruition of the area, in terms of visitors and bathers' security, decency, livability, public order and preservation of the environmental and archaeological heritage of the Park. Such model of sustainable fruition may represent a best practice for all those places where, due to needs of public security and cultural and environmental preservation, it becomes necessary a limitation of public access, guaranteeing a public and free participation, respecting the principles of democracy and plurality that should characterized common goods.

Acknowledgements

The surprising results obtained in these two years and the process of reborn and sustainable usage of the marine resource that is being practiced in the Gaiola Underwater Park is possible thanks to the fruitful synergy between several institutions. So, we would like to thank the competent Ministries (Ministry of Ecologic Transition and Ministry of

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SPATIAL PLANNING PROSPECTS ON CHANGEABILITY PROCESS OF URBAN AND NATURAL (LAND)SCAPE RELATIONS - THE DYNAMICS OF ANCONA ON THE WEST AND RIJEKA ON THE EAST ADRIATIC COAST

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Abstract –The urban and natural landscape relations are temporal, spatial, and perceptive phenomena complemented by providing functions and holistic principles that arise from the spatial planning approach. The research aims to investigate how spatial planning guides the changeability process of landscape relations in the Adriatic cities of Ancona and Rijeka settled between two strong natural elements of the sea and the mountains. The research interconnects the Heritage Urbanism approach and the Urbanscape Emanation concept in establishing identity factors, evaluation criteria, and enhancement models.

Introduction

The process of urban and natural landscape relation testifies to 25 centuries of urban culture and tradition in the Mediterranean. The urban and natural landscape relations are comprehended as temporal, spatial, and perceptive phenomena complemented by providing functions and holistic principles that arise from the spatial planning approach. It is a heritage dimension that embodies landscape reality and its representation, as well as a layer of the Urbanscape Emanation concept [1] understood as the impact of the city-systems on the natural setting. The research theme is induced by the notion that urbanity emerged from the landscape, transforming the natural into a cultural landscape, and transmuting the landscape setting into the city. Interrelation and connections of the urban development process and natural landscape transformation [2] prove the entity wholeness and the changeability process of the urban and natural landscape relation.

Two components of contemporary landscape analysis are neglected – time and networks of relations [3] thus highlighting the need to research complex urban and natural landscape relations as multidimensional processes. The urban and natural landscape as well as the social framework of life is in constant change. It cannot be stopped at a certain moment to be analysed – therefore the constant change in the research domain is a challenge and a great motive for research. Contemporary tools for assessing urban development and expansion into the natural landscape are primarily focused on metrics modelling of spread dynamics - urban size and density, morphology and urban forms, distribution and growth patterns, population density and dynamics, loss of natural land, and land-use change - that are weakly integrated with spatial planning. The quantitative modelling research are focused on how the city spreads while directions of urban development and where (on what landscape) the cities are spreading to are generally under-represented. Data availability is

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considered a strong restraining factor in the widespread applicability of geographic information system and remote sensing modelling.

Relating quantitative physical factors to socio-economic, spatio-temporal, ecological, and environmental factors support the spatially transcendent and sustainable development of a balanced society, economy, and environment [4]. While computation and modelling methods focus on quantitative objectives, the perception methods regard interactions of natural processes and human activities [5] in fostering urban and natural landscape quality as a spatial planning objective. Contemporary approaches to protection, planning, and management of urban and natural landscape promote landscape networks as green infrastructure, core and belt approach from *UNESCO World Heritage* and *MAB Programme*, landscape characterisation from *Landscape Characterisation Assessment* and *Council of Europe Landscape Convention*, and phenomenological approach from *Historical Urban Landscape.* The landscape dynamics, complexity, and continuity of the city setting represent the changeability process of urban and natural landscape relation, which regarded from different perspectives can enable use in spatial planning and enhancement of landscape quality.

The landscape relations can be traced through the history of settling [6], from the prehistoric dwellings, proto-urban settlements, ancient cities, and medieval towns that developed in harmony with the landscape setting and with deep connections to inherited landscape values and characteristics. The processes of industrialisation, urbanisation, and touristification from the 19th century were further intensified by the rapid change in urban development pace from the second half of the 20th century – disrupting the historically balanced urban and natural landscape relation. Spatial problems of extensive urban spread into natural resources and loss of natural landscape, disbalance of urban development and landscape protection, land degradation and abandonment, and loss of urban identity arising from landscape setting indicate the disrupted relation between urban and natural landscape. In the specific context of the Mediterranean and the Adriatic, these spatial problems are further intensified in cities settled between two strong natural elements - the sea and the mountains. The cities of Ancona and Rijeka are selected as representative cases settled between the Adriatic Sea and the mountain hinterland of Apennines and Dinarides where the intensive relation of urban and natural landscape defines a unique place identity.

The research aims to investigate how spatial planning guides and anticipates the changeability process of urban and natural landscape relations in the context of West and East Adriatic Coast cities. Three research levels - theoretical (existing knowledge), spatial (field research and case comparison), and spatial planning (criteria) regard three main research questions:

- What perspectives overlap in establishing the relation character of urban and natural landscape within the spatial planning approach?
- What forms the interrelation of urban and natural landscape on the West and East Adriatic Coast? Which criteria have to be used in evaluating the relation?
- How is the urban and natural landscape relation planned in historical and contemporary spatial plans of Ancona and Rijeka? Which planning provisions regard and which spatial planning criteria are already used to enhance the relation?

Materials and Methods

The urban and natural landscape relations present unified and non-renewable spatial and cultural resources that are explored by overlapping different perspectives. By comprehending landscape relations as heritage resources that emanate toward sustainable development, the research uses the Heritage Urbanism approach [7] to determine identity factors, evaluation criteria, and enhancement models. The landscape relations are explored as part of the Urbanscape Emanation concept of multi-layered values detection and use in spatial planning. The research interconnects the Urbanscape Emanation concept and the Heritage Urbanism approach to aim for a new dynamic in planning balance and achieving holism between multiple layers of the urban and natural landscape. Applied theory-, perception-, and desk-based research methods follow three levels of research – theoretical, spatial, and spatial planning levels, that are used in research synthesis (Table 1).

Table 1 – Structure of applied research methods and materials in setting theoretical (gray), spatial (turquoise), and spatial planning (pink) research levels.

	Research methods	**Materials / sources**	**Application Research synthesis**
Theory-based methods	Literature review	Scientific literature	Overlapping different perspectives in structuring groups of identity factors
	Documents review	Spatial planning documents and policies	
Perception-based methods	Structured observation	Field research data	Field surveys of case cities to identify evaluation criteria
	Photographs taking	Case photographs	
Desk-based methods	Data collection Data analysis	Historical illustrations	Confirmation of evaluation criteria by case comparison
		Historical maps	
		Orthophoto maps	
		Spatial planning documents	Comparison of spatial planning documents for establishing enhancement models

The theoretical knowledge of landscape relations is based on a review of scientific literature and policy documents from various disciplines that provide different perspectives relevant to interconnecting the urban and natural landscape. The review provides a theory-based framework of current terminology and content that establish landscape relations as multidimensional processes. The determined groups of identity factors arise from comprehending the urban and natural landscape relations and the spatial planning approach to landscape assessment, protection, and planning.

The inclusive and holistic approach to spatial research of urban and natural landscape relations interconnects perception-based and desk-based methods in identifying and confirming evaluation criteria. The theory-based identity factors are recognised during field surveys by structured observation and documented by photographs. The identified factors of urban and natural landscape relation are presented by data from historical maps and present-day orthophoto maps, from historical illustrations and contemporary photographs, that are used in the analysis of case cities. By comparing the representative cities of the West and the East Adriatic Coast, criteria for evaluating the relation of the urban and natural landscape are confirmed.

The spatial planning research of urban and natural landscape relations is conducted by detecting the established evaluation criteria in spatial planning documents of each case city. One representative historical and one contemporary spatial plan of regional level are selected for the West and the East Adriatic Coast site. The comparison of spatial plans is assigned to planning provisions that regard the established evaluation criteria of urban and natural landscape relations. The planning provisions are interpreted as existing spatial planning criteria that introduce missing criteria and assist in establishing spatial planning models for enhancing the urban and natural landscape relations.

Results

The research of urban and natural landscape relations introduces new meanings to existing knowledge, spatial values, and spatial planning provisions for evaluating and enhancing urban and natural landscape. It originates from determining the landscape relations as a core notion and evolves through incentives, levels, and scopes towards the Heritage Urbanism approach and Urbanscape Emanation perspectives in fostering the urban and natural landscape relations (Table 2).

Table 2 – Structure of research incentives, levels, scopes, Heritage Urbanism approach, and Urbanscape Emanation perspectives in fostering the urban and natural landscape relations in spatial planning.

Research incentives	Research levels	Research scopes	Heritage Urbanism approach	Urbanscape Emanation perspectives
Research gap	Theoretical level	Theoretical review of existing knowledge	Identity factors	Landscape relations character
Spatial problems	Spatial level	Case studies evaluation of spatial values	Evaluation criteria	City setting
Spatial planning approach	Spatial planning level	Comparing provisions of spatial planning documents	Enhancement models	Spatial planning prospects

Landscape relations character as theory-based groups of identity factors

The Urbanscape Emanation perspectives on connections between urban and natural landscape arise from determining the core notion and forming a structure for literature review. The landscape relations are established as temporal, spatial, and perceptive phenomena complemented by providing functions and holistic principles that arise from the spatial planning approach. The spatial, social, and symbolic dimensions of landscape identity as well as the Heritage Urbanism approach to landscape relations as heritage dimensions confirm the structure of theory-based knowledge on the connections of the urban and natural landscape.

The dimension of time and layers of history are essential to understanding the urban and natural landscape relations as a process [3] and the heritage dimension [1, 8] where the history of landscape as the origin of the urban can be traced back as far as the history of man [6]. Inherited values of landscape continuity and the constant of landscape transformations are embodied in the three natures by Cicero [9] - the first (primeval) nature of wilderness, the second (cultivated) nature of the cultural landscape, and the third (horticultural) nature of designed parks and gardens. The three natures are also regarded physically in the practice of garden theory by Hunt, metaphysically in the Buddhist philosophy on the three natures of being, and further explored by the fourth nature of designed wilderness and restored ecosystems as a response to the Anthropocene era.

The complexity of landscape embodies the perceived reality and the representation of it, which is closely associated with the notions of place and identity. The threefold dimensions of the spatial, social, and symbolic landscape are regarded in the identity of place [10], sense of place by Montgomery, visual perception of landscape by Parris, three ecologies by Guattari, spatial discourse by Foucalt, trialectics of social space by Lefebvre, and thirdspace by Soja. In the landscape concerns, as aims of landscape design and spatial planning objectives, the threefold division originates from Vitruvius' firmitas, utilitas, and venustas as aims of the design process [11] and evolves in areas of landscape architecture knowledge by Thompson, aims of landscape architecture by Turner, landscape patterns by Bell, and concepts of landscape architecture by Fein.

In the inclusive and holistic approach, the connections of the urban and natural landscape are interpreted as the equivalence of all landscape. The approaches that regard the whole as more than merely the sum of its parts is identified in notions of wholeness and universal value [12], authenticity, vivacity and landscape quality, sustainability [13], resilience and adaptive capacity of landscape. The holistic nature of landscape serves as an integration concept for a wide variety of perspectives to study it [5]. The principles of economic and social cohesion, conservation of natural resources and cultural heritage, as well as balanced territory are reflected as European spatial planning objectives [4]. An inclusive and holistic spatial planning approach to exploring the changeability process of the landscape relations is achieved by overlapping temporal, spatial, functional, and perceptual factors of the urban and natural landscape.

The theoretical review on landscape relation knowledge concludes five (5) groups of identity factors as landscape relation characters: (i) temporal character of the landscape as heritage, (ii) spatial character of landscape form, (iii) functional character of the social landscape and use, (iv) perceptual character of landscape symbols, (v) holistic and inclusive character of the balanced urban and natural landscape.

Perception of the urban and natural landscape settings on field research of Ancona and Rijeka

The field research of Ancona and Rijeka urban and natural landscape settings have been conducted from 2018 to 2021 covering the research on coastal maritimescape, urbanscape, and hinterland mountainscape. The theory-based factors are recognised during structured observations and photographic documentation of perceived connections of the urban and natural landscape. The interpretation of field research is done in a descriptive way that is not restricted only to the pre-defined identity factors but allows the recognition of perceived parameters that form the landscape relations.

The field research results highlight that settings form landscape relations – thus different city settings are established as evaluation criteria for the urban and natural landscape relations. Five (5) perspectives on landscape relation characters of Ancona and Rijeka are intertwined to determine settings criteria: (i) landscape setting of different levels and characters, (ii) historical setting of continuity, (iii) heritage setting of tangible and intangible cultural, and natural heritage, (iv) setting transformations of four natures, (v) scenic setting of visual landscape, and (vi) communication setting of historical and contemporary roads and paths.

Confirmation of settings criteria by Ancona and Rijeka comparison

The comparison of case cities has introduced two additional settings: (i) administrative setting as an introduction to the city cases and (ii) spatial planning setting as a concluding structure of historical and contemporary spatial planning documentation relevant for the evaluation and enhancement of urban and natural landscape relations. Eight (8) setting criteria are applied in research catalogues to evaluate urban and natural landscape relations of case cities and to initiate and focus the questions for verification in spatial plans of Ancona and Rijeka.

Ancona and Rijeka are compared as regional centres, similar in size of urban area and population, opening the question of how administrative levels are referred to spatial plans. The landscape settings differ macro-regional, regional, and micro-regional settings, the character of geographic setting, and settlement types for maritime-, urban-, and mountain-scape, thus opening the question of how different levels of landscape, specific characters of urban structures, and landscape forms, spatial problems of urban pressures on the natural landscape, and inaccessible urban coast, are reflected in spatial plans. The continuity of the historical setting is detected in the historical core of Ancona and the two urban cores of Rijeka and Sušak (Figure 1), raising the question of how to promote endogenous planning that respects the authenticity of urban continuity. The heritage settings differ protected natural, tangible cultural, and intangible cultural heritage, thus opening the question of additional possibilities for a network of heritage protection by spatial plans that integrates natural, tangible, and intangible cultural heritage, traditional heritage, and associated cultural places. Confirmed primeval, evolved, planned, and deprived nature of landscape as settings transformations in Ancona and Rijeka raise the question of recognising areas of protection, development, and recovery as different levels of consolidation in spatial plans. The scenic settings of urban vedutas, view corridors, depth of view, and evoking places of iconic views open the question of promoting visual values of interacting urban and natural landscape as identity protection in spatial plans. The compared networks of communication settings in Ancona and Rijeka raise the questions of recognising and protecting historical roads and traditional paths as cultural heritage, and access roads as the urban identity of gateway-pathway heritage, as well as the question of contemporary roads along and across the coast and hinterland as lines of urban spread into natural resources that need to be regarded in spatial plans. The overview of historical and contemporary spatial plans of Ancona and

Rijeka opens the opportunity to learn from different spatial planning continuities, traditions, and structures of programmatic, strategic, operational, and implementation plans. The reflection of formal planning on the activity of informal initiatives exposes the raised objectives of public welfare to be involved in spatial plans.

Figure 1 – Historical illustration (up) and contemporary representation (down) of the urban and natural landscape of Ancona (left) and Rijeka (right) (photo: Authors).

Spatial planning criteria for enhancing relations of the urban and natural landscape as spatial planning prospects for Ancona and Rijeka

The initiated questions from comparing settings criteria for evaluating landscape relations in Ancona and Rijeka have focused on the verification of existing and progress towards missing spatial planning criteria for enhancement of urban and natural landscape relations. The existing spatial planning criteria are assigned to planning provisions that regard the evaluation and enhancement of urban and natural landscape in compared spatial plans. Four (4) spatial planning documents are selected as representative of case cities: (i) General Urban Plan, Municipality of Ancona, 1963, (ii) Coordinating Physical Plan of the Upper Adriatic Region, 1972, (iii) Integrated Territorial Project, Middle Adriatic Metropolitan Area, 2013, (iv) Spatial Plan of the City of Rijeka, 2019.

The planning provisions indicate spatial planning prospects as development tendencies that distinguish integral development of the Metropolitan Area for Ancona and partial development for Urban Agglomeration of Rijeka. The planning prospects interconnect spatial planning criteria for enhancing urban and natural landscape relations, settings criteria for evaluating landscape relations, identity factors as landscape relation character (Table 3), and assist in promoting spatial planning models for enhancing landscape relations.

Discussion

Research synthesis introduces spatial planning models that are summarized from spatial planning criteria for enhancing landscape relations (Table 3) and grouped according to common notions that promote relations of urban and natural landscape (Table 4). The understanding of (i) layers depth, (ii) network structures, (iii) endogenous, (iv) tendency, and (v) archetype models reflect the contributions to scientific research and approaches, spatial planning practice, enhancement of spatial relations, education to relation values and quality, and awareness towards landscape resilience.

Table 3 – Structure of identity factors, evaluation, and enhancement criteria of urban and natural landscape relation.

Landscape relation character Identity factors	**City settings** Evaluation criteria	Spatial planning prospects **Spatial planning criteria for enhancing relation of urban and natural (land)scape**
	Administrative setting	_scope of spatial plans in line with urban systems, scape levels, and city setting.
Temporal character	**Landscape setting**	_maritime plans for the public coastal belt. _structures, forms, topography equal to use.
Spatial character	**Historical setting**	_accessible network of public places. _urban spread balanced with natural resources.
Perceptual character	**Heritage setting**	_indigenous planning of city setting values. _integral network of heritage protection.
Functional character	**Setting transformations**	_planning transformed scapes into heritage. _planning deprived scapes as recovery areas.
	Scenic setting	_protecting visual values as scape identity. _depth of layers as scape homeostasis.
Holistic character	**Communications setting**	_access roads as city identity entrance. _learning from spatial planning tradition.
	Spatial planning setting	_local initiatives indicate welfare objectives. _educating the community to gain relevance.

The landscape is understood as a palimpsest of urban development, an active substratum of the city providing depth, and fostering insight into the whole city understood as a landscape. The landscape always expresses and reflects relations - the networks, connections, and mobilities that drive the ongoing process of place-making. Thus, it should be planned by directing process tendencies and by respecting their evolution. The endogenous development proceeds from within and is derived from internal conditions of landscape organisation rather than externally caused. It plays a decisive role in developing acceptance and ownership by local people, which are essential for their long-term commitment. The notion of archetype helps us to deal with the complex notions of the landscape by acknowledging the values found in different intensities in all landscapes. The urban and natural represent the prime archetypes of landscape as all the shades in between are present in the relations of the urban and natural landscape. The wider context of research results enables the appreciation of all city settings in protected, everyday, and degraded landscapes.

Table 4 – Understanding spatial planning models of enhancing landscape relations by promoting urban and natural landscape notions.

Spatial planning models for enhancing landscape relations	**Promoting urban and natural landscape notions**	**Understanding the model**
Layers depth model	diverse readings, perspectives recognition, overlying, insight	Overlapping diverse layers and notion levels forming depth and providing insight
	layers, strata, zones, areas, belts, assets, phenomenon, levels	
Network structures model	integration, interconnections, synchronicities	System of interconnected and integrated constituents of a complex and unitary whole
	networks, systems, organisation, infrastructures, structures, forms	
Endogenous model	balance, homeostasis, coherence, coexistence, continuity	External balance of landscapes that arise from internal, inherited values
	background, tradition, genius loci, inherited values, authenticity	
Tendency model	tendency, direction, adaptive cycle, threshold, course, dynamic	Planning by directing process tendencies respecting their evolution
	processes, growth, transformation, development, progress, evolution	
Archetype model	education, understanding, awareness, reflections, identity, conceptualisation, abstraction	Education in abstract examples of groups, a conceptualisation that upholds landscape values
	groups, types, classes, places	

Conclusion

The expanded understanding of the urban and natural landscape relation as a process is complemented by the depth of landscape layers, the structure of versatile urban and natural networks, endogenous landscape balance, tendencies of landscape processes, and education in landscape archetypes. These are conducted as the spatial planning models for enhancing landscape relations that provide depth and insight, raise awareness of landscape values, and resist landscape delineation and boundary setting. The dynamics of urban development and natural landscape evolution interconnect the past and present landscapes with spatial planning tendencies. Thus, the research contributes to proposing spatial planning principles that acknowledge the individual and common characteristics as well as the connections that complement urban and natural landscapes as a whole in which one benefits from the other.

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REGENERATION OF HISTORIC CENTERS IN MEDITERRANEAN CITIES: THE CASE STUDY OF THE VENICE DISTRICT IN LIVORNO

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Abstract – The following contribution wants to tell an experience of design research, aimed at the regeneration of a portion of the waterfront of the city of Livorno, which is now fragmented and in a state of decay. The area, located within the historic Venice District near the Fortezza Vecchia and the port, is strongly characterised by the presence of the fish market building, which stands out for its contemporary architecture and its original roof. The research proposes a new spatial arrangement through the re-functionalisation of the building and the design of all the access systems to the area, driveways, pedestrian and cycle paths, which can allow its proper use by citizens and tourists. The change from a wholesale market building to a city market is aimed at a wider accessibility of the building, which for years was limited to a restricted group of users. The project promotes not only a rationalisation of the routes but, above all, a slowing down of the user's journey: it obliges him to walk through it and observe it slowly, to take possession of it again. In order to achieve this aim, a proposal is made to revise the driveways, which currently represents a critical issue in the neighbourhood, to introduce routes for green mobility and to eliminate the non-functional and degrading superfetations that have occupied the area over the years, disfiguring it. The design of the direct connection with the entrance to the port, the new car parks and the large equipped green areas, at different levels, accentuates the new vocation of the site, which from a transit place is transformed into a place of rest and meeting.

Introduction

The contemporary city today is dense but discontinuous, constituted by built, semi-built, and open systems that need to be resolved with a new methodology of intervention: urban regeneration. Regeneration acts on the existing heritage both by redeveloping infrastructures and services and by giving back regenerated spaces to the community. In Italy, historic centres have not only an architectural value but are also the focus of the city's commercial, tourist and social interests: in these areas the first urban settlements arose, the first productive activities developed, and the first commercial buildings were constructed. In the case of cities on the Mediterranean, the value of the historic centre is increased by the presence of the sea, which often represented the trigger for the development of the city and where activities, as well as attractive places, were established from the coastal strip. Afterwards, with the growth of the population and the introduction of new means of transport,

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there was a weakening of the historic centre in favour of an urban extension towards the suburbs. Today, however, the trend of redeveloping the underused and degraded building heritage of historic centres encourages construction in the already built-up area [Schiaffonati et al., 2017]. Some of the buildings that make up the waterfront of Mediterranean cities, once indispensable to promote the relationship between land and sea, now are as empty spaces ad de-functionalised that show the degradation caused by the years and the salty: the waterfront of the city of Livorno represents, from this point of view, an emblematic case. The first Livorno settlements were defensive, coastal and port-related. Livorno is distinguished from other Mediterranean cities by the presence, in addition to the sea, of a system of navigable canals, called Fosso Reale, which crosses a short urban section. The Venice District, so called because it is strongly characterised by the presence of canals, constitutes the city historic core and is located between the two 16th-century fortifications: the Fortezza Vecchia, near the port, and the Fortezza Nuova, in the urban centre [Bortolotti, 1977]. The system of existing canals and fortresses is the testimony of the to the historical-architectural development of a precise urban model, and represents an environmental, commercial, cultural, social and tourist heritage for Livorno [Vanni et al., 2017].

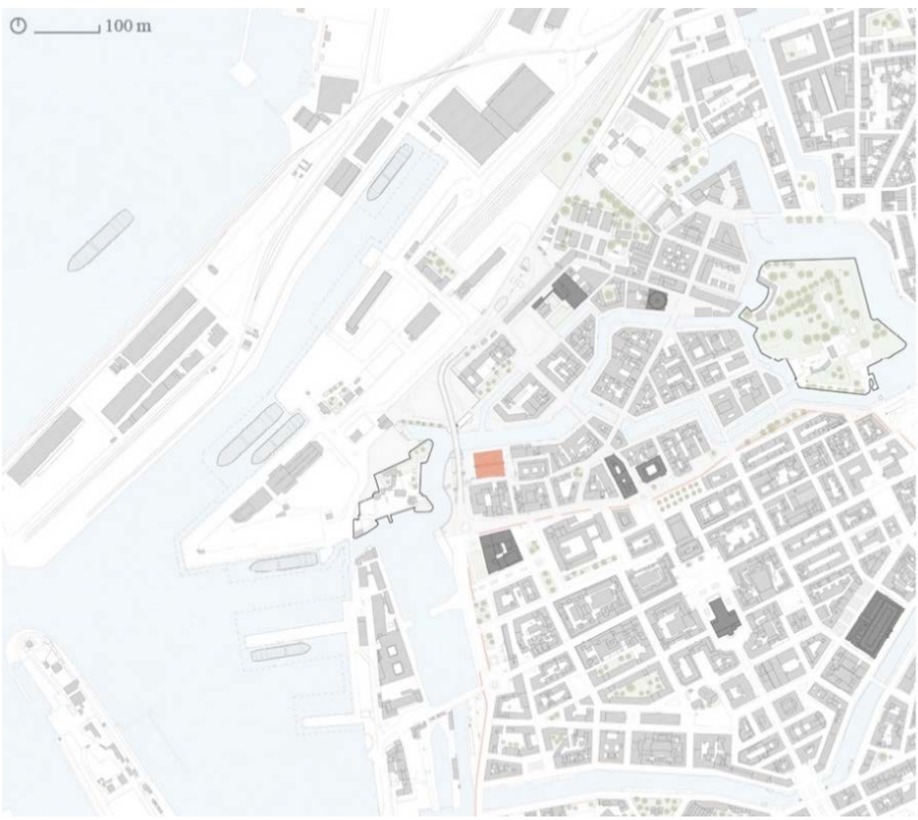

Figure 1 – Livorno, the Venice District with the project area, drawing made by authors.

The area investigated can be identified within the historic district, near the port passenger entrance and the oldest fortification. The area is divided into two parts by the navigable canal and, due to its strategic nature, has always been a place of high social and commercial interest, but at the same time vulnerable to external attacks. Much of the architecture in the area, in fact, was damaged during the two world wars, and in particular the area that was designated in 1960 for the new fish market was cleared following World War II bombing, which affected not only most of the buildings, but also the span of the 19th-century bridge that connected the two banks. The only traces of the 1844 Santa Trinita bridge visible in the area today are the remains of the two bases that served as a storage area. The fish market, designed by architects Beata Di Gaddo (1921-2007) and Pietro Barucci (1922), was built in 1967, following a public competition provided for in the city's Post-War Reconstruction Plans [Micali, 2002]. The building, which the architects proposed for the competition in the Fortress Square, is characterised by its contemporary form that can be perceived both from the outside and from the inside. The market has a rectangular floor plan and is a single space on two levels under a large roof, accessible only to fishermen and wholesalers during the early hours of the day. The functional scheme consists of two independent main paths: the first is dedicated to fish merchandise (on the ground floor) and the second to the public (on the first floor). The two environments visually communicate each other through the balcony on the upper floor and the large tribune in the centre of the hall where the fish auction takes place. The organic and rationalist architecture of the building can be seen especially in its roofing, which was realised thanks to new technologies and experimentation with innovative materials. The roof pitches made of pre-stressed reinforced concrete, shaped according to parabola arches and softly lowered on the lateral supports, emphasise the structure, which inside appears as a large open space without structural interruptions. The designers intention was to create a roof that morphologically resembled a net or sail laid out to dry in the sun after fishing [Tentore et al., 1964].

Figure 2 – The 1967 fish market, photo by authors in 2020.

In the competition phase, the architects proposed the inclusion of a quay for fishing boats near the building, to allow products to enter the market directly from the sea. The quay, together with other proposals regarding the arrangement of the external areas adjacent to the building, were not accepted by the administration, thus forcing the entry of fish only by road [Lenci, 2009]. In 1989, more than twenty years after the construction of the market, a road overpass was built in the area with the aim of connecting the two banks and keep the traffic away from the city centre. The road infrastructure, built over the remains of the 19th-century bridge and in the absence of continuity with the existing built heritage, complicated the normal conduct of fishing activities close to the market [Zucchi, 2016]. In addition to the overpass, the decline in the number of fishermen engaged in the sale of fish also contributed to the degradation of the building and the area, which quickly assumed marginal roles within the city. In fact, in November 2018, due to changing needs, about 85 % of fishermen moved to a new building to conduct their daily fish auction, effectively declaring the loss of commercial attractiveness in the area. However, thanks to its centrality and significant proximity to certain points of interest such as the ancient fortification, the port and the City Museum, the area retained the potential to become a meeting place and a reference point once again for the inhabitants [Merlo, 2006].

The design research, considering the needs of the contemporary Mediterranean city, aims to propose solutions to the deterioration elements in the area through the re-functionalisation of the fish market and the intervention in the public space, giving back to the city of Livorno part of its historic district and delivering to its inhabitants a new place for the community, accessible today only to a conspicuous group of people: fishermen and buyers [Careri, 2006].

Figure 3 – The current state of the area from the canal, author photo in 2020.

Materials and Methods

The contemporary architecture of the fish market set within the complex and degraded area, represents the starting and finishing point of the design experience. The building, in fact, for its architectural value and singularity, is proposed as a new attractive pole open to the public, able to dialogue with the points of interest already existing on the urban waterfront [Massa, 2015]. These are also valorised and made more accessible to pedestrians thanks to the new urban design. The overall objective of the project is to consolidate the identity of the area, making it a strategic crossroads for people coming from all directions, and using the building by architects Barucci and Di Gaddo as a primer for this process. The methodology used had an anthropocentric approach, focusing on the inhabitants as well as tourists and their need to easily reach interest points and to freely access public spaces at the centre, preferring the slow rather than the fast mobility [Gelh, 2008]. In addition, the analysis of the current use of the fish market building, the curiosity about its architectural quality and the desire to open it to a wide public drove the design research to a change of use of the building. The research takes up the challenge of comparing the complex theme of urban regeneration of the Mediterranean city in terms of architectural redevelopment and dialogue with the natural and social context. The research organisation, which is multi-scalar and interdisciplinary, can be divided into four phases: state of the art analysis, urban design, architectural design and detail design.

Results

The preliminary phase of studying the state of the art was necessary to understand the needs of the different user profiles that live in the area and, consequently, to implement planning at the different scales, from urban to detailed. This phase made use of both tools of an analytical and evaluative nature of the framework of needs, as well as tools proper to the discipline of urban sociology. Specifically, the analysis was made possible thanks to the consultation of bibliographic sources, the carrying out of numerous on-site visits and the arranging some interviews. Among these, the most important was certainly the interview with the architect Pietro Barucci, one of the designers of the fish market. The discussion with the architect at the beginnings of research made it possible to deepen the information found in the texts by proposing a respectful and conscious development of the project in its totality [Spagnoli, in publication 2022]. At this stage, various themes were studied, including the historical evolution of the area, the fast and slow mobility flows, the usability and accessibility of the external spaces, the degradation state of the existing architectural elements and their relationship with the context.


Figures 4- 5 – The current state of area, author photos in 2020.

Once it was understood from the previous analysis that the fragmentation and complexity of the project area is the result of numerous focused interventions in response to individual needs, which do not converge into a unified objective, it was necessary it was necessary to work initially at the level of urban planning. The analysis highlighted the virtues to be maintained and the criticalities to be eliminated for the urban and social regeneration of the area. First of all, the research proposed the elimination of the flyover, which represents the main element of degradation as a physical and visual barrier between the city and the sea, transferring car traffic to the underground level and thus not modifying the road system. The urban project provided for the pedestrianisation of almost the entire area with the inclusion of new connections for green mobility, such as the new cycle-pedestrian bridge and the extension of pedestrian and cycle paths. In addition, the new Fortress Square was designed on two levels (at the level of the quay and at the level of the existing square), which allows not only the entrance to the contemporary building, but also a privileged view of the Fortezza Vecchia. The project involved both banks, through the insertion of many green areas with tree species compatible with the Mediterranean climate, pavements, vertical connections and street furniture respecting the existing context and the removal of architectural barriers.

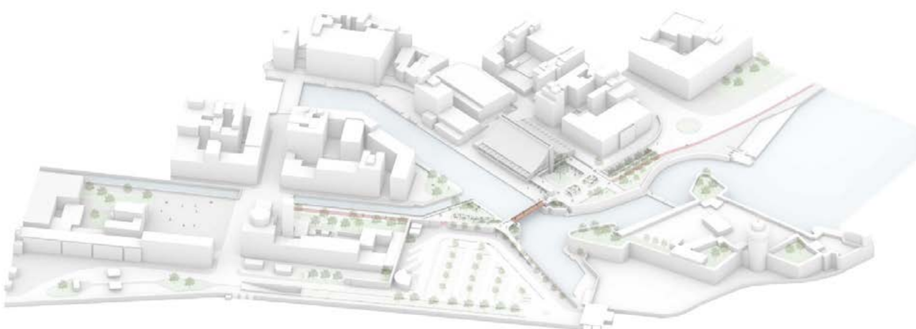

Figure 6 – Project axonometry, image made by the author.

Then it is decided to work on the existing architecture and in particular on the fish market building. The proposed change of use of the building is the result of the survey carried out during the state of the art analysis, from which showed that for some years the use of the wholesale market, also as a result of the new demands of the fish business, has been significantly reduced both in terms of the number of fishermen and buyers and the time they spend there. The results of the survey, together with the desire to make the architecture a public good, were the trigger for the re-functionalisation of the building, which was transformed from a wholesale market into a retail and restaurant market, as well as a covered shared space open to all. The new function, identified with the aim of involving a wider and more heterogeneous group of users, offers the historic district not only a new restaurant service open all day, but also a new meeting point. The re-functionalisation project was designed with respect for the valuable architecture, without making any changes to the original structure, but necessarily sacrificing the semicircular tribune, that had become an obstacle for the new activity. The main access to the building is from the new Fortress Square, but there are secondary entrances on all sides of the building, making it permeable and in constant dialogue with the rest of the city.

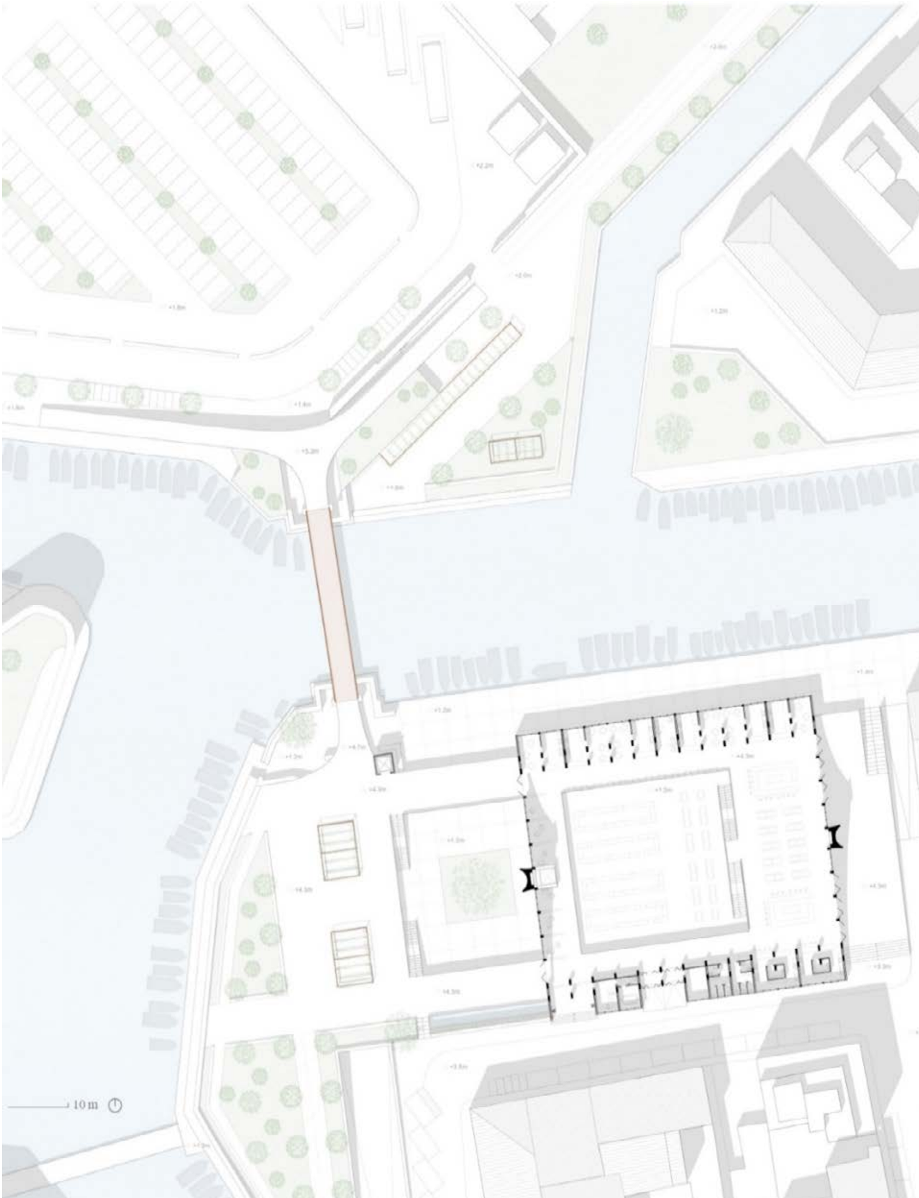

Figure 7 – First floor plan, drawing made by the author.

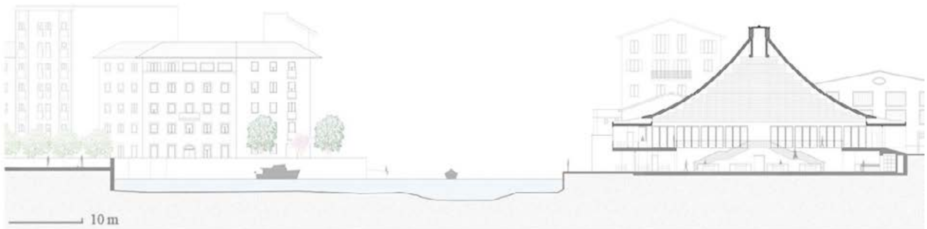

Figure 8 – Transversal section, drawing made by the author.

Figure 9 – Project view of the market interior, image made by author.

Finally, the research studied in detail some significant elements that contributed to the regeneration of the public space, such as the new cycle-pedestrian bridge and the elements of street furniture. The proposal for the new crossing provides the placement of the two pillars, which support the span, within the remains of the 19th-century bases present on both banks, with the intention of emphasising historical memories at the same time as introducing a new element of identity in dialogue with the built environment. The new bridge is characterised by a load-bearing structure in reinforced steel covered with micro-perforated Cor-Ten sheets, a parapet in steel slats and the walking surface in wooden material. The walkway is connected to the two banks by concrete footbridges so as to find continuity with the new square pavements. Lastly, Cor-Ten steel is also used to realize other urban elements such as the parapets and pergolas: essential tools for transforming a transit place into a place to relax, meet and socialize each other.

Figure 10 – Transversal section, drawing made by author.


Figure 11 – Transversal section, drawing made by author.

Conclusion

Public spaces in the Mediterranean historical centres constitute a cultural heritage of great importance for cities and have always represented a place where citizens can meet and relate. The continuous evolution and transformation of the contemporary city, the changing needs of its inhabitants and the use of new technologies by planners have meant that some of these places have lost their identity, even disappearing in some cases [Fatta, 2005]. Today, it appears necessary to rethink Mediterranean cities, avoiding a nostalgic and excessively conservative approach, but, once their history is understood, to enhance them through a process of updating. Architecture is perhaps the ideal tool to achieve this, as it is capable of interpreting changes in an increasingly multi-ethnic society and thus also capable of enhancing its quality of life [Lima, 2020].

The design research on exhibit aims to offer an innovative solution for enhancing a multiplicity of public spaces already present on Livorno's waterfront, but hidden and damaged by sporadic interventions over time. The recovery of appropriately located architecture, as in the case of Pietro Barucci and Beata Di Gaddo's fish market, can become an essential tool for the urban and social regeneration of a degraded area of Livorno. The characteristics of the Mediterranean city contribute to emphasising the regeneration potential of degraded spaces. In particular, the presence of the sea stimulates the relationship with the latter, emphasising the concepts of openness, inclusion and sharing, favouring an urban liveability based on 'slowness' and the need to re-appropriate spaces through the re-appropriation of time. The building, the square, the green areas and the bridge are part of a single great design experience with the ultimate aim of giving back a portion of the city to the inhabitants and visitors of Livorno.

Figure 12 – View of the regenerated area, image made by the author.

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SESSION

COASTAL ENVIRONMENTAL ENGINEERING: POLLUTION, ENERGY PRODUCTION, MONITORING AND ECONOMIC ENVIRONMENTAL ASSESSMENT, REGULATORY CONTEXT

Chairperson: Marcantonio Catelani
Department of Information Engineering
University of Florence

COASTAL ENVIRONMENTAL ENGINEERING: POLLUTION, ENERGY PRODUCTION, MONITORING AND ECONOMIC ENVIRONMENTAL ASSESSMENT, REGULATORY CONTEXT

The coastal environment represents a complex natural context where an interaction of different factors, often heterogeneous, is present. So, a wide variety of disciplines and research activities are involved and developed in this particular context: the goal is to study different phenomena and, if it is possible, give solutions. Engineering science can provide contributes in a wide fields as, for instance, energy production, monitoring and evaluation systems, pollution phenomena, economic environmental assessment, regulatory context. In such fields different approaches for design, monitoring and evaluation, economic assessment are proposed and implemented.

It is important to underline that, from the engineering point of view, particular attention must to be done to national and international standards and reference regulatory framework. This session, with title **Coastal Environmental Engineering**, aims to study the mentioned aspects and includes topics as: plants and techniques for purification and desalination of water; systems and techniques for coastal and marine energy production; systems, sensors and instruments for measuring environmental parameters; techniques and procedures for coastal monitoring; evaluation of the reliability and performance of measurement systems; information acquisition systems and data for the coastal environment; economic assessments in the construction and management of plants; impact analysis of new production plants energy on local economic systems and climate change gas emission; analysis of the reference regulatory framework.

As in the past, also in this IX edition of the International Symposium on Monitoring of Mediterranean Coastal Areas, the Organizing Committee proposes the technical Session *Coastal Environmental Engineering*, that saw a large participation with works proposed by qualified Research Units variously distributed nationally and internationally, demonstrating a shared and widespread general interest for the topic. The variety of research activity and the papers presented in this section confirm the complexity of the topic of the coastal environment.

As below, many interesting contributions has been proposed by Authors, often as case study. Some of them focus on measurement system and instrumentation; others, take into account pollution, with particular attention to microplastic that represent one of fundamental aspect in the present

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environmental situation of pollution. Important considerations are made considering the regulatory framework in particular context. The contributions received in this regard are manifold and of considerable scientific interest, also due to the transversal nature that the topics covered in some of them cover in the broad theme of the Symposium.

In the follows, we propose a summary classification of the contributes in the fields of *Instrumentation and Environmental monitoring, Pollution monitoring of contaminants and microplastics, Energy production.* However, many research activities involve more than one topic of the Session, as demonstration of the interdisciplinary of the context of environmental monitoring.

Instrumentation and Environmental monitoring

- The paper *The ARPA FVG support to oil spill emergency response in the gulf of Trieste* proposed by **M.Bagnarol** from ARPA FVG in Palmanova et Al., focuses the attention on the North Adriatic area, in particular the Gulf of Trieste, where two important harbours Trieste e Monfalcone operate with activities increased fast in the last decade and a perspective to rise further in the next future. ARPA FVG gives support to the local authorities in managing the oil spill emergency in the Gulf of Trieste, so it has been developing and operationally implementing environmental services that are ready to be part of the decision chain, which is activated in case of accidental releases of oil in the sea. In the paper, an operational service that integrates weather and marine forecasts into a numerical model that simulates the dispersion of the oil slick is proposed.
- **F.Benincasa, M.De Vincenzi and G.Fasano** from CNR Institute of BioEconomy in Florence present a paper on *Sea level measurements in mediterranean coast.* Authors speak about how today the sea level is measured and its importance. Particular attention is given to modern ultrasonic altimeters that allow to establish the distance between the reflective surface of the water and an ultrasonic emitter/receiver device. Authors refer, also, to the new generation of radar altimeters and their implementation in more sophisticated approaches for satellite measurement systems. The relevance of such instruments for the sea level measurement, also considering climatic changes is well described in the paper.
- In the paper *The forgotten nautical astronomical instruments* **F.Benincasa, M.De Vincenzi and G.Fasano** from CNR Institute of BioEconomy in Florence, underline the role and the importance of nautical instruments in agriculture. In the paper some of them are reported, in chronological order, with a brief description of their functions. Authors refer to the Mediterranean regions context which, as said, is perhaps the most studied in the world, from a

prehistoric and historical point of view. The contribution intends to underline that in this context there is a *lesser-known history* of forgotten things, in the proposed case of instruments for forecasting and measure, some absurd, others more rational, which, however, are the basis of today's instruments.

- In the paper presented by **Diana Mance** et Al. from Faculty of Physics in Croatia a *Study of ^2H and ^{18}O isotopes as a basis for characterization of coastal Karstic aquifers* is proposed. In the paper the findings of a two-year sampling at three karst springs in Bakar Bay (Croatia), as well as rain gauge stations in their vicinity, is proposed. Based on the isotopic composition of the collected samples, Authors concluded that these karst springs are primarily fed by winter precipitation. The analysis of auto-correlation functions and time series show that there is a difference in the degree of karstification of individual springs, with a higher degree of karstification indicating a greater sensitivity to potential pollution.
- **P. Diviacco** et Al. from National Institute of Oceanography and Applied Geophysics in Trieste (OGS), speak about *Citizen science based marine environmental monitoring. The Moana60 experience.* OGS developed innovative technologies that, as said by Authors, can be used within a citizen science or crowdsensing approach to monitor marine environmental parameters. These technologies consist of an acquisition and transmission device that sends data to the central OGS data collecting facility. The simultaneous installation of multiple such devices on boats of opportunity allows to create a network of mobile monitoring platforms and data management infrastructure able to acquire, store, process, validate and display in quasi-real-time georeferenced data on a web portal.
- In the paper *Application of statistical analysis to estimate the costal hazard. A case study in Liguria region,* **G.Lombardini** et Al. from Scuola Politecnica di Genova, take into account the phenomenon of coastal flood in Liguria region as damage produced by the loss of soil and an indirect damage correlated to the impact on tourism activity, social aspects and damage to heritage buildings. For the Authors the preliminary study put in evidence the impact that the rise of mean sea level caused by climate change (even in the most conservative assumptions), that is significant for the coastal area analyzed. An hazard analysis based on the index Sea Level Rise (SLR) is proposed. Further development considers the action of the wave motion run-up starting from the new mean sea water level modified by the expected SLR as a consequence of the climate change.
- The research proposed by **D. Malcangio** et Al. involve units from Politecnico di Bari, University of L'Aquila and Regione Puglia. The paper concerns *Biodiversity smart monitoring guided by historical analysis of coastal evolution.* It is described the architecture of the smart environmental monitoring system

installed within the frame of the project BEST (Addressing joint Agro and Aqua-Biodiversity pressures Enhancing SuSTainable Rural Development) funded by the INTERREG VA Greece-Italy 2014/2020 Program. Particular attention is paid by Authors to the criteria behind the scene: the selection of the locations of monitoring stations, as well as the identification of the instrumentation and type of sensors. The use of low-cost sensors while keeping the smart features of the system management (i.e. the minimization of the role of human presence at the sensing stations) is also investigated e represented in the paper.

- **Davor Mance** et Al. from Croatia propose the paper *Managing water commons using mediator variables to bridge the gap between environmental factors and anthropogenic pollution indicators,* Authors analysed the rainfall $\delta^{18}O$ data from hinterland locations that might potentially coincide with the locations where anthropogenic pollution originates, and subsequently they analysed $\delta^{18}O$ data from wells and springs at several locations near the beaches. Without $\delta^{18}O$ as a mediator variable, no statistically significant results were obtained by Authors. With $\delta^{18}O$ as a naturally occurring tracer as a mediator indicator variable, Authors were able to obtain acceptable and expectable results. Some consideration concerning policies and regulating prices or imposing taxes are made by Authors in the paper.
- The research proposed by **F.Serafino** et Al. from CNR Firenze and ISPRA Roma, concerns the *Analysis of the limits for the detection of Small Garbage Island immersed in clutter radar.* The aim is to show the limits of the detection capacity of X-band radars, as the sea state changes, in order to identify, discriminate, characterize and track small floating aggregations of marine litter (Small Garbage Island - SGIs) consisting mainly of plastic. Two distinct radar measurement campaigns were conducted by Authors with controlled releases at sea of SGI modules assembled in the laboratory. The measurement campaigns were carried out respectively in conditions of calm sea and almost no wind, in order to test the system in ideal conditions, and in rough sea conditions and presence of wind. The analysis of the data acquired during the experiments confirmed the ability of the X-band radars to detect the aggregations of floating waste on the sea surface, also demonstrating that the state of the sea that characterized the two measurement campaigns identifies the limits within which radars can be used for monitoring plastic marine litters.

Pollution monitoring of contaminants and microplastics

- **V.Mesnage** et Al., from Tunisie and France research centers, propose the paper *Assessment of trace metal contamination and phosphorus dynamic in sediments of Monastir bay.* The case study concerns the environment of Monastir bay.

Such area, located in Tunisia, is considered as fragile due to its weak water renewal and its high anthropogenic discharge, which influence the physico-chemical quality of the water as well as the sediment. In particular, such sediments contain polluting substances, as classified by Authors. The purpose of the research is to evaluate the contamination of the surface sediment and to discuss the sediment phosphorus dynamic. A correlation with the presence of aquatic plants (Posidonia meadow) in the sediment and the residual organic Phosphorous is also proposed.

- **C.Montigny** from the University of Montpellier et Al. present a paper on *Status of water quality and impact of dredging activities in four ports of the Gulf of Aigues Mortes (France)*. In this case study, concerning pollution phenomena, is to carry out a diagnosis of the chemical and microbiological contamination of the waters of the 4 ports located in the Gulf of Aigues Mortes. Regular water sampling was done before, during and after dredging operations. Water column quality/contamination was characterized by major physicochemical water parameters, trace metallic elements and organotin compounds.
- **Dalle Mura** et Al. from ARPA Puglia present the work *A first assessment of microplastics in the sea waters off the Puglia region.* Plastic materials persist in the marine environment with different timing depending on their nature but atmospheric agents contribute to their degradation into smaller fragments, the so called microplastics (MPs). To meet the objectives of the EU Marine Strategy Framework Directive (MSFD, 2008/56/EC), the Puglia Regional Agencies for the Prevention and Protection of the Environment (ARPA Puglia) performed a quantitative and qualitative analysis of the MPs on the basis of the data collected during 2015-2017 monitoring program. A total of 90 samples in 5 campaigns were collected using a manta net. The results represent a first assessment of microplastics at Apulian regional scale, that can be useful for the implementation of predictive circulation models in order to estimate the fate of plastic litters released at the sea.
- In *Assessment of the chemical quality of sediments in the maritime port of reunion. Concentrations in trace metals and natural geochemical backgrounds*, **J. Droit** et Al. from CEREMA – France, propose an analysis of marine sediments sampled in the port and coastal areas of Reunion. The research show, for certain metallic trace elements, significant variations in their contents and regular overruns of the regulatory thresholds for the management of dredged sediments. The goal of this study is to define, based on existing data, whether the observed exceedances of the management thresholds for dredged sediments (N1 and N2) are due to the geology of the island or to contributions of anthropogenic origin.

- **M.Esposito** et Al., from different Research units, present the paper *Environmental investigations in the Gulf of Pozzuoli (Naples) in relation to pahs contamination.* In this research the use of molluscs is considered in order to monitor the pollution phenomenon and the presence of contaminant in the sea water of the Gulf. The study confirms the use of bivalve molluscs as good bioindicators to assess levels and trends of seawater contamination, due to their filter-feeding behaviour and sedentary life, that lead to the accumulation of pollutants in their tissues. The results of sediment analysis seem to confirm the hypothesis that the contamination of molluscs could be attributed to contaminated sediments in the Gulf. As said by Authors, the proposed study highlights the need for in situ current data along the water column, in order to test the model performances as well as the need for a higher frequency of the biological sampling.
- The work presented by **H.Jaziri** from the INSTM in Tunisia, reports a study on microplastic pollution. The title is: *First investigation of microplastic pollution in Monastir sea surface water (Eastern Tunisia).* Authors state that the proposed study is the first to investigate the microplastic abundance and composition in Monastir Sea water. In the framework of COMMON MED-project, a sampling campaign was carried out during the month of December 2020 along two radials located in front of two tourist areas with different characteristics. The results showed different size for the particles of microplastic. This preliminary study should be consolidated by other surveys in time in order to study the effect of the season and in the space with the objective of covering the whole area and mapping the distribution of microplastics in the bay of Monastir.
- Also the research activity of **M.Palazot** et Al. is focused on the microplastic pollution. The title of the paper is *Chemical composition of microplastics floating on the mediterranean sea surface* and involve different research units. The objective of this work is to evaluate the chemical nature of the microplastic pollution at the surface of the Mediterranean Sea. The samples were collected by manta net during the Tara Mediterranean expedition, carried out between June and November 2014. Microplastics from 54 sites were analysed by FTIR spectroscopy, and size, concentrations in mass and in number were measured. New studies involving more geographically targeted samplings, temporal monitoring or numerical modelling are needed to confirm, invalidate or refine some of the hypotheses made here. Authors affirm that further investigations need to explore the potential of infrared spectroscopy to study the fouling of microplastics at sea.
- The research groups of CNR of Naples and CNR of Taranto, with **A.Milia** et Al., present the paper *Grain size, nutrients and heavy metals analysis to evaluate natural vs anthropogenic sources in the sea environment (Naples bay, eastern Tyrrhenian sea).* The study area is located in the Naples Bay, offshore the Sarno

River plain, an area affected by metals contamination as a result of the geogenic nature and the outflow of industrial vaste and the high demographic pressure. Grain size distribution coupled with organic matter, nutrients and metals content were analysed in order to explore how the onshore documented contamination affect the offshore counterpart. Aiming at assessing the natural vs anthropogenic origin of the contaminant, a comparison with the published data analysis conducted onshore in the Sarno Plain was implemented by Authors. Such results allow to characterize different submarine area in the Naples bay.

- **S.F.Ozmen** and other Researchers in Turkey speak about *Determination of natural radioactivity levels of sludges collected from wastewater treatment plants of Antalya/Türkiye.* Authors said that the urban wastewater sludge, end product of urban wastewater treatment, can contains pollutants left over from wastewater treatment. In recent years, the use of sewage sludge in agriculture has been made safer with legal regulations regarding the use of sewage sludge in agricultural lands. However, studies on radioactive contamination of sewage sludge are very limited. In the proposed research, sludge from treatment plants in Antalya region will be evaluated in terms of radioactivity pollution. In particular, Radionuclide concentrations of waste water sludge samples around Antalya were determined and presented in this work.
- **L.Saccalingame** et Al. from IRDL UMR CNRS 6027 in France, speak about *Extraction and characterization methods for microplastics from estuarine and coastal samplings – example of the 2019 Tara expedition.* The Tara Microplastics 2019 project aimed to investigate plastic pollution in rivers across different scientific fields of study: plastic chemistry, physical oceanography and marine biology. In this context, Authors affirm that microplastic extraction and infrared polymer identification were carried out using similar protocols in 9 European rivers. Thus, this investigation presents the advantage to apply a consistent methodological framework to very different sampling sites. Preliminary results showed that the extraction and characterization of plastic particles collected from rivers were significantly more arduous than marine plastics. Indeed, high amounts of organic and inorganic matter were found, making the extraction steps necessary to isolate the microplastics.

Energy production

- In *Optimization model for a hybrid photovoltaic/cold ironing system: life cycle cost and energetic/environmental analysis,* **D.Colarossi** et Al., from the Università Politecnica delle Marche, an optimization model for a hybrid photovoltaic/cold ironing system is proposed. As said by Authors, such system can limit the environmental pollution produced by berthed ships, replacing the on-board diesel generators with a PV plant located in port area and supported by the national grid. The ferries traffic of the port of Ancona (Italy) has been taken as case study. The model investigates the match between the energy production (photovoltaic plant in port area) and the energy demand (auxiliary engines of berthed ships). Results on the trend are shown in the paper. The approach allows to involve in the analysis the entire life of the plant, considering both the initial costs, the operation and maintenance costs and the residual value at the end of the life.

- **P.Ventura** et Al. from Roma speak about *New artificial reef in coastal protection reconversion and electric power production*. In the paper, Authors focus on the sea energy characterized by the conversion of offshore pulsing vertical wave energy into inshore horizontal current energy in the seabed transition of shallow coastal waters. Coming from the offshore deep sea, Authors found that the wind energy produces vertical pulsating waves only until the seabed reaches 10 or 12 m depth. Consequently, a great number of water particles start moving horizontally to the coast, triggering a very strong horizontal current, just below the sea surface, which causes flooding and erosion, accentuated on the seabed by return currents. The proposal is to dampen the currents by means of artificial reefs positioned in the "calm belt zone". This makes it possible to overcome the delicate problem of maintenance of the new reef, which is situated far from the storm area.

As conclusion, after this brief presentation of the papers, we can confirm that the wide and varied works proposed by the researchers for this Session is a valid demonstration on the high interest for the Coastal Environment. Many open points are present, many further developments are proposed by Authors, demonstrating the fact that the environmental engineering and physics need to research activities able to study complex phenomena.

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THE ARPA FVG SUPPORT TO OIL SPILL EMERGENCY RESPONSE IN THE GULF OF TRIESTE

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Abstract – Maritime transport has characterized the human activities since the beginning of the mankind history and it has increased over time its impact on the environment. Nowadays, almost all the seas are interested by shipping lanes where the density of the ships per unit time is very high, and that results in a non-negligible probability of pollutant release in the sea, besides the accidental collisions between ships.

In this work, we focus the attention on the North Adriatic area, in particular the Gulf of Trieste, where two important harbours operate, namely Trieste and Monfalcone, whose activities have increased fast in the last decade, with the perspective to rise further in the next future. In addition, a third port, Porto Nogaro, is located inside the Marano and Grado Lagoon and, even if it has a limited ship traffic in comparison with the two main terminals, it is set inside an important ecosystem included in the NATURA2000 sites [15] (code: IT3320037). According to the above frame, it is extremely important to be able to react promptly to an oil spill emergency, in order to avoid that the pollutant spreads over the limited area of the gulf and the lagoon, possibly reaching the shores. ARPA FVG [1] gives support to the local authorities in managing the oil spill emergency in the Gulf of Trieste, so it has been developing and operationally implementing environmental services that are ready to be part of the decision chain, which is activated in case of accidental releases of oil in the sea. Here we present an operational service that integrates weather and marine forecasts into a numerical model that simulates the dispersion of the oil slick. A description of the computational chain implementing the environmental service is presented, together with applications of the model during simulated ship collisions or accidental released along the routes.

Introduction

The oil spill occurrence is one of the worst hazards for the seas, in particular for the marine and coastal ecosystems. Furthermore, it creates societal problems, including impacts on health of individuals, well-being of communities, and their economic activities [9]. The hazard of oil spill along the ship routes, or in the harbours, may be caused by adverse weather and sea conditions, besides to be function of the density of potential sources of pollutants. Furthermore, the oil dispersion over the sea surface is directly related to the atmospheric conditions and to the surface marine currents.

The Adriatic Sea is a closed, very shallow sea in the northern part of the Mediterranean, communicating with the remaining part through the Otranto strait. Besides

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the ecological intrinsic importance of the sea, as all the seas and oceans of our world do have, the Adriatic coast is an environment hosting a rich biodiversity that is witnessed by the number of NATURA 2000 [15] sites. In addition, plenty of human activities [16], which have a large economic value, populate the shores; among them, worth of mention is the bathing tourism during the warm season.

The Adriatic is also relevant for marine transport, because of its geographical position, so the ship routes develop along the sea extension connecting several important harbours with the world maritime transport network [7]. The possibility of collisions between ships sailing on the ship lanes, or of accidental releases of pollutants from ships when they are at the anchor, before entering the harbour, has a probability that is not negligible [14]. Since one of the factors magnifying the probability of such oil spill events is the number of vessels present per unit area and time [30] [22], the current workload rapid increase of the northern Adriatic ports, i.e., Trieste [17], Monfalcone [20] and Venice [18], rises the oil spill hazard too.

Keeping in mind these evidences, it is straightforward the need for an operational forecast service that supports the emergency response to oil spill events, aiming to limit the impacts of the pollutants on the sea and especially on the shores. In fact, once the oil spill occurs, the size, the shape and the drift of the oil slick have to be contained, to prevent its impact on vulnerable areas and to ease the pollutant reclaim.

In this paper, we present the oil spill forecast service, developed by ARPA FVG [1] as the Agency operational support to the local authorities involved in the oil spill emergency response. The service is based on the oil spill model GNOME [27], which requires forecasts of sea surface currents and winds as mandatory inputs, in turn provided by state-of-the-art atmospheric and oceanographic numerical models. The combination of multiple weather and marine forecast outputs minimizes the probability that the GNOME inputs are not updated when they are needed, that is during emergencies, and this results in a service available 24 hours a day, seven days per week.

The details of the service are described together with the validation procedure and the results of its application during coordinated exercises, which have been conducted according the local Coast Guard offices exercitation plan. In addition, the contribution given by the set of instruments that ARPA FVG deploys in the field during the emergencies, for the identification of the oil type and the real time validation of the model forecasts, is described with the aim to underline that it is the synergy among information collected in situ and simulations of the spill evolution that makes the service efficacy high.

The organization of the dispersion model and the input availability for running simulations on a common laptop, which allows the environmental technicians to execute the simulations wherever their expertise is required, completes the presentation of this cutting edge service, that can be easily exported in other local realities since it has been developed to be sharable.

ARPA FVG is the Regional Environmental Agency of Friuli Venezia Giulia Italian Region [1].

Materials and Methods

An oil spill forecasting system requires a model that simulates the oil release from a source and the dispersion of the pollutant in the sea according to the boundary conditions of the considered area, namely the bathymetry and the coast shape, in addition to models that provide forecasts of the driving forces of the transport, that is the sea currents, the sea state and the atmosphere at the sea surface. Furthermore, if pollutant evolution has to be considered, the oil spill model is required to simulate the wind and the sun effect on the oil.

In the framework of the oil spill emergency response, the model chosen by ARPA FVG is GNOME. GNOME (General NOAA Operational Modeling Tool) [27] is an oil spill model developed by the U.S. NOAA (National Oceanographic and Atmospheric Administration), which predicts the trajectory and the fate of the oil released in the marine environment. It belongs to the class of Lagrangian models, where the oil is represented by a large amount of individual particles (also known as Lagrangian elements, LEs for short), each one independently moving and undergoing biophysicochemical transformations. Lagrangian oil spill models are widely adopted, mainly because of their suitability with different large spatial scales and their effectiveness for operational use.

In GNOME, the oil movement is driven by three main actions, namely the sea currents, the wind field at the sea surface, and the turbulent diffusion. The result of these physical actions on the pollutant depends on a set of user-customizable parameters, among which the windage, i.e., the degree of influence of the wind on the oil trajectory, plays a relevant role. The biophysicochemical transformations of the oil due to different natural processes, which together go under the name of weathering, are also included in the model. These transformations are highly dependent on the oil type, which indeed is one of the model variables. Lastly, GNOME contains beaching and refloating algorithms, to simulate the oil fate when it approaches the shore.

Running a GNOME simulation requires different inputs. Besides the spill details, data of sea currents and sea surface winds have to be provided as input to the model. Furthermore, static boundary conditions, such as coast lines, are also required, in order to simulate the oil behaviour on the shoreline. The accuracy of all these input data clearly influences the reliability of the forecasted oil trajectory, thus it is important for them to be up-to-date and to have a suitable spatiotemporal resolution. In order to minimize the probability that GNOME inputs are not available when needed, it is also important to have a plethora of weather and marine forecasts to be used as input data for the model.

GNOME is provided in different versions: a 2-dimensional GUI version, GNOME Desktop [26], and a 3-dimensional batch version, PyGNOME [28] [29]. GNOME Desktop, written in C++, can be directly installed on any PC and has a very user-friendly interface, which makes it easy to use for any trained user. Therefore, it is the version chosen by ARPA FVG for on-demand emergency response. PyGNOME integrates the C++ code underlying GNOME Desktop with Python code, and it currently represents the up-to-date version of the model. In comparison with GNOME Desktop, PyGNOME is more suitable for use on a HPC infrastructure; indeed, in ARPA FVG, it runs on the HPC cluster serving the FIRESPILL project [5].

Taking advantage of their complementary features, the above two versions of GNOME model have been used by ARPA FVG to provide two different emergency response services, which are available 24/7 and cover the whole Adriatic Sea: on-demand simulations via GNOME Desktop, to be carried out when an emergency occurs, and simulations of once-an-hour releases at fixed hotspots via PyGNOME, which provide ready-to-consult outputs. Since they constitute the main object of the present paper, an extensive description of these services is postponed to the Results section.

In order to evaluate the effectiveness of the services offered, ARPA FVG has been carrying out a validation of the models through tests with the use of Stokes drifters. The Stokes drifter is a low-profile surface current tracking buoy that provides real-time surface current data. It is equipped with GPS positioning by means of Iridium satellite telemetry, which enables the buoy to transmit geo-positional location data in real-time. These features make it the ideal tool for oil spill monitoring and validation of operational oil spill trajectory forecasts. The objective of ARPA FVG's drifter tests is to assess the differences between the spreading of the drifters and the trajectories forecasted by the operational Lagrangian oil spill model.

In order to get a measure of the model accuracy, the Skill Score Index, first introduced by Liu and Weisberg [21], has been used. The Skill Score (SS) is calculated from the Separation Index (S) defined as:

$$S = \frac{\sum_{i=1}^{N} d_i}{\sum_{i=1}^{N} l_{oi}}$$

where $\sum_{i=1}^{N} d_i$ is the sum of distances between the endpoints of each trajectory segment of simulated and observed drifters, and $\sum_{i=1}^{N} l_{oi}$ is the cumulative length of the observed trajectory at time step i. N is the number of time steps since the beginning of the simulation. The Skill Score (SS) is then defined as:

$$SS = \begin{cases} 1 - S/n & \text{if } S \leq n \\ 0 & \text{if } S > n \end{cases}$$

where n is a user-selected tolerance threshold. Typically, n is set to a value of 1, meaning that the error should not exceed the magnitude of the cumulative movement.

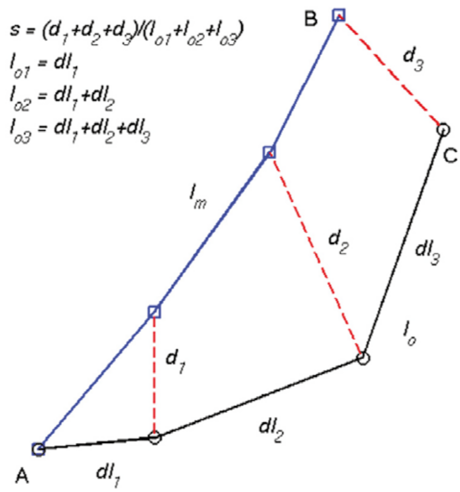

Figure 1 – Example showing the quantities involved in the calculation of the Skill Score Index, where l_o and l_m are the lengths of the observed and modelled paths, respectively. Source: [21].

In the tests already carried out, the GNOME oil spill model was used, in combination with the WRF model as source of wind data, and with both the CMEMS and ROMS models as sources of sea currents data. As the GNOME simulations were run using 10^3 Lagrangian particles, in order to obtain the step-by-step trajectory of the oil, the ARPA FVG's choice was to calculate the centroid of the 10^3 Lagrangian elements and to compare the observed drifter trajectory with the trajectory extracted from the centroid at every time step.

Results

Two services for oil spill emergency response have been developed and tested by ARPA FVG. The first service is the daily preparation and supplying of forecast data of surface winds and sea currents, as well as the supplying of updated coast lines, to be used as inputs for on-demand simulations via GNOME Desktop. In the event of an oil spill emergency, these data can be downloaded from the service webpage and used to run simulations through the GNOME Desktop application installed on the user's PC. In particular, this allows any trained user to run the simulation on his/her own, thus obtaining in a few seconds the forecasted oil trajectory for the specific scenario.

Data are provided on three areas, namely the Gulf of Trieste, the North Adriatic, and the whole Adriatic Sea, at descending spatiotemporal resolution, respectively, with a temporal coverage of +72 h. Furthermore, in order to guarantee the redundancy of the data, which is needed to minimize the risk of non-availability of required GNOME inputs, data originated by multiple meteo-marine models are made available. GNOME inputs are provided in the form of compressed archives, each one containing forecast data of surface winds and currents from specific source models, and the relevant coast lines. Detailed information about data resolutions and sources is displayed in the table below, where each line refers to one of the released archives.

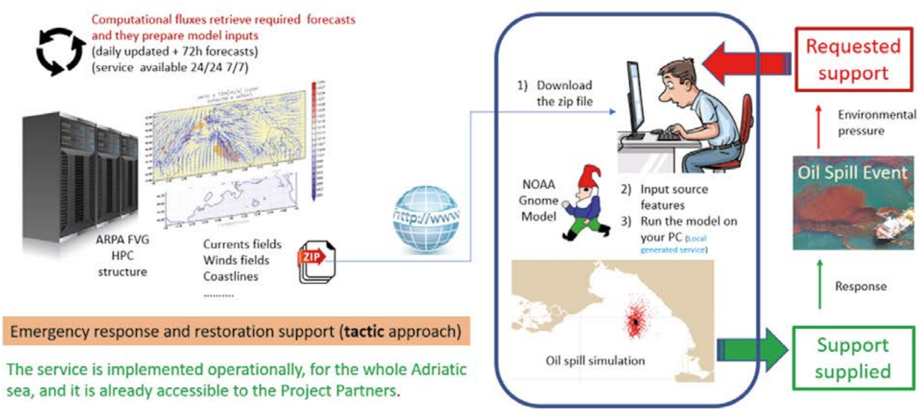

Figure 2 – Summary of the on-demand oil spill modelling service.

Table 1 – Description of meteo-marine input data for GNOME Desktop.

Domain	*Winds at 10 m*			*Sea surface currents*		
	Model	*Resolution*	*Source*	*Model*	*Resolution*	*Source*
Trieste Gulf	WRF[1]	2 km, 1 h	ARPA FVG	MedFS[2]	4 km, 1 h	CMEMS[3]
Trieste Gulf	WRF	2 km, 1 h	ARPA FVG	ROMS[4]	2 km, 3 h	ARPAE[5]
North Adriatic	WRF	2 km, 1 h	ARPA FVG	MedFS	4 km, 1 h	CMEMS
North Adriatic	WRF	2 km,1 h	ARPA FVG	ROMS	2 km, 3 h	ARPAE
Adriatic Sea	WRF	10 km, 3 h	ARPA FVG	MedFS	4 km, 1 h	CMEMS
Adriatic Sea	WRF	10 km, 3 h	ARPA FVG	ROMS	2 km, 3 h	ARPAE

In order for the on-demand service to be effective, the expertise of the operators involved in the emergencies clearly plays a relevant role. Therefore, ARPA FVG has organized a series of training courses on the use of GNOME Desktop via this service, mainly addressed to the personnel in charge of supporting the local authorities during emergency situations, but also to members of such authorities. The course material is publicly available at [2].

The second service developed by ARPA FVG for oil spill emergency response consists in a set of daily oil spreading simulations, carried out through PyGNOME, where the sources are located at certain hotspots, i.e., points or routes at high probability of oil spills, such as the Trieste and Monfalcone harbours. For each identified hotspot, one spill per hour from that fixed source is simulated, leading to a total of 24 simulations per day. The forecasting period of these simulations is usually set to +48 h or +72 h, but it can be effortlessly customized. The output is provided in the form of a GIF animation, which allows the user to have an immediate visualisation of the forecasted oil trajectory. Being the pilot area of ARPA FVG for the FIRESPILL project, the Gulf of Trieste is the main domain of these simulations. However, since the service has been developed to be shared among all project partners, any hotspot in the Adriatic Sea can be easily integrated in the service.

The purpose of the simulations on hotspots is to provide stakeholders, when facing an oil spill emergency in those areas, with an on-the-spot hint about the trajectory that the pollutant will follow, without the need to run a simulation on their own. In particular, this second service does not require any expertise with the oil spill model, hence it is addressed to a broad group of stakeholders.

Both the modelling services developed by ARPA FVG as support to oil spill emergencies, in the framework of FIRESPILL project, are daily updated and available to all stakeholders at the project website [5]. The archives containing forecast data of oil movers for on-demand simulations with GNOME Desktop can be downloaded by accessing the page "GNOME model driving forces" [3], which also contains useful links for the model use.

Graphical output of the daily simulations on hotspots can be viewed at the page "Daily oil spill simulations" [6], where every simulation is identified by an alphanumeric code containing all the information about its specific features.

[1] Weather Research and Forecasting Model [25] [4].
[2] Mediterranean Forecasting System [8].
[3] Copernicus Marine Environment Monitoring Service [24].
[4] Regional Ocean Modeling System [12] implemented on the Adriatic domain.
[5] ARPA Emilia-Romagna.

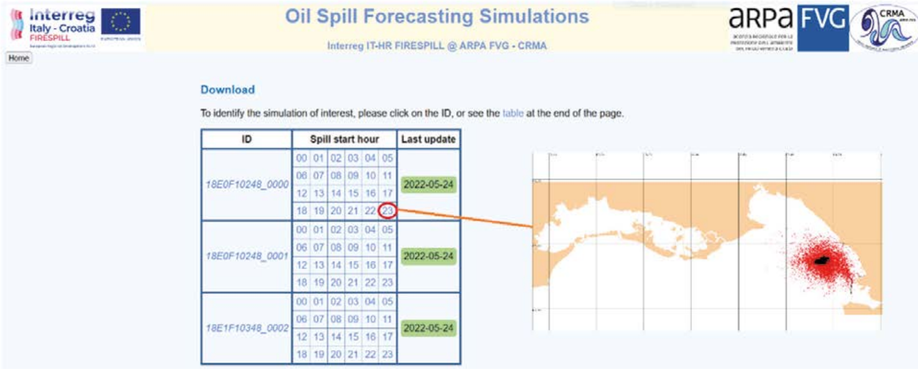

Figure 3 – Output of a PyGNOME simulation on hotspots, from the webpage of the service. In this case, the oil source is located near the Port of Trieste.

The page "GNOME course" [2] is the above-mentioned page containing training material for the on-demand service.

The operational implementation of the described services has been realised by means of the workflow manager ecFlow [13], which eases the execution of all the computational routines. This way, human intervention is limited to unordinary situations, thus enhancing the service operability.

In order to verify the results obtained through the GNOME model simulations, four different release days of the Stokes Drifters were organised between February and May 2022. All releases were carried out in the Gulf of Trieste and lasted from 24 hours to 60 hours.

Three different drifters were used on each test day. In particular, on one occasion, namely on 2022-02-28, the three drifters were released in three different positions in the Gulf of Trieste, while in the other three cases all of them were released at the same point. The choice of using a single release position was made in order to monitor the possible deviation of the drifters themselves after 48 h and, at the same time, to verify the sensitivity of the Skill Score index to slight deviations from the observed trajectory. In none of the releases there was a coastal stranding or any other event that could have affected the natural movement of the drifters.

Tables 2 and 3 present the results obtained in terms of the Skill Score and its standard deviation, respectively. The results are grouped by time bands. The first column takes into account 48 h from release, the second the first 12 h, while the last three columns present the results within 24 h. This representation was chosen in order to visualize how the value of the Skill Score is influenced by the relaxing simulation time. In fact, the value of the Skill Score shows an initial oscillation before reaching an almost constant value.

In the tests conducted by releasing the three drifters at a single position, the deviation of the three drifters among themselves never exceeded 2 km after 48 h. From the calculation of the Skill Score with the three drifter traces observed, only slight non-significant variations on the final value of the Skill Score were seen. Therefore, these preliminary tests provide a clear indication of how the Skill Score index is a robust and useful tool for quantifying the accuracy of the models and of the input data required by them.

From the results obtained, presented in Table 2, the Skill Score values exceeded 0.5 for both source of sea currents data, on all test days except 2022-04-11. This gives a clear insight into how the emergency response system adopted in ARPA FVG is able to provide a reliable forecast.

Table 2 – Summary of the Skill Score (SS) mean collected during the ARPA FVG tests in the period February – May 2022. Results of each set of inputs are presented, namely sea currents from CMEMS and ROMS modelling systems, with the same source for winds, that is WRF model.

Skill Score	48h		12h		24hfrst		24hsnd		24htrd	
Data	CMEMS	ROMS	CMEMS	ROMS	CMEMS	ROMS	CMEMS	ROMS	CMEMS	ROMS
28/02/2022	0.721	0.682	0.549	0.385	0.659	0.567	0.782	0.796	/	/
11/04/2022	0.496	0.442	0.316	0.248	0.383	0.347	0.607	0.536	/	/
18/05/2022	0.561	0.756	0.46	0.676	0.561	0.756	/	/	/	/
20/05/2022	0.756	0.835	0.68	0.759	0.707	0.763	0.791	0.874	0.783	0.899
MEAN	0.634	0.679	0.501	0.517	0.578	0.608	0.727	0.735	0.783	0.899

Table 3 – Summary of the Standard Deviation (SD) collected during the ARPA FVG tests in the period February – May 2022. Results of each set of inputs are presented, namely sea currents from CMEMS and ROMS modelling systems, with the same source for winds, that is WRF model.

Skill Score	48h		12h		24hfrst		24hsnd		24htrd	
Data	CMEMS	ROMS	CMEMS	ROMS	CMEMS	ROMS	CMEMS	ROMS	CMEMS	ROMS
28/02/2022	0.160	0.167	0.243	0.257	0.208	0.216	0.023	0.027	/	/
11/04/2022	0.131	0.129	0.051	0.070	0.095	0.123	0.016	0.011	/	/
18/05/2022	0.154	0.120	0.153	0.120	0.154	0.120	/	/	/	/
20/05/2022	0.067	0.075	0.107	0.088	0.086	0.069	0.010	0.012	0.004	0.006
MEAN	0.1280	0.1228	0.1385	0.1338	0.1358	0.1320	0.0163	0.0167	0.0040	0.0060

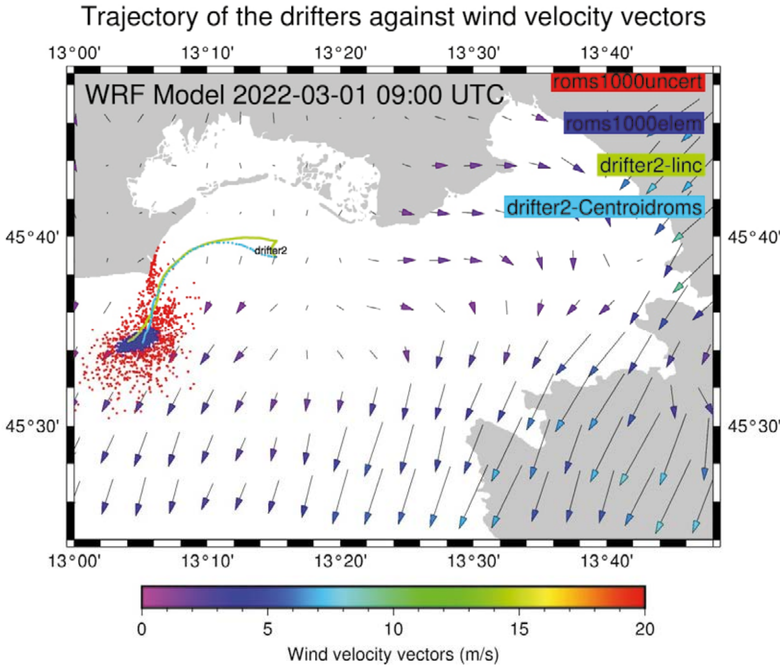

Figure 4 – A snapshot of the simulated (green) and observed (light blue) trajectories. The deterministic prediction by the GNOME model is represented in blue, while the probabilistic one is shown in red. Model inputs are wind velocities from ARPA FVG – WRF model and sea currents from ROMS model. Wind vectors are plotted in the domain, too.

Figure 5 – Picture of a drifter released in the water during a model validation test.

The oil spill forecasting system developed by ARPA FVG was also tested during an anti-pollution and fire-fighting exercise coordinated by the Monfalcone Port Authority on 2021-11-25. In case of an oil spill event, ARPA FVG is indeed one of the authorities committed to organize the intervention groups of the Emergency Response System, with the task of giving support to the authorities in charge of the emergency management, such as the Port Authority, the Fire Brigade, or the Civil Protection. For instance, the presence of ARPA FVG in the accident site is required in order to establish the type of pollutant, both through on-site measurements and through sampling and subsequent laboratory analyses. Besides the on-field teams, ARPA FVG also provides support via its modelling tools, in particular the above-mentioned services for oil spill emergencies.

The exercise, where a ship accident leading to a leak of 5 m^3 of fuel oil within the Port of Monfalcone was simulated, showed the important role of the oil spill forecasting system in addressing the emergency management operations. At the same time, it exposed the need for improvement of the services, in particular when the oil spill occurs very close to the coast. For further information about the observed limits and the planned solutions, see the Discussion section.

Discussion

The services developed by ARPA FVG for oil spill emergencies have proved to be an import tool to support the authorities in the emergency management, providing them with useful information about the oil spreading evolution, as it has emerged from the exercise coordinated by the Monfalcone Port Authority.

The complementary features of the two services presented in this paper make the ARPA FVG's oil spill forecasting system useful and beneficial for a large class of stakeholders. The system has been mainly tested on the Trieste Gulf and the Marano-Grado Lagoon, i.e., the FIRESPILL pilot area of ARPA FVG, but it has actually been developed for the whole Adriatic Sea, in order to be sharable with all project partners. Therefore, any stakeholder in the Adriatic area can benefit from this work.

The validation campaign through drifter tests has confirmed the reliability of the adopted system, including both the oil spill model and the meteo-marine models. This has been highlighted by the results on the Skill Score, whose mean values were greater than 0.5 in all but one test, even with different sources of data of sea currents. Recall that 0.5 is the value which is usually considered the threshold between low and high performance of the trajectory model.

However, the validation has also allowed to understand the current limits of applicability of the services, in particular within lagoon environments or within harbours. The coastal local variations are not captured with sufficient spatial accuracy, and sometimes the inputs time resolution does not allow to capture transient meteorological phenomena, which however considerably influence the results. As a consequence, in correspondence of river mouths, or when strong tidal excursions or rapid changes in the seabed occur, the results obtained in such critical areas are uncertain or unreliable. In addition, the lack of data of sea currents close to the shoreline, due to the resolution of the adopted models, leads the Lagrangian elements to be moved only by the wind field, with a subsequent decrease of the oil spill model performance.

For this reason, a new high-resolution hydrodynamic forecast system, focused on the Trieste Gulf and the Marano-Grado Lagoon, has been designed and is in the implementing phase. It is based on the shallow water model SHYFEM [19], which is driven by means of the Mediterranean basin scale sea state forecasts provided by CMEMS [24] and of the ARPA FVG meteorological forecasts, operationally generated via the WRF model [4]. The quality evaluation of the high-resolution fields has already been performed and the best parameters configuration has been identified.

Furthermore, the implementation of another oil spill model, MEDSLIK-II [10] [11] [23], is in progress and close to be ready for operational purposes. The basic model has been adapted to take as input the same data of driving forces used for GNOME, and a more detailed local cartography than the default one has been added to the model. By adding new forecasts of the oil trajectory and fate to the already existing ones, this will allow to improve the oil spill forecasting system. In particular, the use of this new model, together with the full exploitation of the recent 3D features of PyGNOME, should capture the entire 3D evolution and not only the 2D oil trajectory on the sea surface, as is currently the case.

Finally, in order to keep and improve the service efficiency, the training of the personnel involved in the emergency response has to be maintained constant and updated with the new system features. Only this way the oil spill forecasting system can be used promptly and efficiently, as it is needed during an emergency situation.

Altogether, this set of improvements is expected to allow ARPA FVG to overcome the current limits of the oil spill response services, which anyway are already at a good level of reliability, as shown by the above results.

Conclusion

Oil spill events pose a serious threat to the marine and coastal environment, in particular in an area such as the Adriatic Sea, and more specifically the Gulf of Trieste, where the marine traffic has been constantly increasing in the last years. Among the vulnerable subjects, it is worth mentioning the human activities, such as marine transport, tourism, fishing, fish and mussel farming, besides the entire ecosystem, in which many vulnerable species live. Last but not least, also the historical and cultural heritage sites are vulnerable to the oil spill threat.

This highlights the importance and usefulness of a forecasting system to support the authorities in the management of oil spill emergencies. The services described in this work exactly aim at providing such an efficient and reliable operational system, focused on the Gulf of Trieste and the Adriatic Sea, with the ability of being employable by different users. Public availability is one of the important features of these services, which have indeed been developed to be sharable.

The oil spill forecasting system of ARPA FVG has been under continuous validation, which has shown, together with on-field experiences like the participation in a Coast Guard exercise, its value and reliability. Of course, some limits of the services have also emerged, requiring further development and improvement, on which ARPA FVG is currently working.

The beneficiaries of this work are various, including all the stakeholders related to the above-mentioned vulnerable subjects, and the public entities in charge of managing the marine emergencies, like the Port Authorities, or the society safety, such as the Civil Protection.

Acknowledgments

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ASSESSMENT OF TRACE METAL CONTAMINATION AND PHOSPHORUS DYNAMIC IN SEDIMENTS OF MONASTIR BAY (TUNISIA)

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Abstract – Located in the eastern coast of Tunisia, the Monastir bay is considered as a fragile area due to its weak water renewal and its high anthropogenic discharge, which influence the physico-chemical quality of the water as well as the sediment. To establish the state of sediment ‘s pollution of Metallic Trace Elements (MTE), Total Organic Carbon (TOC), Total Phosphorus (Total P), Phosphorus particulate fractions, and granulometric distribution were analyzed at sediment sampling stations. The purpose of this research is to evaluate the contamination of the surface sediment and to discuss the sediment phosphorus dynamic: is sediment a sink or a source of phosphorus? Then the geochemical data and the statistical analysis highlighted a moderate pollution of the sediment, in particular by Mn, Ni and Cu, in the northern part of the bay. Overall, the MTE concentrations are much lower than those reported in the Gulf of Tunis and Gabès. Although the sediments of the bay of Monastir do not seem to be affected by a strong inorganic pollution even with the large impact of human activity. Furthermore the sediment phosphorus distribution seems to be controlled by the phosphorus bound to refractory organic matter (Residual Organic Phosphate, ROP) and bound to Calcium carbonate (P-$CaCO_3$). The ROP fraction concentration is very high and can be interpretate by the enrichment with seagrass. Furthermore, the PCA results show two trends: surface sediment enriched with iron (Fe) and TOC versus an other one enriched with carbonate but with weak concentration Fe and TOC. The phosphorus dynamic is controlled by environmental conditions, (i) oxic sediment with basic pH conditions enhance the FeOOH formation and consequently the phosphorus fixation on FeOOH or CaCO3 in sediment (P-FeOOH, P-CaCO3) whatever the sediment lithology and (ii) anoxic and acidic sediment enhance the formation of ROP (Residual Organic Phosphorus) in correlation with the presence of aquatic plants (Posidonia meadow) in the sediment.

Introduction

Coastal ecosystems represent 6 % of earth surface and 8,5% of marine biomes, they are among the most productive in the world. Mediterranean Sea holds a wide biodiversity, even with its little surface area, which is 0,7 % of global marine waters [14], [16]. Scientific community is interested in the sensitivity of coastal zones to anthropogenic discharges [18], [32]. Indeed, Mediterranean ecosystem has been affected by natural and anthropic factors,

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especially wastewater rejects. The latters influence chemicophysical quality of marine sediments [4].

Monastir bay is considered as a vulnerable area on account of its reduced hydrodynamic [36]. The bay has been studied in order to determine pollution levels in (i) organic matter and MTE [34], (ii) in hydrocarbons [39], (iii) in PCB et PBDE [27]; these studies lead to the conclusion that Monastir bay surface sediments are enhanced with an organometallic pollution. Monastir bay is used for aquaculture, so it is regularly dragged to pull out sediment stocks charged in nutrients. Khniss drain, built in early 1970's, collects domestic and industrial wastewaters of nearby cities. It permits the drainage of Monastir sebkha water to sea during rise period [34]. Consequently, Khniss drain is considered as the most important source of nutrients and MTE of the bay [6]. All these anthropogenic activities generate organic pollution that causes eutrophication. This leads to chronic anoxia of the Bay's surface waters as well as the emission of solid waste and polluted water [19]. These pollutants come from many sources such as wastewater treatment plants of Khniss, Ksibet El Mediouni, Lamta-Sayada Monastir cities which are discharged into the bay, the Khniss drain and the fishing harbours.

The aim of this research study is to discover the state of contamination of the sediments surface and to discuss the sediment phosphorus dynamic: is sediment a sink or a source of phosphorus? Thus Metallic Trace Elements (MTE), Total Organic Carbon (TOC), Total Phosphorus (Total P), Phosphorus particulate fractions, and granulometric distribution have been measured in surface sediment.

The results allowed us to answer the following scientific questions: (i) Is the pollution of Monastir bay's sediments similar to other marine environments in Tunisia? (ii) Is the Monastir bay surface sediment polluted according to the sediment quality standards? The scientific interest is in the chemical characterisation, by fractioning the forms of particulate phosphorus to discuss the dynamics of sedimentary phosphorus in relation to other sediment characteristics (MTE, TOC, Carbonate).

Material and methods

Monastir bay (35°47'N et 35°37'N; 10°45'E et 11°50'E) is closed, to the north by a rocky escarpment of 17 m high (Cap Monastir) and to the south by the high ground of Teboulba extending as far as the Kuriat islands (Figure 1). This marine environment is characterised by a bathymetric slope in its north-eastern direction: the -1 m isobath is located at a distance of 1 mile from the shore. This particularity is at the origin of the formation of an extensive flat area [1], [28]. The bottoms closest to the coast are generally sandy-muddy to muddy and are largely covered by a black muddy film with various seagrass beds favourable to many organisms [33], [12]. The prevailling winds are characterised by a speed between 1 and 5 m/s and come from three main directions of W, NNE and E [36] – figure 1. Socio-economic context of this bay is characterised by strong development, one of the most intense that Tunisia has undergone in the last twenty years. The textile industry predominating, covering 79 % of the regional industrial fabric [19]. This region concentrates 12 % of Tunisia's industrial activity [7] and 44 % of the national fisheries production comes from fishering and aquaculture in the bay with four fishing harbours equipped with refrigeration complexes [11] – Figure 2. Geological context, described in the works of [23] and [31], is composed of Mio-Plio-Quaternary formations at the level of the Monastir cliff and Tyrrhéniennes formations (Ksibet Mediouni) at the level of the hills bordering the Bay. Watershed belongs to the Sahel platform and is formed by the Moknine tableland and the two NE-SW anticlines of Bir and Taieb and Zéramdine, separated by the broad syncline of Jammel, which in turn passes to the NE at the anticline of Bodeur. The Monastir Sebkha is boundes by the Skanes-Khnis fault to the east and the Sahline flexure to the west. The sedimentary formations spread out from the Miocene to the Quaternary, are essentially formed of sandy-clay continental sediments, with in the Lower Pliocene and Tyrrhenian, marine carbonate deposits, of a sandy to gravelly nature that are more or less consolidated, oolitic or calcarintic. The bay is therefore composed mainly of fine and medium sands including a variety of minerals, especially quartz and calcite [9].

Surface sediment sampling stations were sampled in April 2017 with a Shipek-type sediment grab (Figure 2). The measurement of Total Organic Carbon (TOC) was carried out using the Walkley-Black method [10]. The determination of carbonates was carried out by the calcimeter method of Bernard. For the MTE analyses sediment samples were digested in teflon bombs using a mixed solution (*v*/*v*) 20 mL $HClO_4$ and 10 mL HF, method following the protocol of [29]. Then, MTE (Fe, Mn, Pb, Zn, Cu, Ni, and Co) were analyzed by flame atomic absorption spectrometry (SOLAAR). Phosphate fractionation was carried out according to the chemical method of [20]. The inorganic fraction phosphate: iron bound-phosphate, Fe(OOH)-P and calcium-bound-phosphate, $CaCO_3$-P, have been extracted with chelating agents (NTA and EDTA). Acid Soluble Organic Phosphate (ASOP) has required a single extraction with H_2SO_4 0.25 M. Then followed a 2 M NaOH (90°C) with heating step to extract the Residual Organic Phosphate (ROP). The GIS spatial representation has been performed with Surfer software [2]. Statistical analyses, with a Principal Component Analysis (PCA) and inter-elemental correlation have been performer by PCA R-software.

Results

Organic carbon content (TOC - Table 1) fluctuates from 1 to 5.8 %; highest concentrations are near the Monastir Harbour and in the aquaculture area (sediment sampling stations 2, 7, 8 – Figure 2). High concentrations of CaCO3 from 32 to 65 % (table 1) in sediments can be easily explain by the sedimentary carboneous origin of the watershed around the Monastir Bay.

The spatial variation of MTE concentrations in the surface sediments are presented in figures 3, 4 and 5. The copper and nickel concentrations vary between 16 and 58 ppm and between 9 and 44 ppm respectively (figure 3), with maximum concentrations in the sediments of the Monastir and Sayada Harbours' (Figure 3). Measured copper and nickel values have increased since 2015 [13] and then remained stable between 2017 and 2020 [7]. The copper concentrations in the sediments of Monastir bay are slightly higher and those of nickel of the same order of magnitude as in other Tunisian coastal ecosystems studied, in Sfax [21], in the El Melah lagoon [22] and in the Golf of Tunis [38] and Gabès [3], [15].

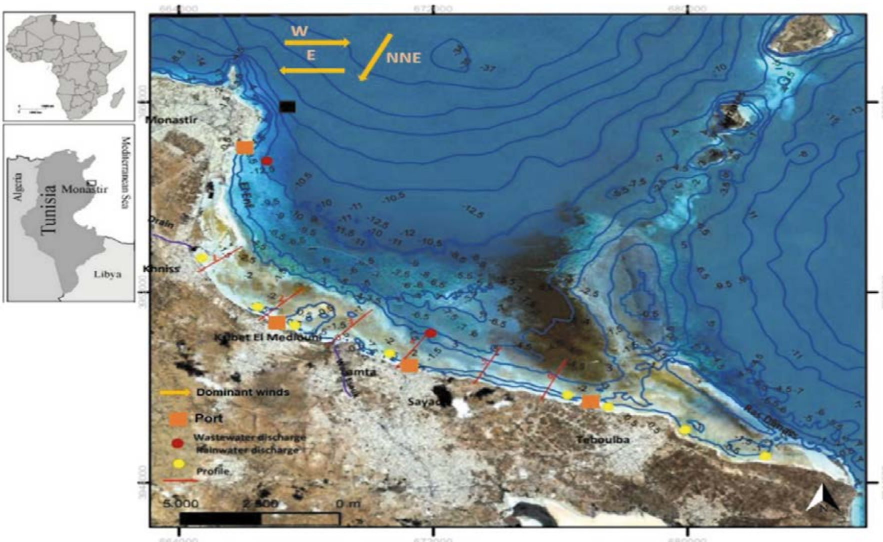

Figure 1 – Location and bathymetry of the study area: The Monastir Bay in Tunisia.

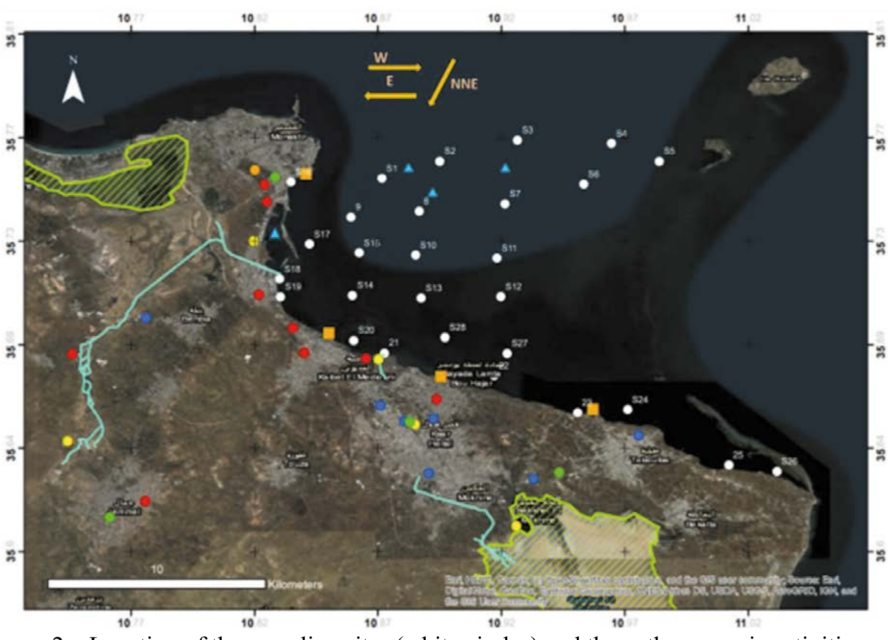

Figure 2 – Location of the sampling sites (white circles) and the anthropogenic activities and of the Monastir Bay: aquaculture (blue triangle), sewage treatment (yellow circle), textile factory (blue circle), chemical factory (red circle), car factory (green circle), harbour (orange square), drains (blue line), sebkra (green hatching).

Table 1 – Granulometric and geochemical characteristics of sediment.

Sample stations	**1**	**2**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**14**	**15**	**16**	**17**	**18**	**24**	**25**	**28**
Lat.	35° 45’ 20.08’’	35° 45’ 45.12’’	35° 45’ 11.47’’	35° 44’ 42.56’’	35° 44’ 32.02’’	35° 44’ 23.48’’	35° 43’ 26.50’’	35° 43’ 22.22’’	35° 42’ 25.37	35° 42’ 27.21’’	35° 43’ 29.83’’	35° 45’ 14.81’’	35° 43’ 42.75’’	35° 42’ 51.27’’	35° 39’ 38.54’’	35° 38’ 16.89’’	35° 41’ 25.24’’
Long.	10° 52’ 7.79’’	10° 53’ 33.73’’	10° 57’ 7.87’’	10° 55’ 11.04	10° 53’ 3.26’’	10° 51’ 21.92’’	10° 52’ 58.10’’	10° 54’ 59.16’’	10° 55’ 4.92’’	10° 51’ 24.19’’	10° 51’ 34.30’’	10° 49’ 52.60’’	10° 50’ 20.27	10° 49’ 35.70’’	10° 58’ 13.43’’	11° 0’ 43.93’’	10° 53’ 41.81’’
Granulometry (< 63 µm) (%)	27.6	25.93	41.84	32.58	47.29	38.44	19.54	15.92	61.58	15.68	nm	8.51	27.33	27.6	13.97	9.76	55.08
MgO (ppm)	1.68	1.95	2.79	2.82	1.92	1.59	1.96	2.13	3.02	2.52	nm	1.33	2.31	2	1.15	1.31	3.15
O.M. (%)	7.44	22.53	19.56	22.1	19.1	17.2	14.86	nm	nm	8.23	18.6	nm	14.28	9.85	nm	nm	18.46
T.O.C (%)	1.4	5.5	4.37	4.14	3.3	3.04	2.43	5.54	5.8	2.1	3.3	0.97	2.1	3.38	1.5	1.82	2.9
$CaCO_3$ (%)	44.25	31.99	48.27	36.45	36.85	41.93	51.31	nm	54.64	61.53	41.12	nm	63.53	36.77	nm	nm	65.26
Zn (ppm)	37	68.53	48.11	123.44	61.7	88	64.18	69.51	86.5	41.75	nm	117.3	57.94	45.46	38.63	47.44	41.42
Pb (ppm)	19.65	56.44	25.18	30.14	37.2	25.72	26.2	53.76	35.23	3.94	nm	47.96	19.2	21.5	26.96	19.09	11.45
Cd (ppm)	0.17	0.82	0.72	0.33	0.4	0.5	0.81	0.68	0.76	1.4	nm	0.62	0.64	0.13	0.71	0.68	121.43
Cu (ppm)	18.83	29.1	24,95	26.04	23.75	23.56	22.36	34.6	24.24	21.3	nm	58.45	28.72	20.75	26.2	34.6	16.23
Ni (ppm)	16.7	22.5	28.9	28.44	27.28	22.81	22.06	40.6	16.8	30	nm	44.5	28.1	16.64	20.25	18.76	9.43
Fe (%)	0.63	1.3	1.36	1.63	1.56	1.15	0.74	1.82	0.74	0.52	nm	1.14	0.66	0.96	0.63	0.35	0.59
Mn (ppm)	105.76	103	84.4	121.95	90.63	85.56	85.71	110.25	75.2	117.9	nm	308.32	76.91	120.21	115.94	103.1	88.3
Sr (%)	0.54	0.38	0.47	0.36	0.43	0	0.6	0.34	0.51	0.69	nm	0.31	0.7	0.34	0.3	0.55	0.54
Cr (ppm)	48.75	62.55	113.5	88.3	88.9	72.85	63.03	70.75	79.5	106.6	nm	94.31	133.6	99.63	76.14	63.6	80.4
P-FeOOH ($\mu gP.g^{-1}$)	24.4	111.9	16.8	43.6	30.7	66.9	41.5	nm	nm	100.3	34.4	167.6	66.6	19.7	39.3	nm	69.4
P-$CaCO_3$ ($\mu gP.g^{-1}$)	161.4	144.5	82.2	149	121.6	194.1	81.6	nm	nm	219.4	89.5	311.6	107	98	79.8	nm	169.8
P-OM ASOP ($\mu gP.g^{-1}$)	15	17.8	17.1	22.2	23	17.6	12.3	nm	nm	8	18.8	40	12	13.7	17.5	nm	11.3
P-OM ROP ($\mu gP.g^{-1}$)	156.2	234.5	216.2	245.1	235.7	245.1	199.1	nm	nm	156.16	206.6	112.4	238.1	186	159.8	nm	218.5
Total P ($\mu gP.g^{-1}$)	357.6	511.9	332.5	461.2	412.9	527.4	337.1	nm	nm	487	351.1	642.5	425.9	318	298.7	nm	470.8

nm: no measurement.

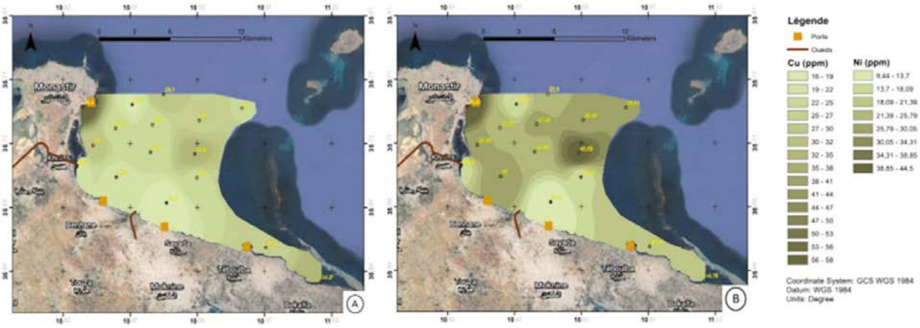

Figure 3 – Spatial distribution of MTE in Monastir Bay surface sediments : (A) Cupper (Cu in ppm), (B) Nickel (Ni in ppm).

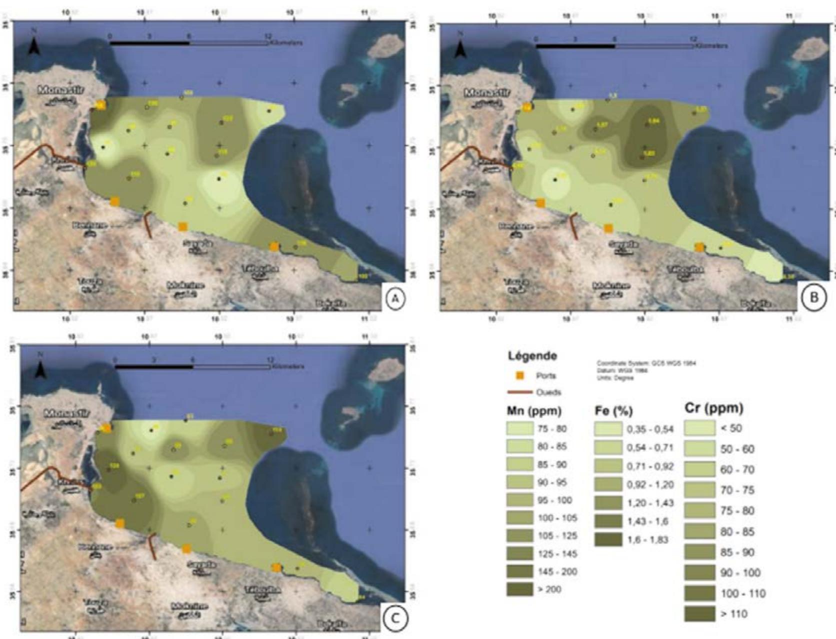

Figure 4 – Spatial distribution of MTE in Monastir Bay surface sediments: (A) Manganese (Mn in ppm), (B) Iron (Fe in %), (C) Zinc (Zn in ppm).

The manganese, chromium and iron concentrations vary between 75 and 308 ppm, 49 and 134 ppm and 0.3 and 1.8 % (i.e. between 3 000 and 18 000 ppm) respectively (Figure 4). The highest concentrations measured in the sediments of Monastir's Harbour and off this area forming a gradient of enrichment of the sediments towards the east of the Bay, of these three metals. The sediments in line with the Khniss drain also have the highest concentrations of Mn, Cr and iron in this bay and they are more polluted in these MTE than in other Tunisian coastal areas.

The concentrations of lead (4 - 56 ppm) and zinc (37 - 123 ppm) - figure 5 - are also maximum in the sediments of the port of Monastir and offshore with an accumulation gradient to the east. Their concentration in sediments were high in 2015 [13], and then decreased and are of the same order as the measurements of [7]. The lead values in the sediments of the Bay of Monastir are comparable to those obtained along the coast of Sfax; higher than near the coast of Gabes and slightly lower than in the Gulf of Tunis. The zinc concentrations are similar to those of the Sfax coast (39 - 117 ppm) but seem much lower than those of the Gabes coast in 2013 and the Gulf of Tunis where the maximum values reach 7165 ppm and 451 ppm respectively.

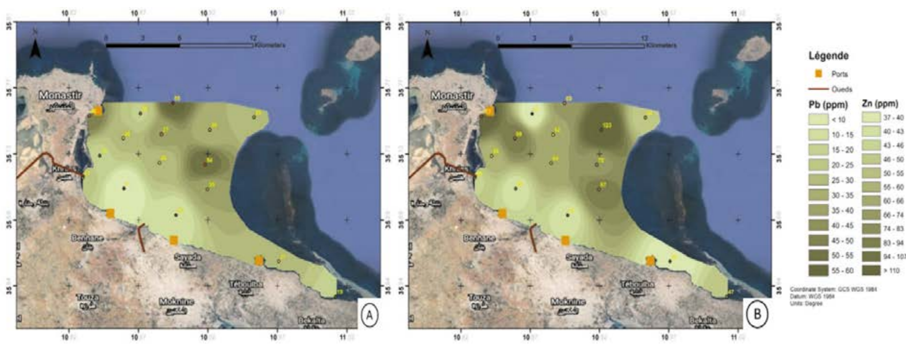

Figure 5 – Spatial distribution of MTE in Monastir Bay surface sediments: (A) Lead (Pb in ppm) and Zinc (Zn in ppm).

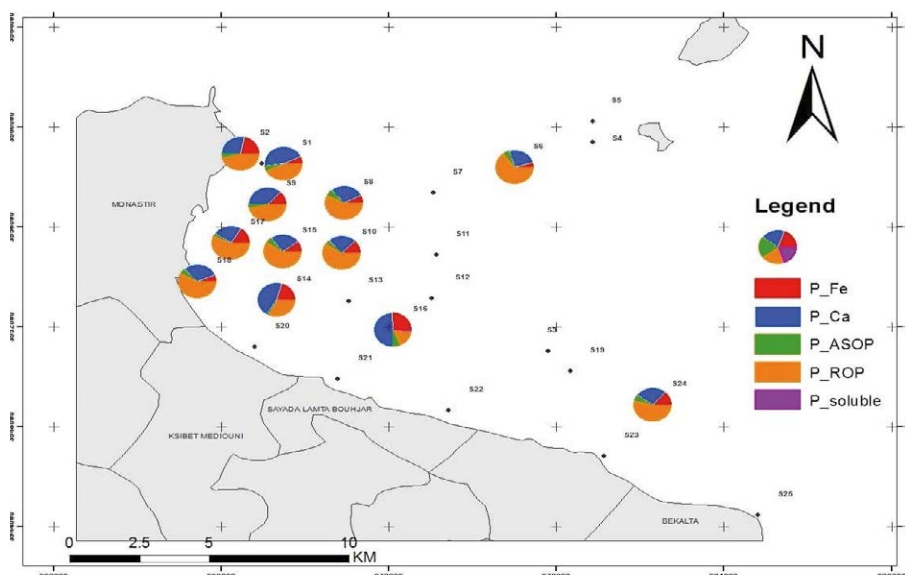

Figure 6 – Spatial distribution of phosphate particulate fractions in Monastir Bay surface sediment.

The total phosphorus concentrations in the surface sediments of the Bay of Monastir vary between 300 and 643 µg/g (Table 1), values in the ranges of those measured in other coastal ecosystems in Tunisia: Tunis Lake and the Korba [30] or Bizerte Lagoons [26]; but much stronger than in other Mediterranean coastal ecosystems in Italy (397 tot. P µg/g, [35]) or in Greece (205 tot. P µg/g, [25]).

Chemical fractionation of phosphorus has identified four main forms of particulate P.: inorganic P. bound to iron hydroxides (P-FeOOH) and carbonates (P-CaCO3) and organic P. bound to biodegradable MO (ASOP) and refractory (ROP) – Figure 6 – It appears that the dominant form is ROP (52 %) and P-CaCO3 (32 %), this distribution of forms of particulate P. is related to geochemical characteristics sediments: richness in OM (high TOC and loss on ignition contents) and in carbonates. The spatial distribution of the ROP is explained by the high concentrations of MOP at the level of the Port, discharges from the Khniss Canal and north of the Bay (aquaculture basins) and the presence of the aquatic plants (Posidonia meadow).

The PCA results (Figure 7), loading plots of the F1 factor highlight two groups of sediment sampling stations: the first one relatively enriched with P-FeOOH and P-CaCO3 fractions and relatively poor in ROP and TOC, the second one, at the opposite: poor with P-FeOOH and PCaCO3 fractions and enriched in ROP and TOC.

In contrast, the loading plots of the F2 factor demonstrate a trend with sediment stations enriched with organic matter and total phosphorus in opposite with others sediment stations poor in organic matter and total phosphorus. Then organic matter is clearly the phosphorus source. To summarize, the PCA results show two trends: surface sediment enriched with Fe and TOC versus an other one enriched with carbonate but with weak concentration of Fe and TOC.

	P-$CaCO_3$	ASOP	ROP	TP	Silt-Clay	OM	TOC	$CaCO_3$	Fe
P-FeOOH	0.441	-0.137	-0.760	0.624	-0.159	0.021	-0.187	0.288	-0.081
P-$CaCO_3$		-0.111	-0.907	0.311	0.173	-0.275	-0.351	0.175	-0.369
ASOP			0.013	0.165	-0.310	-0.167	-0.305	-0.317	0.181
ROP				-0.533	-0.009	0.211	0.379	-0.217	0.278
TP					0.147	0.440	-0.181	-0.128	0.255
Silt-Clay						0.484	0.511	-0.007	0.223
OM							0.576	-0.323	0.446
TOC								-0.336	0.613
$CaCO_3$									-0.495

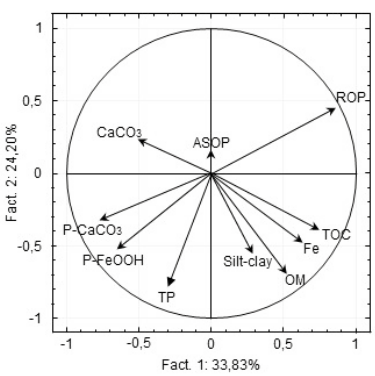

Figure 7 – The Principal Component Analyse: Loading plots of the two factors (F1 and F2) and inter-elemental correlation table.

Discussion

The sediments of the coastal areas, by their very adsorbent silto-organic nature, are a sink of MTE. They therefore constitute markers of the various human activities of this Bay [11], [37]. Indeed, the chemical and metallurgical industry, present all along the coast, from Monastir to Ksibet El Mediouni, explains the high concentrations of chromium and iron [34].

On the other hand, the harbour's activity which uses fuels, anti-corrosion and anti-rust paints (antifouling), explains the accumulations of Pb, Zn and Sr in the sediments of the four harbours of this Bay. The textile industry, with factories located at Oued Essouk, produces Cu, Zn, Pb and Sr which accumulate in the surface sediments. The determination of the degree of pollution of the surface sediments in the bay, by comparison with a standardized standard [4], shows that the sediments, in 2017-2020, present acceptable MTE concentrations, below this international sediment quality standard (Dutch criteria, [4]).

However the strong increase in MTE in 5 years (2015-2020) is worrying because it denotes the exponential increase in MTE discharges following activities industries and harbours in full expansion in the Bay of Monastir. Furthermore, the PCA results demonstrate the environmental sediment conditions necessary for the phosphorus dynamic (i) well oxic sediment with basic pH conditions enhance the FeOOH formation and consequently the phosphorus fixation on FeOOH or $CaCO_3$ in sediment (P-FeOOH, P-$CaCO_3$) whatever the sediment lithology; (ii) anoxic and acidic sediment enhance the formation of ROP (Residual Organic Phosphorus) in correlation with the presence of algae (Posidonia, [8]) in the sediment.

Conclusion

This geochemical study shows that the spatial distribution of particulate organic matter and MTE in the sediments, can be explain by discharges (wastewater and harbours activities) but also by morphological (shallow bay) and hydrodynamic (weak current sailor) specific. This confinement of the Bay accelerates the storage of pollutants in the sediments. Even if the concentrations of MTE remain within acceptable thresholds in view of international legislation; their sharp increase in a few years, from 2015 to 2022, suggests that this metal pollution will soon reach a critical state.

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THE FORGOTTEN NAUTICAL ASTRONOMICAL INSTRUMENTS

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Abstract – Astrology and meteorology have always had great importance for agriculture and navigation. This paper describes some measuring and forecasting instruments which, at their design epoch, had a moderate success in sailing a small sea like the Mediterranean, but then over time they were forgotten because they were supplanted by other more reliable instruments even in the largest seas. In particular, we refer to the instruments for astrology, starting with a device, the *parapegma*, made when meteorology was still a particular aspect of astrology. The second instrument is a calculator for determining the position of the stars; so some instruments are then described to establish, for example, the position of a ship with respect to the Sun or the North Pole, and others to determine direction and speed of ship.
The short list ends with a return to meteorology with two storm forecasters, essential for quite sailing which, unfortunately, never worked as their inventors hoped.

1. Introduction

The connection between astronomy and meteorology started long time ago and remained stable for a long period. The Alexandrian astronomer Claudius Ptolemy (circa 100 - circa 175) in his work, *Phaseis - Phases of the fixed stars and their data collection*[1] [11] included a meteorological calendar, a list of dates of regular seasonal climate changes, first and last apparitions of stars or constellations, at sunrise and sunset, and solar events such as the solstices; all information organized according to the solar year. Ptolemy believed that astronomical phenomena caused the seasonal changes of the weather; he attributed the lack of perfect correlation between these events to the physical influences of other celestial bodies; for the astronomer, the weather forecasting was a particular aspect of astrology.

These aspects had a practical purpose relating to both agriculture and navigation. In this work we refer more to this latter aspect; in fact, we propose some forgotten forecasting and measurement instruments, starting with a device (*parapegma*) that shows how ancient meteorology was within a cultural framework of astrological type. More markedly astronomy-oriented instruments are then shown, which were fundamental for navigating the "small" Mediterranean and, subsequently, they were used to get out and start the great ocean crossings. It will therefore be no surprising to note that the most ancient instruments were conceived and carried out in Mediterranean regions, where they were found, even in their most archaic forms.

From the instruments reported here, in chronological order, we give a description of their functions; for the methods of operation and use, we refer to the, unfortunately, quantitatively modest bibliography.

[1] Only the second book of the work has survived [1001].

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2. The instruments in chronological order

2.1 Parapegma (5th century BC)

The Greeks had no meteorological instruments to confirm or deny their insights regarding the weather, which was related as a rule to astronomical events. For this purpose, public almanacs were placed in many squares in Mediterranean cities, called *parapegmata* (plural of *parapegma* from the Greek verb *parapegma* to fix into), which indicated the position of the stars and the weather in the local area, sometimes with the addition of rudimentary forecasts. For example: *"the shoulders of the Virgo* [constellation] *are rising"*, *"Rising of Arcturus* [of the constellation Boötes]*: south wind, rain and thunder", and "the weather will likely change"* ([6] p.32). The first versions of parapegma were carved on stone; next to the descriptions of the events there were holes in which pegs were inserted to identify the day, the month, etc., fig. 1.

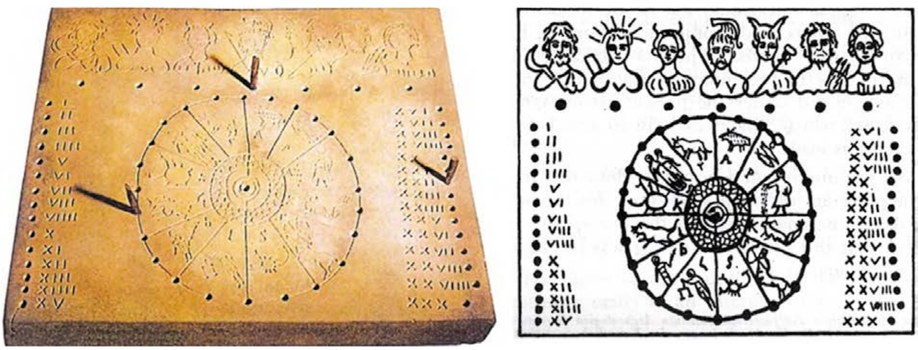

Figure 1 – On left: modern reconstruction of the parapegma found in the *Terme di Traiano* (Rome) at the beginning of the nineteenth century [9]. On right: reproduction of the drawing traced on the *parapegma*; above, from left to right, the days of the week dedicated to: Saturn, Sun, Moon, Mars, Mercury, Jupiter, Venus; the zodiac signs in the circle, Aries at the top right, indicated by "A", and the other zodiac signs proceeding counterclockwise, on the sides the days of the month.

2.2 Antikythera calculator (1st century BC)

In 1902 in the north-west of Crete, in a wreck in the depths of the Antikythera island, a mechanical device was found. It was indefinable because covered with encrustations; on the mechanism some engravings were glimpsed that referred to astronomical events dating back to 77 BC. The first rigorous studies on this strange mechanism were carried out in 1951, but only in the 1970s it was possible to understand, at least in part, its functioning.

After a thorough cleaning of the encrustations, some inscriptions could be deciphered that bear the words: *76 years*, *19 years*.

The first number recalls the Greek astronomer Callippus of Cyzicus (Asia minor 4th century BC), a pupil of Eudoxus and he worked with Aristotle at the Lyceum, known for having completed the geocentric theory and for having established a period (*Callippic cycle*) of *76 solar years*. This period is useful for the determination of eclipses and corresponds to four times the *cycle of Meton*[2], which is 19 years; this cycle is a period after which the phenomena related to the Sun and the Moon are repeated in the same order, in the same months and roughly the same days.

In the line below the one in which there are the above-mentioned numbers, there is the number *223* which most likely refers to the cycle of eclipses. They occur, with a good approximation, according to a cycle, called *saros* (Chaldean word, first millennium BC), which is repeated every *223* synodic lunar *months*, and since these are 29,53059 days, the cycle lasts 6585,32 days (i.e., 18 years, 11 days, 8 hours). After this time interval, the Sun, Earth, and Moon find themselves in almost the same positions assumed in the previous cycle and therefore the eclipses are repeated with the same sequence. After this time interval, the Sun, Earth, and Moon assume almost the same positions of the previous cycle and therefore the eclipses are repeated with the same sequence.

The X-ray investigations allowed to explore the interior of the limestone block. This made possible to understand that it was a complex mechanical machine that allow to predict the position of celestial bodies, the dates and times of eclipses, the lunar phases, etc. The most recent studies, carried out with computed tomography and high-resolution digital processing of the exposed surfaces, have been able to show previously neglected details and decipher previously undetected inscriptions. The positions of the Sun and the Moon on the Zodiac traced on one of the two quadrants, with which the device is equipped, were more evident; moreover, it was clarified how it was possible to predict the eclipses of the Sun and the Moon. Other previously undetected inscriptions have suggested that the mechanism was also able to predict the movements of the planets, figure 2. [12] [13] [15] [1007].

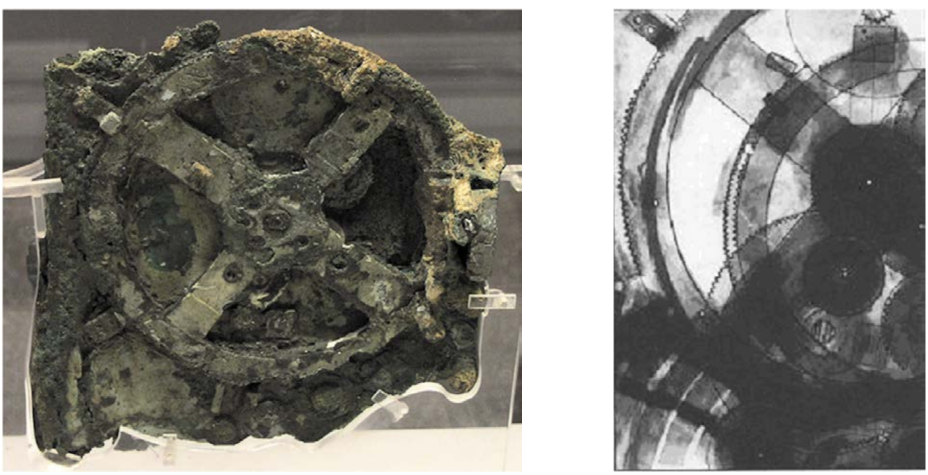

Figure 2 – On left: Antikythera mechanism, preserved at the National Archaeological Museum of Athens. The mechanism consists of a complex system of 30 wheels and plates with engravings relating to zodiac signs, months, eclipses [1008]. On right: an image obtained by computerized axial tomography of the artefact [1007].

[2] Meton of Athens was a Greek astronomer of the 5th century BC.

2.3 Astrolabe (2nd century AD)

Astrolabe, from the Greek *astrolabon* lit. "which takes the stars", is an instrument that allows to measure the (angular) height of the Moon, the Sun, and other celestial bodies, without using mathematical formulas. The astrolabe also permits to determine the hours of the day and night, to draw horoscopes, to establish the height of the mountains, etc. The theory on which the astrolabe (about 150 BC) is based can be traced back to the Greek astronomer Hipparchus of Nicaea (194 BC - 120 BC); but only Claudius Ptolemy, author of the *Planisphaerium*, the oldest treatise on the subject, gives some certainty about his knowledge of the astrolabe. However, the oldest existing astrolabes are from the 9th - 10th centuries, while from the previous period there are only attestations by Greek and Syriac authors who describe their functioning and evolution. In the Middle Ages the astrolabe was perfected by the Arabs who introduced it to Europe through Spain. For further information, see [1], [8], [17].

Figure 3 shows an astrolabe in gilt brass (diameter 165 mm), of Arab workmanship; the astronomical data reported on the tool indicate that it was made to operate at latitudes between 30° and 40° and suggest that the construction is prior AD 1000; according to tradition the instrument would date back to the time of Charlemagne (9th century).

Figure 3 – Astrolabe in gilt brass, of Arab workmanship, with case. Reproduction by permission of *Museo Galileo*, Firenze – Photo by Franca Principe.

2.4 Nocturnal or nocturlabe (possibly 13th century)

The *nocturnal*, or *nocturlabe*, is a sort of astrolabe for the night sky, showing the positions of some brilliant circumpolar stars, such as those of the constellation *Ursa Major*, with respect to the *Pole Star*. Some authors attribute the invention of the nocturnal to the Spanish astrologer, from Palma de Mallorca, Ramon Llull (1232 - 1316), but others report citations relating to this type of instrument in much earlier periods. [4] [1009]. Although it is unknown when the first versions of the nocturnal were made, it is known that it was used, in limited way, until the 18th century.

2.5 Jacob's staff or *Baculo mensorio* (13th-14th century)

Jacob's staff or *cross-staff*, also known in Italian as *Baculo mensorio*, was able to measure an amplitude or angular opening, with respect to a predetermined point, for example of two stars, or the extremes of a tower or mast of a ship. The first descriptions of this instrument have been attributed to the rabbi and mathematician Levi ben Gershon (1288 - 1344), who lived in Provence (Southern France). In its simplest configuration, the instrument consisted of two wooden rods, one shorter, mounted transversely to the other and could slide over it. Figure 4 shows Jacob's Staff and an illustration explaining its use. On the long rod some subdivision notches were engraved which were used to identify, on it, the position of the sliding rod. For measuring the angular distance between two fixed points, the extreme marked of the long rod approached the eye and the short rod was sliding until its extreme points overlapped the two fixed points. The illustration in Figure 4 shows an operator measuring the height of the Sun on the sea horizon.

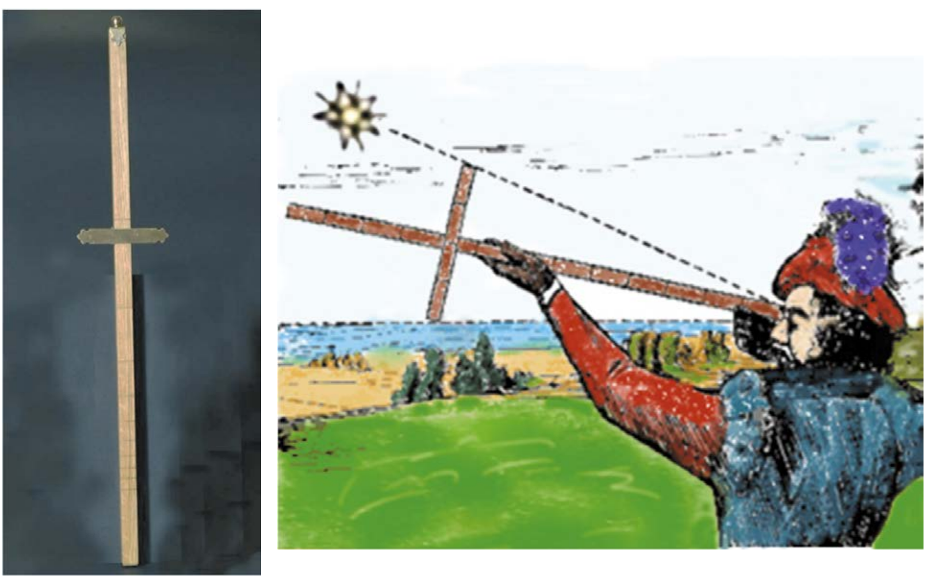

Figure 4 – Jacob's staff (on left); an operator measures the height of the Sun on sea horizon (on right) [1002].

In seafaring practice, the joint use of Jacob's staff and compass was helpful for quick, even if rough, bearings. In astronomical practice, under more controlled measurement conditions, the instrument was used to study the motion of the stars and to compute the Ephemerides. This instrument was widely used in Europe throughout the Middle Ages; between the 15th and 16th centuries, its construction and use were described in numerous treatises. With the 17th century the staff was replaced by the *quadrant* which in turn was abandoned in the 18th century, with the adoption of the *octant*.

2.6 Nautical or sea astrolabe or mariner's astrolabe (16th century)

In the 16th century, a Spanish-Portuguese reinterpretation of the astrolabe (previously described) made it particularly useful in the seafaring, for the detection of the height of the Sun and the Pole Star. Figure 5 shows the instrument and an illustration explaining its use to detect the angular height of a star. The frame of the sea astrolabe was heavy and widely holed to facilitate observation in adverse weather conditions: the weight kept the instrument on the vertical, despite the pitch and roll of the ship; the holed frame prevented the instrument, with strong winds, from behaving like a sail and swinging in the observer's hands. Despite these precautions, the absolute immobility and verticality of the instrument, during the measurement, could only be guaranteed on land. From the 16th century the astrolabe became a fundamental instrument for navigation and remained in use until the 18th century when it was replaced by a new instrument, first the octant and later the sextant.


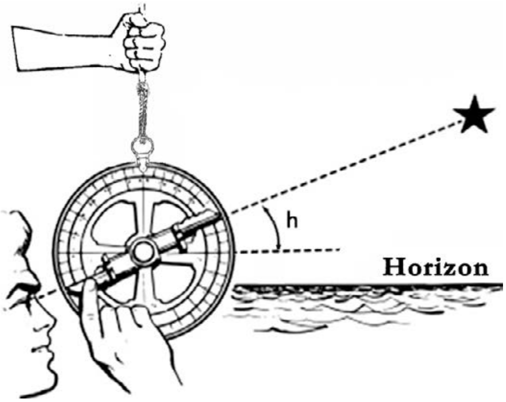

Figure 5 – Nautical astrolabe by Francisco de Goes, 1608, and its use [1003]. Medici collections (Robert Dudley bequest), *Museo Galileo* (inv. 1119), Firenze. Image reproduction by permission of *Museo Galileo,* Firenze – Photo by Franca Principe.

2.7 Ship log or chip log (16th century)

Until the 16th century, the measurement of the speed of a boat could not be performed reliably because there were no fixed references in open sea. […] *Experienced pilots could make reasonably good guesses at how fast they were going by spitting in the water and timing (by saying Hail Marys) how quickly the spittle was carried away, but that* *was obviously not a high-precision method* [...] [2] pp.228-229. For this purpose, in the sixteenth century, a weighted triangular wooden tablet began to be used, a chip log figure 6, fixed with a long line to a roller placed on the stern. The tablet was thrown into the sea, in the time of 30 seconds (1/120 of an hour), detected through a sandglass, it was measured how much line the tablet had dragged into the sea; this provided the length of the distance traveled by the ship in that time interval. Length of the distance traveled, and time taken provided an estimate of the ship speed. For an immediate indication of the speed, on the line were knotted, at regular intervals, some little cables, then counting how many of these knots were seen going down into the water in the 30 seconds. The number of knots went down into the water, in 30 seconds, provided the speed of ship, expressed in knots over the time indicateted. Obviously, the obtained measurement (being conditioned by currents, wind, etc.) was different from the one that would have been detected with reference to the seabed.

In her book *Longitude* [14], pp. 13-14, Dava Sobel, an American science popularizer and science reporter, states on the use of the ship log: […] *The captain would throw a log overboard and observe how quickly the ship receded from this temporary guidepost. He noted the crude speedometer reading in his ship's logbook, along with the direction of travel, which he took from the stars or a compass, and the length of time on a particular course, counted with a sandglass or a pocket watch. Factoring in the effects of ocean currents, fickle winds, and errors in judgment, he then determined his longitude. He routinely missed his mark, of course searching in vain for the island where he had hoped to find fresh water, or even the continent that was his destination. Too often, the technique of dead reckoning marked him for a dead man* [...].

Figure 6 – Ship log and sandglass to estimate the relative speed of the ship [1004].

2.8 Davis Quadrant (16th century)

The Davis quadrant originates from the Staff of Jacob; in the two hundred years in which it was used on ships all over the world, the quadrant underwent a notable evolution from its first elementary form. The instrument allowed to detect the height of the Sun without having to observe the star continuously and directly, with the danger of ruining of the view, as often happened to sailors. Perhaps the first quadrant was made by Thomas Harriot [16]. The most famous, however, is the quadrant of Captain John Davis (1550-1605) who described the first two versions of his instrument in a book of 1594, "*The Seaman's Secrets*" [1005]. However, we want to underline that Davis was neither the first nor the last to design quadrants, but he was the one who managed to establish himself, in the history of navigation instruments, also thanks to other manufacturers who, over time, have essentially improved his prototypes. [10].

The third, more complex version, was made by an anonymous manufacturer in the mid-seventeenth century and constitutes the instrument that today we identify as the *Davis Quadrant* which operated on a quarter of a circumference (hence the name of the *quadrant*). Figure 7 shows the third version of the quadrant and an illustration explaining its use.

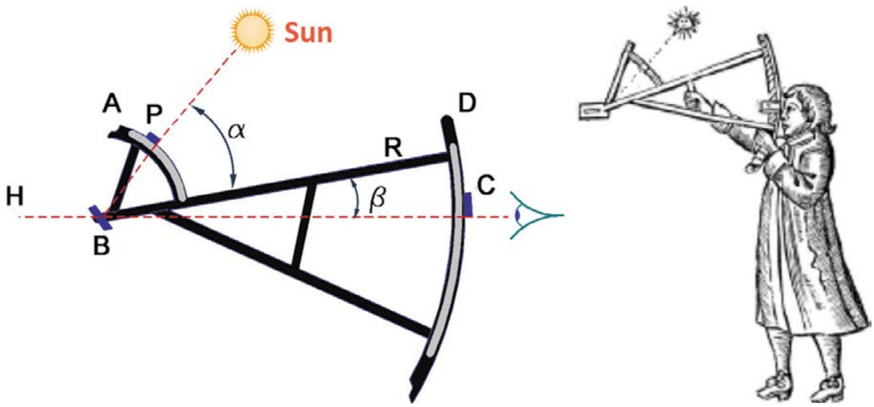

Figure 7 – Third version of Davis quadrant and an illustration, from [7], explaining its use.

A: 60° graduated arc bracket on which P flows.	**B:** sight of horizon.	**C:** ocular.
D: graduated arc bracket on which C flows.	**H:** horizon.	**P** shadow fin.
R: ruler.	**α + β** =h: elevation of Sun.	

2.9 Octant (18th century)

The measurement of the altitude of the Sun or other celestial bodies on the horizon, or the angular distance between them in relation to an observation point, especially during navigation, was not effectively resolved either with the astrolabe or with the instruments that followed, from the primitive Jacob Staff of to the more sophisticated Quadrants of the seventeenth century. Only in the 18th century navigators began use of the *Octant*, an instrument so called due to its shape: a circular sector with an arc of one eighth of circumference. The instrument, used together with the Ephemeris and a clock, allowed to determine, with sufficient precision, one's position on the nautical chart, when the sea was not too rough. Several people, independently of each other, brought innovations to the octant, such as in 1731 the English mathematician John Hadley (1682 - 1744) and in 1732 the French mathematician and astronomer Jean Paul Fouchy (1707 - 1788). In its latest version the instrument was equipped with a double reflection mirror system that made the image of the celestial body observed considerably more stable on the horizon; with an only flaw: the device could not measure angles greater than 90°. This limitation was overcome at the end of the 18th century when a similar instrument was made but on an arc of one sixth of a circumference, called the *Sextant*. The two-mirror system, while maintaining the accuracy of the octant, has expanded the possibility of measuring angles up to 120°; the latter instruments, albeit in much more complex forms, are still used today.

2.10 Storm indicators (19th century)

During navigation it was important always know direction and speed of the ship, but was it also needed to forecast the arrival of storms. This quick excursus on forgotten navigation instruments ends by citing two versions of *storm indicators*, or meteorological instruments, as is the first instrument with which this work begins.

The first instrument, called *Stormglass*, was built in the second half of the 18th century and perfected in the mid-19th century by Admiral Robert FitzRoy (1805 - 1865). The Stormglass consisted of a sealed glass cylinder containing a mixture based on distilled water, ethanol, camphor, ammonium chloride and potassium nitrate. The liquid was clear at high temperatures, but, according to the Admiral, as the temperature and pressure changed, the clearness decreased due to the formation of saline crystals of various shapes and sizes inside the cylinder [1006]:

- If the liquid in the *Stormglass* is clear, the weather will be clear and bright.
- If the liquid is turbid, the weather will be cloudy and possibly with precipitation.
- If there are little dots in the liquid, the weather will be humid or foggy.
- If there are small crystals in the liquid, thunderstorms can be expected.
- If the liquid contains small crystals on sunny winter days, snow is coming.
- If there are large crystals in the liquid, the weather will be cloudy in temperate zones or snowy in winter.
- If there are crystals in the liquid at the bottom of glass, this will indicate frost in the winter.
- If there are filaments in the liquid at the top of glass, it will be windy.

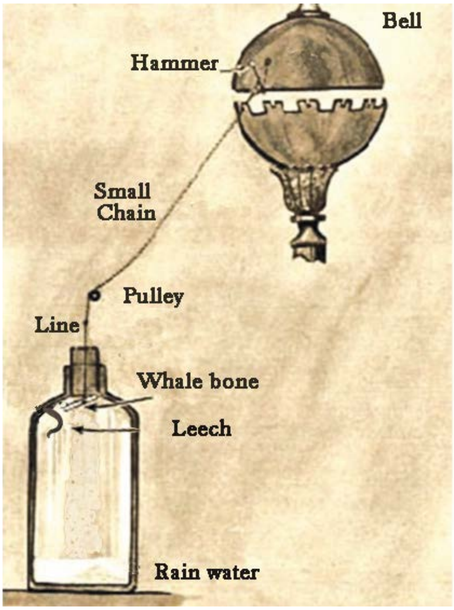

Figure 8 – *Tempest prognosticator* or *leech barometer*. On left, the operating principle is shown; on right, the realization presented in the First Great Universal Exhibition of 1851 in London. This device never found a practical application.

The second storm indicator, called also *tempest prognosticator* or *leech barometer* (figure 8) since the main component was this small animal, was made by the English surgeon George Merryweather (1794 - 1870). He was convinced that medicinal leeches were able to forecast the weather, given that they were agitated when a storm came. In Italy the instrument was known as *Bdelleudiometro* from the Greek *bdelle* = leech, *éudios* = good, in reference to weather, and *métron* = measure [3]. Using this "effect", Merryweather invented a device comprising of a dozen glass bottles, containing rainwater, in each of which a leech was placed. Each bottle was topped with a tube containing a piece of whalebone wire connected to a small hammer that would strike a bell when the leech attempted to get out of the tube. The greater the number of leeches ringing the bell, the greater the likelihood of a storm approaching [5].

The first of the two instruments, *Stormglass,* was more successful as the English Crown, following the violent storm that sank the Royal Chater ship with its 370 passengers, distributed stormglasses to many small fishing communities for consultation before setting sail from their ports. However, it was an ephemeral success since its real validity was never confirmed by practical application.

3. Conclusions

In the selection of the instruments, we mainly referred to the Mediterranean regions which are perhaps the most studied in the world, from a prehistoric and historical point of view. This contribution intends to underline that in this context, together with the *Great History* of men and events that determined the birth and development of civilizations, there is also a *lesser-known history* of forgotten things, in our case of instruments for forecasting and measure, some absurd, others more rational, which, however, are the basis of today's instruments.

We say nothing new by stating that *ex nihilo nihil fit,* nothing comes from nothing, and if today we have an electronic technology that can everything, this is the daughter of humble technology made with stones and wood. It is only by remembering the modest origins of the parents that one can appreciate, in the right measure, the sensational successes of the children.

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SEA LEVEL MEASUREMENTS IN MEDITERRANEAN COAST

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Abstract – The great travels for the geographical studies made it necessary, in order to establish the height of the elevations, to refer all the heights to the same surface to which to attribute the zero level, to make the results comparable. The sea surface was immediately thought of as a reference level, but unfortunately it is neither the same nor constant throughout the Earth and, moreover, it varies over time. As early as the 17th century, measurement protocols were proposed to establish the sea level. However, only in the first half of the 19th century, with the advent of tide gauge with automatic recording, were obtained, for many seas, sufficiently numerous and reliable series of measurements to establish a shared methodology to define the tide level zero. From that moment on, procedures and instruments quickly improved to the current satellite instruments that measure altitudes with the uncertainty of about 2 centimeters. This work is limited to the first stages of this fascinating story referring, in particular, to the Mediterranean basin.

1 Introduction

The great travels around the world in the 18th and 19th centuries and the affirmation of physical geography as a discipline of study, highlighted that to establish the height of mountains or the depth of terrestrial depressions, it needed to refer to a starting level, reference datum zero or zero elevation, common to all.

In the volume *La Terra nelle sue relazioni col cielo e coll'uomo: ossia Instituzioni di geografia matematica, fisica, e politica: secondo le più recenti mutazioni e scoperte e con copiose notizie statistiche, commerciali, ecc.* [23], published in 1869 the geographer Alfeo Pozzi wrote at page 125: […] *I continenti le isole e le varie loro parti si elevano a differenti altezze. A poter misurare tutte queste altezze in modo che sieno fra loro confrontabili bisogna trovare un termine a tutte comune, un punto di partenza uguale, una superficie in somma ugualmente distante in tutti i punti dal centro del globo. Questa superficie è quella dell'Oceano. Il livello dunque del mare è il termine fisso da cui si parte per valutare l'elevazione di qualsivoglia punto terrestre. L'elevazione di un luogo cosi valutata dicesi altitudine o altezza assoluta* […][1].

The quote of the sea zero level, *going upwards,* allows to establish the tides levels, the altitudes of the countries, the heights of the mountains, etc., all starting from the same reference; the geographers highlight this aspect by placing, after the value of the height and

[1] [...] *The continents, the islands and their various parts rise to different heights. In order to measure all these heights so that they are comparable to each other, it is necessary to find a term common to all, an equal starting point, a surface in sum equally distant in all points from the center of the globe. This surface is that of the Ocean. The sea level is therefore the fixed term from which we start to evaluate the elevation of any point on earth. The elevation of a place evaluated in this way is called absolute altitude or height* [...]. (Translated by the Authors).

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the unit of measurement, the abbreviation a.s.l. (above sea level). The zero quote also allows, *going downwards*, to establish the depression of the areas, the deepest depression is that of the Dead Sea about 400 m below sea level, the depth of the seas and ocean trenches, the deepest is that of the Marianas in the Pacific Ocean of 11 521 m.

But the level of marine surface is neither the same nor constant on whole Earth; if there were no currents, waves and tides in the seas, their surface would be orthogonally arranged in the direction of the acceleration of gravity and the size and shape of the Earth could be defined as the average level of the sea. In fact, in any point on Earth, the average sea level, in addition to being conditioned by the terrestrial rotation, is generally higher at the end of summer, when the water is warmer, than at the end of winter, when the water is colder and is deposited, in greater quantities, on mainland as surface water, snow and ice. In some parts of the world, especially where the effect of the monsoons is more intense, seasonal variations in sea level are more sensitive to the decisive changes of wind and currents, but annual variations are also observed mainly due to the melting of the polar ice caps and the oceans warming [6].

In the first case there is an increase in the mass of liquid water, in the second case there is a thermal expansion of this. In other words […] *sea levels in areas of warm water are higher than sea levels in areas of cold water. A rise in sea level of an average of 3 mm/yr was observed between 1993 and 2008* [worldwide]. *This rise, however, was not the same everywhere. In some regions it was much higher than average, while in others it was much lower* [1001]. For example, in the Atlantic Ocean the increase was about 0.5 mm / year while in the Mediterranean Sea it was from 0.6 to 1.5 mm / year, depending on the various areas [3].

All this has led to have to establish a method for defining the *altimetric zero* in reference to the average level of the marine surface, a level to be re-evaluated at least each decade as a result of the aforementioned annual variations.

The close link between the tidal reference and the quote of terrestrial objects is well highlighted by Giorgio Poretti of the University of Trieste in [22]: […] *The Italian measurements in the Alps are, for example, referred to the mareograph in Genoa, the Austrian ones to the mareograph of Trieste, while those of the Swiss State Office for Geodesy and Topography refer to an average between the mareograph of Genoa and that of Bordeaux. For this reason, the Italian and Swiss measurements present a constant difference of about 20 centimetres* […].

We report in this work some notes relating to the first stations for the detection of the *marine altimetric zero* of the Mediterranean coastal areas, carried out by the nineteenth century with some mentions to the current situation.

2 The first measurements

The oldest protocol for a rigorous sea level survey is by Robert Moray[2] (1666), where indications are also given on how to build the observatory and with which devices and instruments to equip it, including also meteorological instruments [17].

Moray refuted some theories circulating at the time, that he considered invalid. Then he drew up a protocol on the procedures to be followed to detect, uniformly in each site, the sea level. Moray also provided guidance on how the observatory was to be built and how the

[2] Sir Robert Moray (1609 - 1673), scientist and statesman, was one of the principal architects in 1660 of the *Royal Society of London for the Improvement of Natural Knowledge.*

various devices were to be installed. In his work he did not only indicate two possible detection sites, Bristol (south-west England) and Chepstow (south-east Wales), but also, he specified the temporal cadence of the measurements, he explained the operation of the various equipment and he described the meteorological measurements to be carried out to complement the marine ones: wind intensity and direction, air temperature and humidity, atmospheric pressure. Several documents attest that both Moray and other scholars carried out surveys in accordance with the aforementioned protocol, but unfortunately the data obtained either have not been published or have been lost.

The first observations of sea level on the Atlantic coast of Brittany, published in France in 1683, were from the period 1679 - 1681. The "official" surveys on the Mediterranean coast French were carried out between 1777 and 1778 in Toulon, at the time the only maritime arsenal on this coast, at the eastern end of the Gulf of Lion.

The first automatic recordings of sea level were conducted by the English engineer Henry Robinson Palmer (1793 - 1844) with a marigraph of his own invention described in 1831 in the *Journal of Philosophical Transaction of Royal Society* [18]. The measures were conducted at Sheerness on the east coast of England. It will be necessary to wait until 1842 to have the French coasts equipped with the first automatic marigraph made by the hydrologist Antoine Marie Rémi Chazallon (1802 - 1872).

The first marigraph on a "geographically" Italian coast was installed in Trieste in 1859. The clarification is necessary because the city, in the year indicated, was still part of the Habsburg Empire. Starting from the Middle Ages Trieste, while remaining a free municipality, first came under the influence of the Republic of Venice, then it came under the rules of the County of Gorizia, then the Patriarchate of Aquileia and finally Trieste was annexed to the Duchy of Austria; until in the second half of the fifteenth century it submitted to the Habsburgs of Austria. On June 2, 1717, Emperor Charles VI of Habsburg declared freedom of navigation in the Adriatic and in 1719 established the free port of Trieste whose rights, extended by his daughter Empress Maria Theresa of Austria (1717 - 1780), led, in the eighteenth century, to an intense development of the city. After the Napoleonic parenthesis, Trieste under the Habsburg government continued to develop, becoming both the capital of the province of the "Austrian Littoral" and the main commercial port of the Empire, following the entry into operation, in 1857, of the railway connection with Vienna.

In 1864 the European countries met in Berlin (for Conference of Central European degree measurement [8]) to adopt the following provisions: "*The heights of each country will be referred to a single zero point, strictly established; all these starting points will be connected to each other by precision leveling. The average level of the different seas will have to be determined in the largest number of ports, and preferably by means of recorders instruments [...]. According to the results of all these measures, the general plan of comparison for all heights of Europe will be chosen subsequently*" [5]

3 The measurement instruments

We have mentioned above an automatic mareograph that is an instrument that draws on a strip of paper the rises and falls in sea level (tide gauge) due basically to tidal variations: the average of the values recorded in the time interval considered (daily, weekly, monthly, annual), allows to establish the average sea level to which to attribute the zero altimetric value.

A method for determining the average sea level is based on the calculation of the average of all hourly heights detected by marigraphs over an interval of several years. A second criterion is to calculate the average all high and low tides obtained from mareograms. The difference between the two procedures indicated is negligible since it does not exceed 0,1 mm [21].

To avoid the problem of the operator who had to average the values of water level indicated by the mareograph, which records moment by moment, Charles Lallemande (1857 - 1938) in 1888 invented an instrument that automatically performed the average, not through a calculation but by means of a particular realization of the instrument, which he called *medimaremeter* (in French *médimarémètre*), where the prefix *medi* wants to indicate the specificity of the instrument [11]. To better understand the difference between the two instruments, below, we report a very brief description of the principle of their operations.

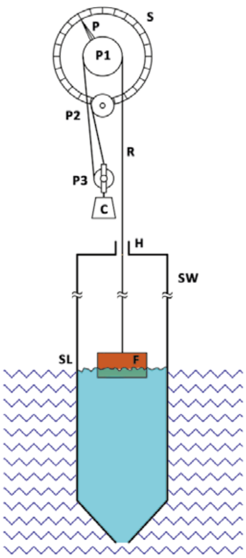

Figure 1 – Marigraph scheme:
the float follows the variations of:
sea level, then, with a pulleys system, sends this movement to a pointer or to a recorder, which show the instantaneous values of the marine level.
F float
SL sea level
SW stilling well
R rope
C counterweight
P1, P2, P3 pulleys
P pointer
S scale
H hole for passage of R

- *Marigraph*: the instrument, in its essence, it is a float that follows the ups and downs of the sea level, and transmits this movement to an indicator device, a pointer on a scale, or a paper tape recorder, moved by clockwork gears, on which a writing system traces the movement of the float. Figure 1 shows a scheme of marigraph: a cylindrical float F follows the vertical motion of the SL level of the sea, protected, in its movement, by a cylinder that constitutes the SW stilling well, with which the ripples of the sea are reduced. SW is open on the bottom, to let water in, and it has a hole, on top, to pass the rope R to which F is tied. The motion of F is transmitted to the R rope, always held in tension by the counterweight C, through the pulleys P1, P2, P3. The movement of F transmitted via R to P1 causes the rotation of P1 which in turn shifts the pointer P on the S scale, that it is divided into degrees ranging from the minimum level to the maximum, which can reach the sea at that site.

Obviously, the average value of sea level, in a certain time interval, had to be calculated by performing, manually, the average of the instantaneous values. This last aspect was somehow made "automatic" by the medimaremeter.

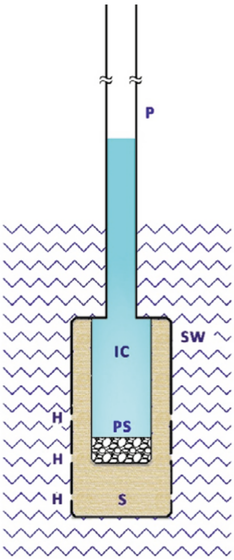

Figure 2 – Medimaremeter scheme:
as a result of the sand and porous septum, in the stilling well, the variations of water level are slower and less entity, in other words the instant level values are not recorded but the device records the average values.
P pipe
SW stilling well
H holes
PS porous septum
IC interior chamber
S sand

- *Medimaremeter*: the fundamental part of this instrument was in the stilling well SW (figure 2), which, unlike the marigraph, was closed on the bottom and with H holes in the side wall, also had a porous septum SP that separated it from the interior chamber IC, finally between SW and IC there was sand S. Sea water entered through the holes, and sand prevented the ingress of impurities. As a result of the sand and porous septum, in the stilling well, the variations of water level in P were slower and less entity, in other words the instant level values were not recorded but the device recorded the average values.

In the only version carried out there were no recording mechanism, and the readings were performed manually with a metric rod that was inserted, from above to the porous septum, in the P pipe, which reached a height above the maximum tide level. On the rod, for each measure, a sensitive paper tape was placed that blackened on contact with water. Reading on the rod the value at the end of the blackening of the paper, you had a sort of average value of sea level over time between two consecutive readings. The maintenance of the porous septum, which tended to occlude itself, made complex the functionality of the system.

Today, despite technological evolution, mechanical marigraph, although improved over time, with float position electronic detectors and with the automatic calculation of the average, are still in operation on the coasts of many countries. The same cannot be said of the medimaremeters that showed inconveniences related to their maintenance, detected by the inventor himself [12] and, over time, also by other authors [2], [30].

4 The zero tidal of Mediterranean Sea

As indicated by the already mentioned Provisions of Berlin of 1864, to define local variations in sea level, it was necessary to establish a conventional quote with respect to which to measure the level moment by moment, in order to then calculate, for a given interval of time, the average level.

For this purpose, in ports, in maritime stations, in hydrographic institutes, a quote called zero tidal or zero hydrometric (benchmark) was established to which to refer to detect, over time, the variations in the level of the free surface of the water. These variations are defined by the difference between two consecutive measurements of the distance of water from the benchmark. Such a definition made these differential measures independent of the quote at which the benchmark was set, provided that it was above the maximum tide level.

In the subsequent paragraphs we briefly describe the first tidal observatories in which the benchmarks of the main Mediterranean countries are indicated.

4.1 Italy

Trieste was the first town to have a marigraph in 1859 [25], as already mentioned, at that moment the city was Italian only geographically; the instrument was carried out at the *Imperial Regia Accademia di Commercio e Nautica* (today, *Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - National Institute of Oceanography and Applied Geophysics – OGS*). The instrument was placed in the *Casa Rossa* at the end of the *Molo Sartorio* (Sartorio Pier). The hydrometer for the control measurements consisted of a vertical cast iron pipe buried in the pier; the upper edge of this tube, placed at ground level, defined the *"Zero of the Sartorio Pier"*. Mareographic data of Trieste were published from 1869 by the *Commission for the Adriatic Sea* [20], [28]. The Trieste marigraph is still the mareographic reference for Austria.

Previous, to the aforementioned marigraph, a hydrometer was installed near the *Ponte Rosso*. It was an indicator of a level carved in the stone and graduated in Paris feet (in French *pied du roi*) and inches (in French *pounce*)[3] who could date back to 1785 [20]. The zero of this hydrometer is known as a *Zero Ponte Rosso*. The hydrometer is likely to serve for occasional sea level observations, useful for the transit of boats in the channel.

Rimini was equipped with a marigraph, installed in the canal port in 1867, and in 1896-7 Ravenna also had one. Currently the first is managed by the Municipality of Rimini, since it serves the sewerage network, while the second is part of the National Tide Gauge Network which has thirty-five measurement sites (see figure 3).

In Venice, the first reference level, called the *Comune Marino*, was defined in 1825 as the average level of high tides, coinciding with the *"line of green"* formed by the algae present on the walls of the buildings and on the *fondamenta* (roads flanking the canals). This quote was materialized on the walls of some buildings by carving a horizontal line and a letter C. The zero was then set at 1,50 m below the *Comune Marino*, so as not to have to use negative numerical values [1002]. However, in Venice, the systematic measurements of the sea level, as well as of the maximum and minimum tides, began 1871, when Tommaso Mati (1823 - after May 1894) carried out the first marigraph at *Palazzo Loredan* in *Campo Santo Stefano*, at the headquarters of the Public Works Department. This date represents the beginning of the tide recordings according to the Berlin provisions, that is with the introduction of a reference level from which the tide heights recorded, with the established procedures, at specific times could be inferred. Due to its tides of such amplitudes that are not comparable with those of the rest of Italy, Venice has always referred to autonomous *benchmarks.* The last tidal zero was established in 1923 at *Punta della Salute*, in the Giudecca Canal, averaging the values measured from 1885 to 1909 and setting the central year of the period (1897) as a reference

[3] 1 foot = 12 inches, 1 inch = 27,07 mm.

value. The introduction of this reference, connected to the Venetian soil, makes it possible to compare high waters of the same height, but which occurred at different times. In fact, in these cases the same percentage of flooding should occur in the city of Venice. [1002], figure 3.

In Genoa there is the *hydrometric zero* of the Italian survey network, which is indicated by benchmark, inside a marigraph (carried out in 1883), managed the Italian Navy Hydrographic Institute. The level was defined using the average of observations, of the sea level, carried out in the period 1937 - 1946 and it has conventional value of 3,249 m on the m.s.l. (mean sea level). The height of all the benchmarks of the peninsular leveling network (about 18 000 km, physically marked with a benchmark about each kilometer) are derived from the Genoa's one (figure 3) [15], [27].

For the larger islands, the reference role is played by the marigraph of Catania (installed after 1896) which calculated the mean of the sea level values observed during the year 1965, and by the marigraph of Cagliari (installed after 1896) which considered the period 1955-1957 [7]. After 1896 marigraphs were installed in: Imperia, Leghorn, Civitavecchia, Naples, Ancona, Palermo, La Maddalena; Finally, other mareographic sites were carried out in the twentieth century. [10].

Figure 3 – The 35 stations of The National Tide Gauge Network (Italy):
Trieste, Venice-Lido, Ravenna, Ancona, San Benedetto del Tronto, Ortona, Isole Tremiti, Vieste, Bari, Otranto, Taranto, Crotone, Reggio Calabria, Messina, Catania, Porto Empedocle, Sciacca, Lampedusa, Palermo, Ginostra, Palinuro, Salerno, Naples, Cagliari, Carloforte, Porto Torres, Ponza, Gaeta, Anzio, Civitavecchia, Marina di Campo, Leghorn, La Spezia, Genoa and Imperia. Source: [1003].

4.2 France

The French mediterranean mareographic surveys, subsequent to the aforementioned Toulon surveys, began in 1884 when another tide gauge was installed in Marseille. The survey station was carried out, on the basis of an 1879 resolution of the *Commission Centrale du Nivellement Gènèral de la France,* to determine the exact average sea level in order to establish an altimetric reference for the subsequent leveling of the territory French. On the indication of Charles Lallemand it was chosen a *totalizer* (*totalisateur* in French) marigraph (published in 1878) equal to the one that the civil engineer F. H. Reitz [31] had already installed on the island of Helgoland (Germany, North Sea) and in the port of Cadiz (Spain, Atlantic Ocean).

From February 1st, 1885 the average sea level was placed at 0,471 m below the […] *Zero of the tide scale* […] established without any measurement, in 1860, by the director of the Port of Marseille in reference […] *traces more or less apparent than waters, in their movements of rise and decrease, leave against the quay walls* […] [5]. In Corsica, the altimetric zero quote was fixed following the observations of the tide made in Ajaccio from 1912 to 1937. Figure 4 shows the sites of the mareographic stations installed by France on the Mediterranean coast: eleven mareographs from Port-Vendres, at the western end of the Gulf of Lion, to Nice, followed by a survey station of the Principality of Monaco; while four mareographs are placed in Corsica [1004].

Figure 4 – The 13 Mediterranean French Mareographic stations:
1 Port Vendres, 2 Port La Nouvelle, 3 Sete, 4 Fos sur Mer, 5 Marseille, 6 Toulon, 7 Port Ferréol, 8 La Figuerette, 9 Nice, 10 Centuri, 11 Ile Rousse, 12 Ajaccio, 13 Solenzara.

4.3 Spain

The first Spanish marigraph, permanently installed to establish the altitudes of the terrestrial reliefs, was placed in Alicante, a Mediterranean port south of Valencia and north of Cartagena. Here the average sea level was calculated from the first data collected in the decade 1870 - 1880 with reference to a benchmark sited on the first step of the stairs of Alicante town hall. In this measuring station the sea level records continued until 1920 for daily average measurements, afterwards hourly averages were done. In 1953 a second marigraph was carried out in Alicante; both instruments are still active. Therefore, the mareographic data series of Alicante represents the longest series of the Mediterranean Sea [14]. In 1876 the second Spanish marigraph was made in Santander, on the Atlantic coast, at the extreme west of the Gulf of Biscay [14]. As regards the measurement of the heights of the islands, the average local sea level obtained from marigraphs permanently installed on them is used. Currently Spain has installed on its Mediterranean coasts several mareographic stations, all carried out or upgraded between the end of 1990 and 2012; fourteen are located from Tarifa, on the Strait of Gibraltar, to Barcelona, seven are on the Balearic Islands and two in the small Spanish enclaves of Morocco: Ceuta, in front of Gibraltar and Melilla, at the eastern end of the Morocco, figure 5 [1004].

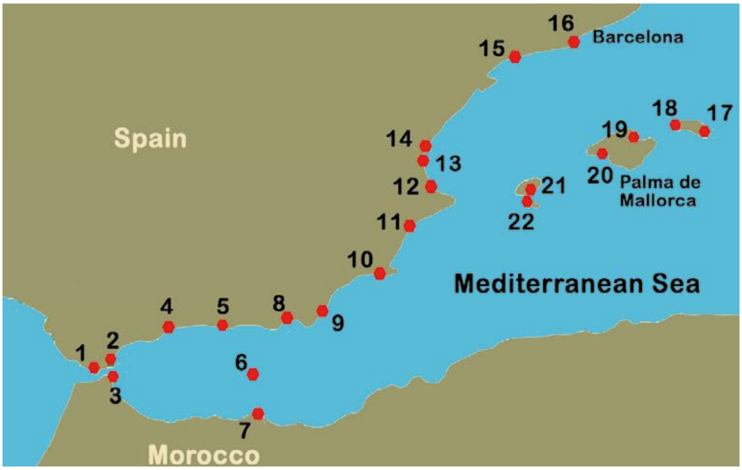

Figure 5 – The 22 Mediterranean Spanish Mareographic Stations:
1 Tarifa, 2 Algeciras, 3 Ceuta, 4 Malaga, 5 Motril, 6 Alboran, 7 Melilla, 8, Almeria, 9 Carboneras, 10 Murcia, 11 Alicante, 12 Gandia, 13 Valencia, 14 Sagunto, 15 Tarragona, 16 Barcellona, 17 Mahon, 18 Ciutabella, 19 Alcudia, 20 Palma de Majorca, 21 Ibiza, 22 Formentera.

4.4 Eastern Adriatic Sea

Going down from Trieste along the coast of the republics of the former Yugoslavia, up to the whole of Albania, there are practically no monitoring stations of any importance, capable of forming an albeit minimal detection network of sea level. A first station is present on the Greek island of Corfu, that is after passing the Otranto canal that separates the Adriatic Sea and the Ionian Sea (1 in figure 6).

4.5 Greece

We did not find sufficiently meaningful references on the marigraphic stations of Greece in the period of our interest. A 1987 publication [24] talks about of short recordings of sea level measurements made in the years before 1969: too "modern" for our purposes. We therefore limit ourselves to indicate in figure 6 the current situation of the mareographic network of the Greek Hydrographic Service.

Figure 6 – The 23 Greek Mareographic stations:
1 Kerkira (Corfù), 2 Preveza, 3 Katakolo, 4 Kyparissia, 5 Kalamata, 6 Koroni, 7 Kapsali, 8 Kasteli, 9 Paleochora, 10 Hrakleio, 11 Ierapetra, 12 Gavdos, 13 Kalathos, 14 Kos Marina, 15 Kos, 16 Syros, 17 Peiraias, 18 Corinth, 19 Itea, 20 Panormos, 21 Aigios, 22 Thessaloniki, 23 Plomari (Lesbos).

Figure 7 – The 11 Mediterranean Turkish Mareographic stations:
1 Gokcead, 2 Bozcaada, 3 Mentes, 4 Bodrum, 5 Marmaris, 6 Fethiye, 7 Anthalia, 8 Bozzyazi, 9 Tasucu, 10 Erdemli, 11 Iskenderun.

4.6 Turkey, Syria, Lebanon

As with Greece, even in the past of the Turkish coast there is not enough indication of its mareographic stations. Even worse is today's situation of the Turkey's marine level monitoring network which is absolutely lacking (figure 7). The other two nations indicated, Syria and Lebanon, from this point of view and not only, are even worse off than Turkey.

4.7 Cyprus

After passing under the control of different states, from the end of the 16th century to the second half of the 19th century, the island was dominated by the Turks. It is with a convention of 1878 that in fact Cyprus passes under Great Britain, while remaining nominally Turkish, but only in 1925 the island obtains the status of British Crown colony. Following the irredentist movements against the British administration and the clashes between the Greek Cypriot and Turkish Cypriot factions in 1960, Cyprus became an independent republic governed by representatives of the two ethnic groups. Soon the two factions came into conflict supported by their respective nations of origin. In 1975 the island was in fact divided, horizontally, in two distinct national entities: the Turkish one in the north and the Greek one in the south; the capital of both states was the city of Nicosia crossed by the border line.

In the southern part (Greek Cypriot area) there are two British military bases that, most likely, have influenced the carrying out of four mareographic stations, while on the north coast (Turkish Cypriot area) no station is active (figure 8).

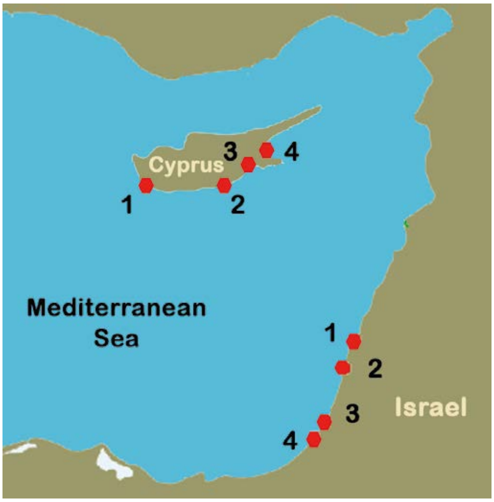

Figure 8 – Marigraphs on the coasts of:
- Cyprus: 1 Paphos, 2 Zygi, 3 Larnaca, 4 Paralimni;
- Israel: 1 Haifa, 2 Hader, 3 Ashod Port, 4 Ashkleton.

4.8 Israel

The historical events of this region are known, to which, politically, after the Second World War, this name was attributed, while geographically it can still be called Palestine.

Absolutely singular is the history of altimetry in this region. In fact, for cartographic reasons (at least originally it was not required great accuracy for heights) the method of triangulation was used. The method allows to obtain the height of an object, with respect to the ground, by referring to objects of known height, completely neglecting the *marine altimetric zero*.

In 1779 a cartographer French Pierre Jacotin drew the first elevation map of the Palestinian reliefs by triangulating them with respect to the Egyptian Great Pyramid of Giza.

In 1841 J. F. Anthony Symonds carried out triangulations, with a leveling network, Acre (north of Haifa) with Lake Tiberias or Kinneret (Sea of Galilee), and a second network was made from Jaffa (Mediterranean port of Tel Aviv) to the Dead Sea, via Jerusalem, in order to determine the quotes of the Dead Sea and Lake Tiberias compared to the Mediterranean.

During the period 1861 - 1864 further surveys, conducted by Arthur Mansell included the Israeli coast as far south as Syria. The map indicated the depth of the water in relation to a fixed point established on land, for each stretch of sea. In 1865 with a leveling network realized by Charles W. Wilson, measures were carried out by Jerusalem in the direction of both Jaffa's Dead Sea. In 1881 with all the maps produced, twenty-six sheets divided in three volumes were published by the Palestine Exploration Fund [4]. The good accuracy of the cartographers of the time that chose, to determine the altitudes, a terrestrial reference, and not a marine one, is to be attributed to the fact that the Mediterranean coast of Israel has not had vertical tectonic variations for at least 22 000 years [9], [26, while sea level is strongly influenced by climatic conditions.

The first instrumental measurements of the average sea level were carried out in 1927 in the old port of Jaffa with a medimaremeter. In 1928 a similar instrument was installed in Haifa and a second in Jaffa; the measurements were carried out daily at 7:30 and 13:30 [13]. The medimaremeter measurements became reference measurements for the Israeli leveling network beginning in 1934, figure 8 [29].

4.9 Malta

In 1814 Malta officially became a part of the British Empire. After the Suez Canal opened (1869), the island became fundamental for the British in the new route for India. For this strategic function London granted it a partial autonomy suspended in 1930 and definitively repealed to the outbreak of the Second World War. In 1957 there was a first step in the British disengagement in the Mediterranean, with the dismantlement of the naval arsenal of La Valletta (capital of the Island), the main support of the island economy. In July 1964 an agreement of mutual defense and assistance guaranteed the uses of Maltese bases to Great Britain. In September of the same year Malta was proclaimed independent state in the context of the Commonwealth. In December 1974 the State of Malta became the Republic of Malta always within the Commonwealth. Also, in this case the strong presence of the British ships, in the Maltese ports, was decisive for the carrying out of the two marigraphs in the archipelago (figure 9).

Figure 9 – Maltese Mareographs:
1 Malta, 2 Portomaso.

4.10 Northern Africa

Unfortunately, the geographical distribution of instruments and their quality are of very low level. There is not even a basic instrumentation that could be extremely useful to allow quick decisions in the event of *tsunami*, on a coast where important cultural and touristic town are hosted.

5 Conclusions

Over time, with the development of new measurement methodologies, other definitions of average sea level and tidal zero have been elaborated, given in turn according to the applications and in relation to the different geodetic representations of the Earth: *zero of the port (*or *harbour zero), tide gauge zero*, *geodetic datum*, *hydrographic zero (or nautical chart zero)*, etc. [10], [16], [19]. With reference only to the definition of the hydrographic zero, the Italian Navy Hydrographic Institute states that [19]:

- Since the infrastructural works in the coastal or port area are carried out over time and space, strictly speaking it is not enough to consider the mere *local average sea level* as *hydrographic zero.* In fact, it is also necessary to detect, in a regular and systematic way, the excursion of the sea level both at the time of the infrastructure installation and in its operational phase.
- The above requires the estimate of the tides trend in the local area, in relation to:
  - the fundamental astronomical components which cause the phenomenon;
  - the local meteorological component which, especially in the Mediterranean, determines a significant aspect of the phenomenon amplitude.

Today the sea level is measured using tide gauges based on technologies at all different from those of the first instruments, which we mentioned previously. Ultrasonic altimeters are widely used. With these instruments, the measure of the distance between a reflective surface (the water in this case), and an ultrasonic emitter/receiver device, is deduced from the measure of the round-trip time of the ultrasonic wave transmitted ([1] p. 93) [28]. The radar altimeters of the new generations are based on the same principle, but with the use of electromagnetic microwave generators [10]. In any case, in today's measurement stations to the transmitter/receiver a floating level sensor is associated, which uses a linear *encoder*, with chart recorder: for the punctual verification of the measures, for the analysis of particular events and phenomena and for the recovery of data in the event of the main instrument failure [15]. The most recent measurement systems are based on satellite altimetry. This technique uses radar altimeters mounted on orbiting spacecraft, to measure height of: mainland; ice; ocean and sea waves, with accuracy of about 2 cm [1001]. Each second, the altimeter installed on the satellite radiates the Earth's surface with microwave trains and picks up the echoes reflected by it, correcting the interference, on the measurement, produced by the atmosphere. The precise orbital position of the satellite is controlled by two laser systems and GPS that make it an absolutely reliable reference [1005]. Today, in the presence of even more marked climate change, the study of sea level becomes always more important because of reduction of the glaciers and polar ice cap, with consequent raising of the sea level. Moreover, with the use and urbanization of the land closest to the low coasts it is increasingly important to have alarm systems that in the presence of a rapid propagation, along the coasts, of the rise in the water level, due to tsunamis, can promptly give alarm signals; something easily obtainable with a system of tide gauges connected to each other in an international network.

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STATUS OF WATER QUALITY AND IMPACT OF DREDGING ACTIVITIES IN FOUR PORTS OF THE GULF OF AIGUES MORTES (FRANCE)

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Abstract – Coastal hydrosystems, located at the land-sea interface, are both subject to autochthonous sources of pollution but also form a receptacle for terrigenous inputs from upstream areas.

The Gulf of Aigues Mortes (GAM) extends along the western margin of the Rhone delta. The marinas spread over this restricted geographical area present variable management problems depending on their size and location. Due to silting and/or siltation phenomena, the situation is becoming increasingly difficult to manage to maintain the depths of most ports. In these marinas that are not dredged regularly, the quantities of potentially contaminated sediments (organic and metallic micro-pollutants) to be extracted represent from a few thousand to several tens of thousands of m^3 of sediments on the scale of each port.

Four ports of the GAM have joined together to set up a mutualized dredging project based on the valorization of dredged sediments.

The objective of this work is to carry out a diagnosis of the chemical and microbiological contamination of the waters of the 4 ports located in the Gulf of Aigues Mortes. Regular water sampling was done before, during and after dredging operations. Water column quality/contamination was characterized by major physicochemical water parameters, trace metallic elements and organotin compounds. In addition to chemical parameters, indicators of faecal contamination were also monitoring.

Dredging operations have induced the resuspension and/or readsorption on suspended matter of trace metal elements and organotin compounds in the water column. A significant increase in the concentrations of As (enrichment factors ranging from 1.2 to 2.15 times the post-dredging values) inducing exceedance of the EQS was observed. The behavior of copper and zinc is different according to the ports studied and during dredging operations. The resuspension of sediments, constituting both a sink and a source for (organo)metallic compounds, generated modifications of physico-chemical conditions and favoured increasing or decreasing of chemical elements concentrations observed in the dissolved fraction of the water column. These resuspensions are themselves related to the nature of the dredged sediments.

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1. Introduction

The Mediterranean coastal zone represents an important socio-economic and ecological area under great pressure [1,2]. The ports represent both areas of heavy pollution linked to the density of activity, but also areas of refuge for many biological species [3]. The attractiveness of these environments leads to high population densities, the permanent development of activities and the construction of infrastructures, resulting in the qualitative degradation of coastal aquatic environments. This is particularly true in the case of marinas, which are both places of dense internal activities (yachting, marina, shipyards (careening and maintenance of boats)) but also receptacles of waters from the catchment areas loaded with suspended solids and / or contaminants, to which they are connected.

In order to maintain good seaworthiness conditions, four ports in the Gulf of Aigues-Mortes (GAM) (Palavas, Pérols, Port-Camargue and Carnon) carried out joint dredging as part of the regional dredging scheme in Occitanie based on the recovery of dredged sediments. In France, dredging operations are authorized by prefectural decrees established for each port. The decree of 16/06/2002 defines levels N1 and N2 to guide the choice of the administrative procedure for the examination of dredging files, in accordance with article L.214-1 and following of the environmental code [4]. These are not thresholds aimed at authorizing or prohibiting the dumping of sediments, but rather benchmarks for deciding on the administrative regime of the operation (declaration or authorization), for assessing the impact that the planned operation may have, and for directing the dumping or management of sediments on land. Thus, the N1 and N2 levels have been established according to the concentration of pollutant in the sediments:

- Lower than N1: too little pollutant for any impact, or negligible impact.
- Greater than or equal to N1 but less than N2 (N1<N2): alert level. If N1 is exceeded research can be done on the actual impact of the pollutants. Although the pollutant concentration is still considered "acceptable" and can therefore be discharged or reused as is.
- Greater than or equal to N2: further investigation is necessary because there are significant indications of a potential negative impact of the operation (a specific study on the sensitivity of the environment to the substances concerned, with at least a global ecotoxicity test of the sediments, an assessment of the foreseeable impact on the environment and, if necessary, refinement of the sampling grid in the area concerned.

These authorizations are drafted in relation to the levels of chemical contamination of the sediments to be dredged and for given durations. The monitoring of water quality during dredging operations is also defined in these decrees. In the ports studied, only turbidity or suspended matter concentration monitoring is required during the work.

The objective of this study is to acquire environmental datas in these harbors by carrying out a diagnostic of chemical contamination and microbiological waters. The four studied harbors offer us the possibility to work on sites of different sizes with heterogeneous sedimentary materials and levels of contamination, which will allow us to determine the parameters likely to influence the phenomena of sorption/desorption of contaminants during dredging operations. The monitoring of the chemical and microbiological qualities of port waters during these dredging operations aims at determining the impact of these operations on the resuspension of contaminants. Indeed, these operations can lead to a resuspension of pollutants in the water column in the more or less long term. At certain levels, these can harm ecosystems either at sea during dredging or on land when these sediments are stored long after dredging operations have ended. These data will make it possible to determine if the monitoring currently in place is sufficient to measure the impact of these dredges on the aquatic ecosystems

2. Materials and Methods

2.1: Study areas

The Gulf of Aigues-Mortes contains the Natura 2000 area, under the Gulf of Lion entity. It is the northernmost part of the Gulf of Lion, between the commune of Villeneuve-lès-Maguelone and the commune of Grau du Roi, at the point of Espiguette. This small gulf borders the territory of the communes of Villeneuve-lès-Maguelone (in its eastern part), Palavas-les-Flots, Mauguio (Carnon) and La Grande-Motte, all four located in the department of Herault, as well as the territory of the municipality of Grau du Roi, (up to the point of Espiguette), located in the Gard (Figure 1).

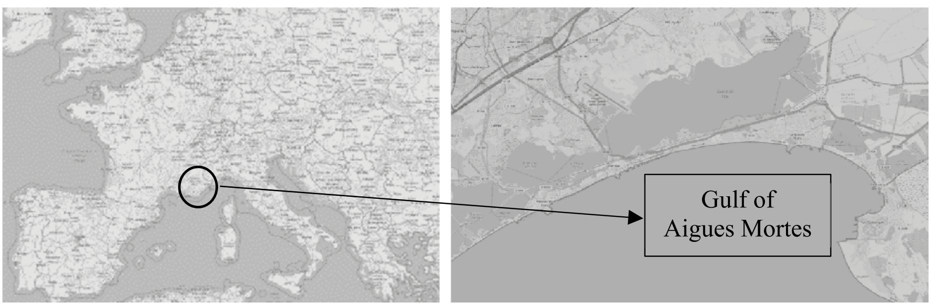


Figure 1 – Gulf of Aigues Mortes localization.

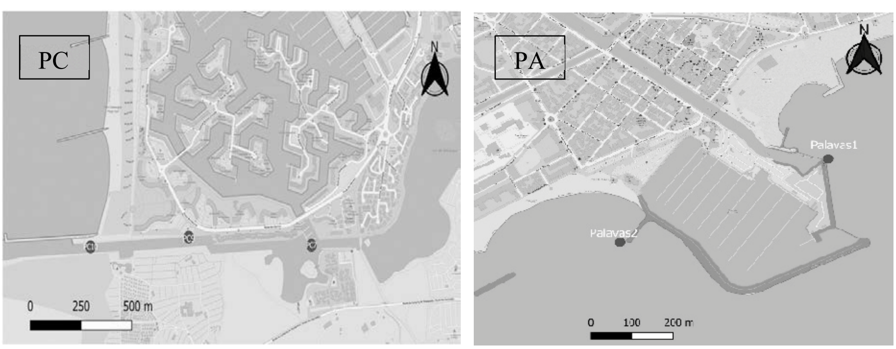
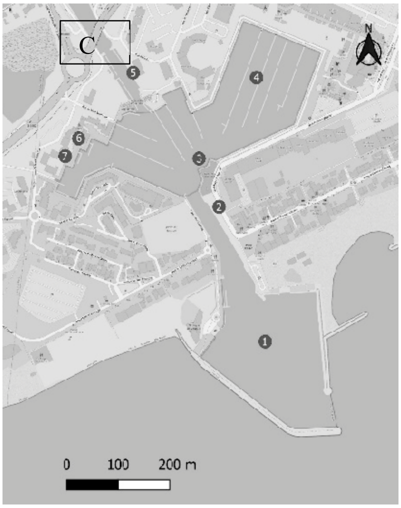


Figure 2 – Location of the ports studied: (PC) Port-Camargue, (PA) Palavas-les-Flots.



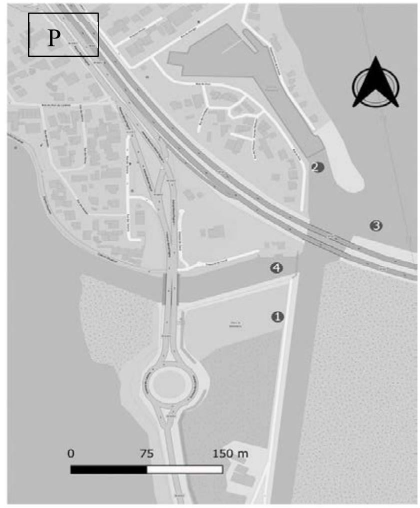


Figure 3 – Location of the ports studied: (C) Carnon, (P) Pérols.

Our study concerns four ports in the Bay of Aigues Mortes (Figures 2 and 3). The size of the marinas varies from 130 to 5000 boat places. The volume of dredged sediments is between 5 000 m^3 of sand and 30 000 m^3 of mud.

2.2: Methodology

Quality monitoring in harbour waters and sediments prior to dredging was implemented. These are surface water withdrawals filtered (0.22 µm acetate) and acidified with pure HNO_3 (Nitric acid). Measurements of physical-chemical parameters of water (T°C, pH, [O_2], Salinity, Turbidity) are performed by Multiparameter Probes portable HACH® (Hq40d) LDO101, pHC301 and CDC40101. The quantification of trace metals elements (ETM) is carried out by inductively coupled plasma mass spectrometry (ICP-MS) (iCAP-Q, Thermo Fisher Scientific) and a speciation analysis of organotin compounds (OSn) is performed by coupling SPME-GC-ICP-MS (TRACE 1300 GC Thermo Fisher Scientific-ICP-MS X Series II-Thermo Fisher Scientific ®). A particular focus will be made on Copper (Cu) and tributyltin (TBT) used in the compositional anti-fouling paints applied on the hulls of boats. Note that the use of TBT-based paints has been prohibited in Europe since 2008 and are replaced by Cu-based paints.

Surface sediment samples are collected at various ports for further analysis. Sediments were digested using a mixture of HF/ HNO_3 /HCl suprapur acids (Merck Millipore®). Digestion was carried out in a microwave oven (Ultrawave, Milestone ®). Trace element concentrations were measured using ICP-MS-Q, iCAP-Q (Thermo scientific ®) equipped with high matrix interface. The accuracy and the precision of the methods have been tested using certified reference materials (CASS-6 and PACS-2; Canadian National Research Council).

The resulting trace metals and TBT concentrations were compared to the N1 and N2 thresholds reported by the Geode [4] (Table1).

In order to enumerate faecal indicator bacteria (thermotolerant coliforms (TTC) and intestinal enterococci (IE)), the collected water samples were treated according to the reference methods ISO 9308-1:2014 and ISO 7899-2:2000, respectively. Water volumes were filtered on 0.45 µm cellulose nitrate membrane (Sartorius). TTC were quantified on Lactose Triphenyl Tetrazolium Chloride Tergitol-7 agar (Biokar) incubated for 24 h at 44 °C, and IE were enumerated on Slanetz-Bartley agar (Biokar) incubated for 48 h at 37 °C. The results are expressed as Colony Forming Units (CFU) per liter.

Dredging operations - The dredging was carried out hydraulically with a stationary suction dredger in Port-Camargue, Pérols and Palavas. The dredging of the port of Carnon has not yet started:

- Port Camargue - The work consisted of spot maintenance dredging of the south channel to an average depth of 3.5 meters. A suction dredge was used to pump the dredged sediments to a floating pipe that mixes the water and sediments towards a calibration workshop installed on the bank near the channel. The dredged sediments were screened at 80 µm by hydrocycloning and then separated into two streams: the fine sands above 80µm are used to recharge the beach, the muddy materials below 80µm are drained into geotubes and then reused as reclamation materials. According to the prefectural decree DREAL/DMMC-30-202-001, the turbidity of the water in the channel is measured continuously (turbidimeter) immediately downstream of the discharge of the water from the buffer basin during the entire duration of the discharge.
- Pérols - The works consisted in carrying out a punctual maintenance dredging of the access channel to the harbour basin to recover an average depth of -1.4 m NGF. The mixture of water and sediment sucked up by the dredger is discharged into filtering geotextiles for the dehydration of the sediments. The lowering of the dryness of the sediments will allow the acceptance or the elimination in a waste storage channel adapted to the nature of the waste or their valorization. According to the prefectural order DREAL/DMMC-34-2019-003, a physico-chemical monitoring (pH, dissolved oxygen, turbidity and conductivity) at three stations: around the dredge, near the sediment dewatering area and in the channel must be performed daily and every 3 hours before, during and after dredging at the 3 stations.
- Palavas - The Prefectural Order PEL-2015-001 authorizes for a period of 10 years the dredging work necessary to maintain the nautical characteristics of the entrance to the port of Palavas and to ensure access by users in good conditions of navigability and safety (-2.50 m NGF). The sediments sucked up by the dredger are discharged directly through pipes for the seasonal recharging of the adjoining beaches for bathing use. Water quality monitoring includes continuous visual monitoring of the intensity and diffusion into the marine environment of the turbidity plume that will be generated by the dredging work, daily monitoring of turbidity levels.

3. Results and discussion

3.1: Quality of dredged sediments

The concentration of trace metals and organotin compounds in the sediments of the studied harbors was determined. The concentrations obtained were compared to the Geode N1 and N2 levels (Table 1).

Table 1 – Qualitative assessment of sediments in the four ports relative to threshold levels (Geode, 2018).

	French dredging sediment classification (Geode,2018)	
PC : Port Camargue	<N1	Except [Cu] = 77 ± 53 mg/kg >N2
P: Pérols	<N1	Except [Cu] = 77 ± 7 mg/kg >N1
PA: Palavas les flots	<N1	Except [Cu] = 155 ±25 mg/kg >N2
C: Carnon	<N1	Except [Cu] = 126 ±77 mg/kg >N1 or >N2 Except [TBT]= 198 µg(Sn)/kg >N2 careening area

In all 4 harbors, copper concentrations above the N1 level (45 $mg.kg^{-1}$) or even the N2 level (90 $mg \cdot kg^{-1}$) were measured. In the port of Carnon, TBT concentrations above the N2 level were also measured in the technical areas (N1 = 41 $ng(Sn)\cdot g^{-1}$, N2 = 164 $ng(Sn)\cdot g^{-1}$).

3.2: Water quality before dredging operations

3.2.1: Physico-chemical parameters measured in situ

Physical-chemical measures varied from port to port. This variation can be explained by the geographical location of ports and the effect of current, (table 2).

Table 2 – Physicio-chemical parameters in the four ports before dredging operations.

	Port Camargue	Port Pérols	Port Palavas les Flots	Port Carnon
Sampling dates	**Janv-21**	**Nov-20**	**Janv-21**	**Sept-21**
Temperature (°C)	7.7	12.2	14.0	24.8
pH	8.28	8.34	8.28	7.96
%O_2	11.2	86.1	115.2	7.9
Salinity (PSU)	32.6	27.9	32.2	37.1

3.2.2: Trace metals and organotin concentrations

The Arsenic (As) concentration is consistently above the Environmental Quality Standard (EQS) before dredging begins in all 4 ports (Table 3).

The concentrations of Copper (Cu) and Zinc (Zn) are below the EQS prior to dredging operations except for Cu in the port of Carnon.

All three forms of butyltins (MBT, DBT, and TBT) are detected at all points at spatially and temporally variable concentrations. The presence of contaminated sediments in the dredged areas could be the cause of resuspension in the water column.

The establishment of environmental quality standards (EQS) has been proposed (Directive No. 2008/105/EC) for these substances. The EQS propose values of annual average concentrations (AA) and maximum allowable concentrations (MAC) to ensure the protection of the aquatic environment and human health against long-term and chronic effects and against direct and acute ecotoxic effects respectively. These values are lower than $ng(Sn)\cdot L^{-1}$ for tributyltin compounds (EQS-MA = 0.082 $ng(Sn)\cdot L^{-1}$ and EQS-CMA = 0.61 $ng(Sn)\cdot L^{-1}$). The average TBT concentrations largely exceed the EQS-MA in the four studied ports (Table 3).

Table 3 – Trace metals and organotin dissolved concentrations in the four ports before dredging operations.

		PORT-CAMARGUE	PÉROLS	PALAVAS	CARNON	EQS	
As	µg·L^{-1}	1.68±0.21	0.79±0.46	1.37±0.02	1.38±0.23	*0.83*	
Cu		1.48±0.81	1.49±0.39	0.56±0.13	3.60±2.42	*1.6*	
Ni		0.37±0.04	1.27±0.05	0.70±0.01	0.45±0.06	*4*	
Zn		1.39±0.33	2.10±2.81	0.67±0.01	2.41±1.2	*3.1*	
						AA-EQS	*MAC-EQS*
MBT	ng(Sn)/L^{-1}	2.41±0.39	5.26±2.05	8.02±2.19	2.09±0.76		
DBT		0.84±0.07	0.44±0.12	1.20±0.3	0.56±0.08		
TBT		0.28±0.05	0.28±0.10	0.38±0.09	0.14±0.15	*0.082*	*0.61*

EQS: Environmental Quality Standards; AA: annual average; MAC: maximum allowable concentration

3.2.3: Microbiological quality

Faecal indicator bacteria (thermotolerant coliforms (TTC) and intestinal enterococci (IE)) ranged from 0 to 25 CFU/100mL in the ports studied.

3.3: Impact of dredging activities

3.3.1. Physicochemical parameters

The dredging operations do not lead to modifications of the physico-chemical parameters, except for turbidity which can double or even quadruple compared to the initial values.

3.3.2: Tributyltin TBT

The dredging operation significantly increased the concentrations of organotin compounds including monobutyltin (MBT), dibutyltin (DBT) and tributyltin (TBT) in the water column during monitoring in the Port-Camargue marina. Formerly used in antifouling paints, TBT and its degradation products present in the sediments resuspended in Port Camargue and Pérols. The maximum concentrations in the dissolved phase measured were 13.4, 2.2 and 1.5 ng(Sn)·L^{-1} respectively for MBT, DBT and TBT.

In the port of Pérols, the resuspension took place at the end of the dredging operation, probably linked to the dredging of a sedimentary zone more contaminated with TBT.

3.3.3: Trace metals

In Port Camargue, the concentrations of arsenic measured are systematically higher than the EQS. For copper, only one sampling point (PC7) systematically shows values above the EQS. For the other points and for Zinc only 25 % of the sampled points present values higher than the EQS. Concerning Palavas, the measured concentrations of arsenic are systematically higher than the EQS, while copper and zinc never exceed the EQS. Concerning Pérols, the measured concentrations are in 76 % for arsenic, 11 % for copper and 3 % for zinc above the EQS.

In order to quantify the impact of dredging operations, water enrichment factors (EF) of arsenic (Figure 4), copper (Figure 5) and zinc (figure 6) are calculated using as a reference the measured post-dredging concentration (Table 2) in the water columns of the four ports and compared with the concentrations measured during and after dredging:

$$EF = \frac{[Element_i\ concentration]_{post\ dredging}}{[Element_i\ concentration]_{during\ dredging}}$$

If the enrichment factor (EF) is greater than 1, then enrichment in the dissolved phase means that remobilization of metals from the sediment and suspended particles is occurring in the dissolved phase. Conversely, if the enrichment factor is less than 1, then there is no resuspension into the dissolved phase, which means re-adsorption onto the solid phase. The following graphs represent the dissolution (EF-1>0) or the sorption (EF-1>0) of Arsenic, Copper and Zinc in the different ports during dredging operations.

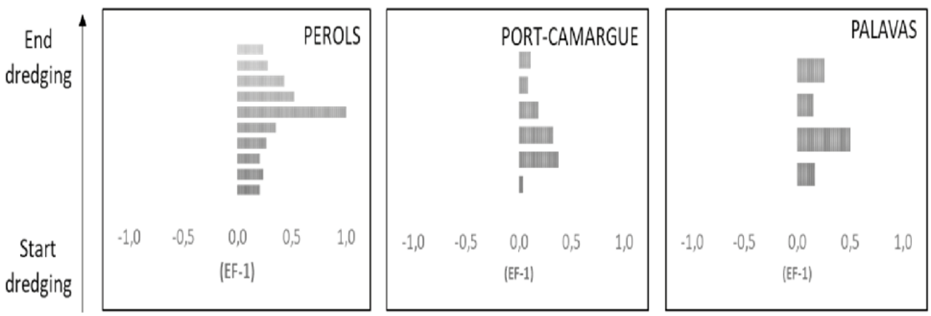


Figure 4 – Arsenic enrichment factors during dredging of Pérols (P), Palavas (PA) and Port-Camargue (PC).

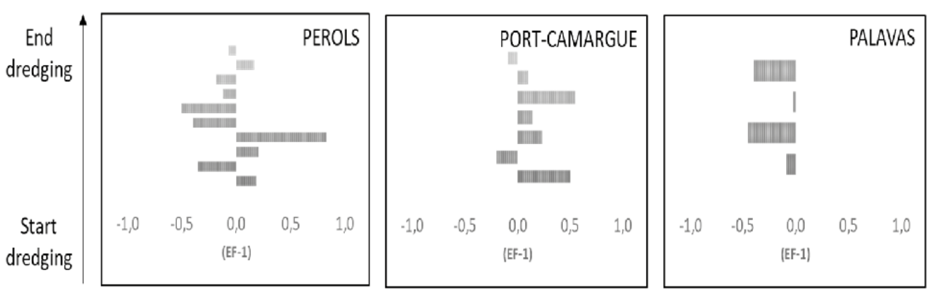


Figure 5 – Evolution of Copper enrichment factors during dredging of Pérols (P), Palavas (PA) and Port-Camargue (PC).

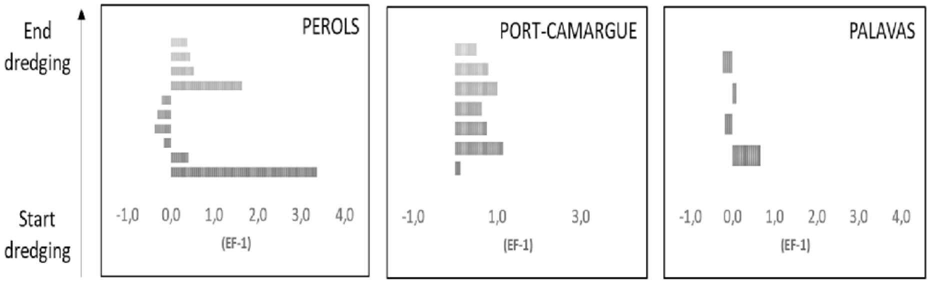


Figure 6 – Evolution of Zinc enrichment factors during dredging of Pérols (P), Palavas (PA) and Port-Camargue (PC).

It should be noted that the dredging operation of Port Camargue leads to a significant increase in the concentrations of As, Cu and Zn with enrichment factors ranging from 1.2 to 2.15 times the reference value inducing exceedance of the EQS.

The results of the EF calculations show a significant resuspension of As and Zn (EF>1) from the beginning of the dredging operation for the three ports with a more marked effect for the port of Pérols (Figures 4 and 6).

The behavior of copper is different in the three ports studied. A re-adsorption of Cu on the particulate phases (EF<1) seems to occur from the beginning of the dredging operations in the ports of Pérols and Palavas. In the case of Port Camargue an enrichment in the dissolved phase (EF>1) is observed. These phenomena are certainly related to the different natures of the sediments (sands, silts, clays, granulometry...).

3.3.4: Microbiological

The dredging operation do not lead to modifications of the microbiological quality.

4. Conclusion

The monitoring of all the chemical and microbiological contamination of the water during the dredging operations in three ports has made it possible to observe a certain number of phenomena, and in particular a resuspension of metallic trace elements and organotin compounds in the water column. The sometimes-high enrichment factors observed indicate that, in some cases, the environmental quality standards recommended by the Water Framework Directive have been exceeded.

The increase or decreasing of chemical element concentrations observed in the water column is directly related to the presence of these compounds in the sediments, which constitute both a sink and a source for (organo)metallic compounds. Indeed, the resuspension of sediments generates modifications of the physico-chemical conditions (oxygenation, modification of the redox conditions...).

The results obtained in this study show a potential for resuspension or readsorption of (organo)metallic compounds. The intensity of remobilization and reabsorption seems to depend, according to the elements considered, on the stability of the inorganic or organic complexes, the nature of the sediments and the particulate load. The environmental monitoring carried out in the case of harbour dredging on even slightly contaminated sediments (level N1) must include the monitoring of these compounds in order to estimate and take into account the potential impact on the ecosystems.

These results will be particularly useful for the dredging works planned in the port of Carnon, which is more contaminated, taking into account the distribution of contaminants in the sediments.

Acknowledgements

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OPTIMIZATION MODEL FOR A HYBRID PHOTOVOLTAIC/COLD IRONING SYSTEM: LIFE CYCLE COST AND ENERGETIC/ENVIRONMENTAL ANALYSIS

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Abstract – Traditional cold ironing provides for powering berthed ships in port with electricity from the national grid. This way ships can shut down their auxiliary engines and exploit the onshore power supply. Alternatively, a local energy production improves the energetic self-sufficiency of the port areas and avoid stressing the national grid with continuous peaks of energy demand. The port area becomes a microgrid, characterized by both energy producers and consumers. This paper presents an optimization model for a combined photovoltaic (PV)/cold ironing system. The energy demand of a list of ferries has been analyzed, taking the port of Ancona (Italy) as case study. Then the match with the energy production has been investigated. The proposed model returns the percentage of the energy demand covered, the interactions with the national grid, the optimal size of the PV plant based on a Life Cycle Cost (LCC) approach and the environmental savings obtained. Results show that the optimal PV plant size is 2100 kW and 3700 kW for two scenarios with different initial and operational costs. The reduction of CO_2 emissions is 54.1 % for a traditional grid-based scenario, while 64.9 % and 73.1 % for the 2100 kW and 3700 kW scenario, respectively.

Introduction

Over the years the continuous increase in maritime traffic of goods and people, both by ferries and cruises (which have the highest growth rate), highlights the problem of environmental pollution in port areas, especially when the port is in the proximity of urban areas. According to IMO (International Maritime Organization), maritime traffic contributes to CO_2 global emissions for approximately 2.2 % (2014) [1]. In addition, ships contribute to NO_x, SO_x and PM emissions in varying degrees depending on the type of engines and fuel used by the ships. As reported from the 4th GHG study[1], the greenhouse gas (GHG) emissions of total shipping have increased of 9.6 % from 2012 (977 million tons) to 1076 million tons in 2018, passing from 2.76 % to 2.89 % of the global anthropogenic emissions. The progressive increase of the maritime traffics has caused an always greater impact on the ports, often located in densely populated areas. The decarbonization of maritime traffics turns out to be a mandatory step to reduce the environmental impact of the sector [2].

Among the studied solutions, cold ironing systems plan to power berthed ships with an onshore power supply [3]. In fact, ships keep the auxiliary engines running during the stay time at the quay, to produce the necessary electricity to hoteling activities (such as indoor air conditioning, lighting, pumps and fans). Cold ironing ensures a high level of local pollutants

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abatement [4], as allows to replace the energy from on-board diesel generators with energy from the national grid [5]. Globally, with a lower environmental impact of the grid energy mix, a higher abatement efficiency is achieved [6].

In addition, the trend of local and smart grid must be considered [7]. Traditional grid is designed to transmit electricity from centralized producers to consumers, while in future multidirectional network consumers are the producers themselves [8]. The local electricity production provides technical benefits [9], such as the reduction of losses and congestion in the grid [10]. In this sense the integration of renewable sources is fundamental to produce clean energy, given its proximity to urban areas, and to match the energy demand of ports [11].

This paper investigates the energetic, economic and environmental feasibility of a photovoltaic (PV) plant located in port area. An optimization model has been developed and implemented on MATLAB, to provide the best sizing of the production plant. The model is based on an hourly time step over a one-year period. The chosen parameter for the optimization is the Life Cycle Cost (LCC), as it allows to consider the entire life of the components [12]. The proposed model first provides the match between the energy production and the energy demand, returning the percentage of the energy demand covered and the interactions with the national grid. Then the optimal model with the size of the PV plant based on the minimum Life Cycle Cost (LCC) has been simulated. On this scenario the environmental savings obtained has been calculated.

Materials and methods

The optimization model proposed aims to provide the best sizing of a photovoltaic plant coupled to a cold ironing system. The port of Ancona is taken as case study. In this work the analysis is limited to ferry ships, but the methodology is valid for all kind of ships. Ferries are characterized by regular frequency of calls in port, and an average energy demand compared to cruises (higher power required) and container ships (lower power required). The calculation is hourly based over a period of one year. In the case study proposed, the period considered is from August 1st, 2018 to July 31st, 2019.

Once the pattern of ships has been chosen, the input data for the analysis are the nominal and the used power at berth, the duration of the stay and the number of calls. A typical week for each month has been determined, in order to model the annual profile of the electrical load.

The power required by the ships present in port at a given time i (hour), P_i, is calculated as follows (Eq. 1):

$$P_i = P_{i-1} + P_a - P_d \qquad \text{(kW)} \qquad 1$$

where P_{i-1} is the power required by ships at berth at the previous time step, P_a is the power of the ships that arrive in the port at time i, and P_d is the power demand of the ships that depart from the port.

Table 1 summarizes the ferry ships involved in this work. "EP" indicates the rated power of the generator, while "avg. power" the real power required during the berthing time (in summer and in winter). "t" refers to the number of hours in port related to the energy demand.

Table 1 – Energy demand of ships and dwell time at the quay.

	N° generators	EP nominal power [kW]	Summer			Winter		
			N° gen used	Avg. Power [kW]	t [h]	N° gen used	Avg. Power [kW]	t [h]
Ship 1	3	2100	1	1600	513.8	1	1600	893.2
Ship 2	3	1400	2	1400 150	314.2	1	1000	845.7
Ship 3	3	1400	2	1400 150	310.8	1	1000	859.5
Ship 4	3	1900	2	1900 300	254.7	2	1900 300	441.2
Ship 5	3	3800	1	2200	310.2	1	2200	433.8
Ship 6	4	850	2	850 350	573.0	2	850 350	253.2
Ship 7	3	1360	1	800	857.3	1	800	1007.8
Ship 8	2	960	1	500	272.2	1	350	131.4
Ship 9	4	783	1	600	871.0	1	600	946.1
Ship 10	3	945	1	800	694.5	1	800	0.0

Eq. 1 is calculated for the year under study and the trend is shown in figure 1. The energy demand is very variable during the different weeks and seasons and ranges between 0 W, in absence of ships in port, to 6400 kW, during the maximum contemporaneity of ships.

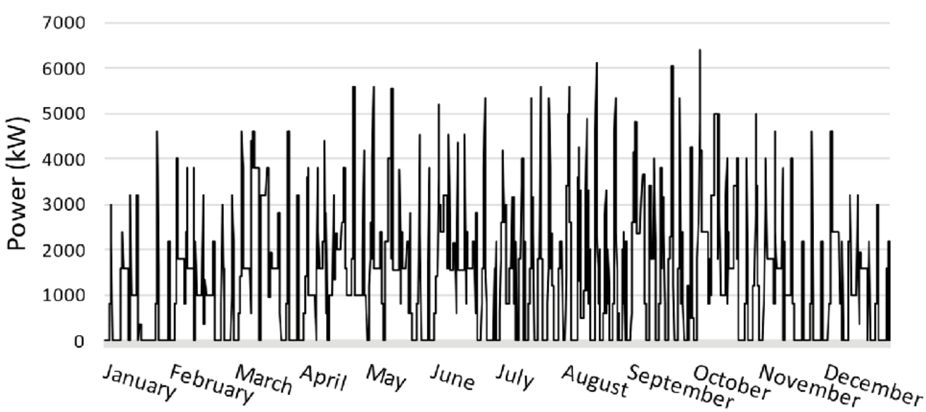

Figure 1 – Annual profile of the energy demand by berthed ships.

As regard the energy production, the proposed system consists of a PV plant, located in port area, that provides energy to cover the energy demand of berthed ships. In absence of solar radiation or in case of deficit of energy production, the electricity is taken from the national grid. In case of energy surplus, which means that the energy production is higher than the energy demand of ships, the energy surplus is given to the national grid. The data required for the calculation of the output power of a PV system are the ambient temperature and the irradiance over the analyzed period. The data were collected considering the climatic condition of Ancona (Italy), from 01/08/2018 to 31/07/2019, on an hourly basis. The output power (P_{PV}) is calculated with the following equation (Eq. 2):

$$P_{PV} = P_r \cdot f_{PV} \cdot \left(\frac{G_T}{G_{T,STC}}\right) \cdot \left[1 + \alpha_p \cdot \left(T_C - T_{C,STC}\right)\right] \quad (kW) \qquad 2$$

where P_r is the rated capacity of the PV array, meaning its power output under standard test conditions [kW]. f_{PV} is the PV derating factor [%], G_T the solar radiation incident on the PV array in the current time step [W/m^2], $G_{T,STC}$ the incident radiation at standard test conditions. αP is the temperature coefficient of power [%/°C], T_C the PV cell temperature in the current time step [°C] and $T_{C,STC}$ the PV cell temperature under standard test conditions. STC (Standard Test Conditions) refers to 1000 W/m^2 and 25 °C. The cell temperature during the working time of a PV panel can be expressed as a function of the ambient temperature and the incident solar radiation on the panel (Eq. 3):

$$T_C = T_a \cdot G_t \cdot \left(\frac{NOCT - 20}{800}\right) \quad (°C) \qquad 3$$

where T_a is the ambient temperature at the current time step [°C] and NOCT is the operative temperature of the PV panel. In this study, considering monocrystalline PV panels, the NOCT is assumed to be 45 °C and the coefficient of power α_P equal to − 0.5 %/°C. The PV derating factor f_{PV} is equal to 93 %.

The economic analysis has been performed through a Life Cycle Cost approach (LCC). This method allows to consider the initial investment costs and the operation and maintenance costs for all the duration of the system, and eventually the recovered value at the end of the life cycle. The method combines the energetic and economic aspect. The LCC index can be calculated with the following equation (Eq. 4):

$$LCC = C_I + \sum_{t=1}^{n} \frac{C_{M,i} + C_{O,i}}{q^i} \quad (€) \qquad 4$$

where C_I represents the initial investment costs, $C_{M,i}$ and $C_{O,i}$ are the maintenance and operation costs over the period i, respectively. q^i is defined as $(a + 1)^i$, where a is the discount rate during the n- years of the project. The method allows to compare different scenarios. The best one is the one with the lowest LCC index.

The environmental analysis aims, once the best scenario has been determined, to provide the emission saving. The method compares the pollutant emissions of the auxiliary engines of ships, usually diesel generators, with the emission factor of the energy mix of the grid. The analysis is provided for a list of pollutants, namely CO_2, NO_x, SO_x and BC. The environmental emissions of a pollutant can be calculated with the following equations (Eq. 5):

$$\varepsilon_i = EF_i \cdot E_i \quad (kg) \qquad 5$$

where ε_i (kg) is the emission of the pollutant "i", EF_i (kg/kWh) is the emission factor and E_i (kWh) is the energy withdrawn from the electrical grid. The values of the emission factors are taken from SINAnet ISPRA [13], which refers to electricity from the Italian energy mix. The emission factors are summarized in table 2.

Table 2 – Emission factors (kg/kWh) for grid and (kg/ kg of fuel) for ships.

	CO_2	SO_2	NO_x	BC
Ships	3.082	0.022	0.057	3.37E-03
Grid	0.258	4.81E-05	2.11E-04	3.99E-08

Two different numerical models have been developed and implemented on MATLAB. The first one allows to determine the share of energy demand of ships at berth covered by the photovoltaic plant. This is the share that directly match the energy production and the energy demand. The remaining share of the energy demand is provided by the national grid. The model is based on an hourly time step. The input data are the solar radiation (Gt), the ambient temperature (Ta) and the power required by ships (Pi). The model calculates and returns the PV production in according to Eq. 2 and Eq. 3, and then matches, for each time step over one year, the energy production and the energy demand. At each time step, in presence of ships in port, assigns the correct share of energy to the PV plant or to the national grid. The diagram flow of the model is shown in figure 2. In figure, Epv is the energy provided by the PV plant to ships, SU is the energy surplus and DE is the energy deficit.

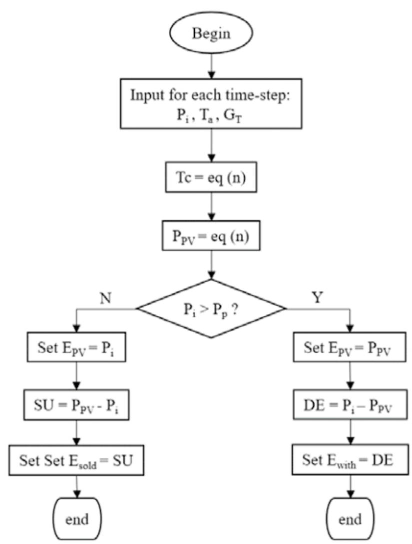

Figure 2 – Diagram flow of a photovoltaic scenario.

The second model is the optimization tool based on the minimization of the LCC index, as presented in Eq. 4. The input data are the results of the previous model (figure 2), and in addition the economic and environmental parameters, namely initial, operation and maintenance costs and emission factor. The model returns the LCC index, considering a life cycle of 20 years. Then the loop increases the PV plant size of a power step and repeats the loop. For each scenario the LCC index is calculated and at the end the optimal size of the plant is highlighted (the one with the lowest LCC). Figure 2 shows the diagram flow.

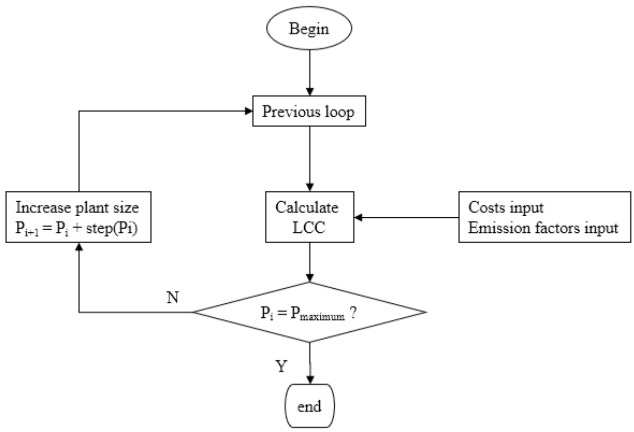

Figure 3 – Diagram flow of LCC loop.

Results and discussions

Two different scenarios have been simulated, comparing different costs:

- Traditional cold ironing, namely the energy demand is directly provided by the national grid.
- "Scenario 1", with 1400 €/kW for the initial cost of the PV plant and 0.2 €/kWh for the energy purchased from the national grid.
- "Scenario 2", with 1800 €/kW for the initial cost of the PV plant is, while 0.4 €/kWh for the energy purchased from the national grid. This scenario hypothesizes a spike of energy and material prices.

The first result analyzed is the match between the energy production (PV plant) and the energy demand (berthed ships). Both trends are characterized by a high grade of variability. In fact, the PV production strongly depends on the presence of the solar radiation, while the energy demand on the presence of ships in port. The PV plant size has been varied between 1000 kW and 10000 kW. Results are shown in figure 4.

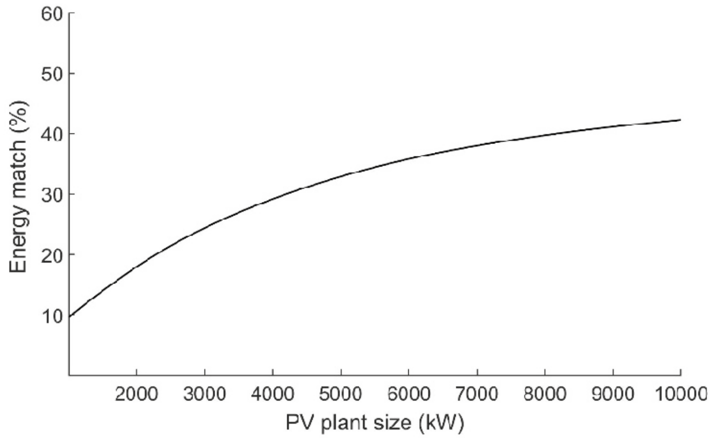

Figure 4 – Energy match (%) between energy production and demand.

The energy that directly met energy production and demand ranges from 9.5% (for a PV plant of 1000 kW) to 42 % (for the 10000 kW case). The trend is not linear, in fact increasing the PV plant size the slope tends to become horizontal. This means that a share of the energy demand occurs in period of absence of energy production (such as at night) and accordingly is independent from the size of the plant. In addition if while increasing the power of the PV plant the match with the energy demand does not increase, there is an increase of the energy surplus that is given to the national grid. This phenomenon has been investigated for the same range of power, from 1000 kW to 10000 kW. Result is shown in figure 5.

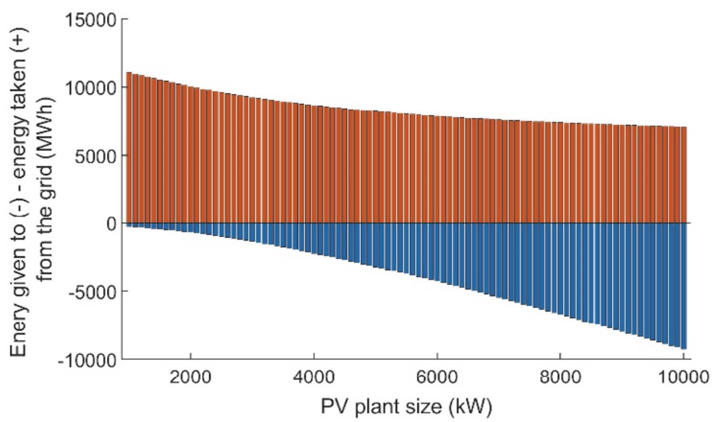

Figure 5 – Energy interaction with the national grid.

It is clearly visible that increase the PV plant size produces an increase of the energy surplus given to the grid, while the energy taken from the grid remains almost constant (after a first decrease). To investigate the optimal size, the LCC approach has been simulated.

The optimization model returns the best PV plant size based on a LCC approach. The model presented has been simulated for both scenarios. The best PV plant size turns out to be 2100 kW (with a LCC of 23.1M€) for the scenario with average prices, while 3700 kW (with a LCC of 42.7M€) for the one considering a spike of prices. In figure 6 the values of LCC have been normalized to better compare the two scenarios, setting a reference value of 100 to the minimum LCC.

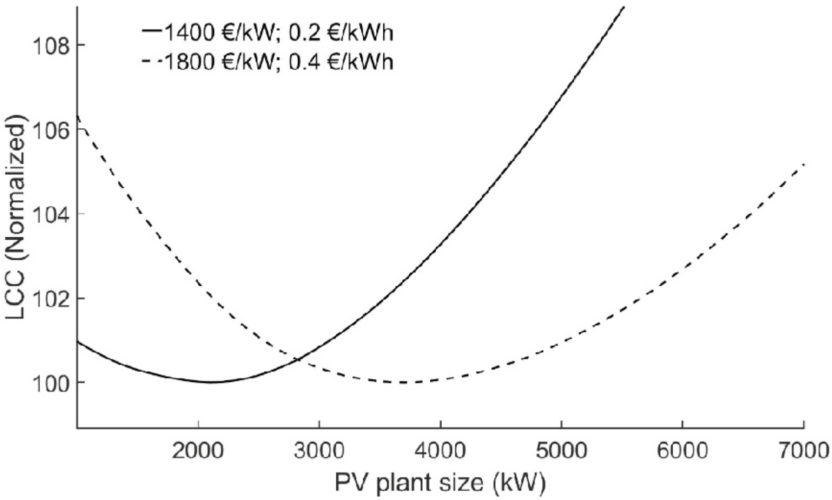

Figure 6 – LCC optimization for the two scenarios considered.

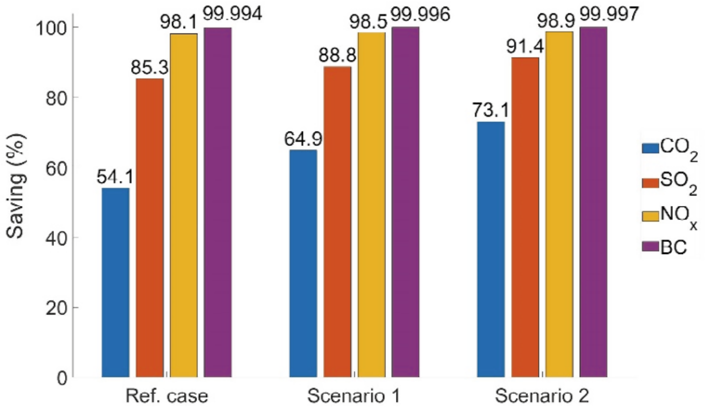

Figure 7 – Saving of polluting emissions.

The environmental analysis has been performed only for the two best plant sizes. Both scenarios are compared with a reference case, namely the traditional cold ironing entirely powered by the national grid. The CO_2 emission saving is 54.1 %, 64.9 % and 73.1 % for the reference case, the 2100 kW power plant and the 3700 kW power plant, respectively. Results for the all the pollutants considered are summarized in figure 7 and table 2. It is worth noting that the percentages of saving obtained depends on the energy mix considered.

Conclusions

This paper presents an optimization model for a hybrid photovoltaic/cold ironing system. The proposed system can limit the environmental pollution produced by berthed ships, replacing the on-board diesel generators with a PV plant located in port area and supported by the national grid. The ferries traffic of the port of Ancona (Italy) has been taken as case study. A numerical model has been written and implemented on MATLAB. The model investigates the match between the energy production (photovoltaic plant in port area) and the energy demand (auxiliary engines of berthed ships). Results show that the trend of the percentage energy match tends to become asymptotic, and ranges between 9.5 % (for a PV plant of 1000 kW) to 42 % (for the 10000 kW case). In fact, the analysis of the energy interactions with the national grid returns that the energy given to the grid increase with the PV plant size, while the energy taken from the grid remains almost constant. Then a second model provides the optimization of the PV plant size based on the Life Cycle Cost (LCC) approach. This approach allows to involve in the analysis the entire life of the plant, considering both the initial costs, the operation and maintenance costs and the residual value at the end of the life. The model returns that the optimal PV plant size is 2100 kW for the scenario with average prices, while 3700 kW considering a spike of prices. The results of the environmental analysis show that a traditional cold ironing (energy demand fully provided by the national grid) allows a reduction of the CO_2 emissions of 54.1 %. The two scenarios resulting from the optimization model ensure a CO_2 emission saving equal to 64.9 % and 73.1 %, respectively. A future extension of the work will include the possibility of an energy storage system, to increase and maximize the self sufficiency of the system.

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A FIRST ASSESSMENT OF MICROPLASTICS IN THE SEA WATERS OFF THE PUGLIA REGION

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Abstract – Plastic materials persist in the marine environment with different timing depending on their nature but atmospheric agents contribute to their degradation into smaller fragments, the so called microplastics (MPs). To meet the objectives of the EU Marine Strategy Framework Directive (MSFD, 2008/56/EC), the Puglia Regional Agencies for the Prevention and Protection of the Environment (ARPA Puglia) performed a quantitative and qualitative analysis of the MPs on the basis of the data collected during 2015-2017 monitoring program. A total of 90 samples in 5 campaigns were collected using a manta net. The MPs average density of 0.469 n/m³ was calculated for the entire dataset, a value comparable with those previously reported for others Adriatic and Mediterranean waters. No significant statistical differences were detected among sampling sites, campaigns and distance from the coast. The results represent a first assessment of microplastics at Apulian regional scale, that can be useful for the implementation of predictive circulation models in order to estimate the fate of plastic litters released at the sea.

Introduction

The growing impact of plastics on ecosystems is now in the public domain as an emerging issue of global concern involving numerous actions worldwide, both in the field of research, in public awareness campaigns and in the field of environmental policies.

Plastic materials persist in the marine environment with different timing depending on their nature but atmospheric agents contribute to their degradation into smaller fragments, the so called microplastics (MPs). The common definition of MPs, as reported by Frias *et al.* (2019), is "*synthetic solid particles or polymeric matrices, with regular or irregular shape and with size ranging from 1 µm to 5 mm (5000 µm), of either primary or secondary manufacturing origin, which are insoluble in water*".

The Mediterranean Sea host numerous peculiar habitats and several endemic species, being a very studied basin. However, its position and geo-morphological conformation as well as the strong anthropization of the basin makes it more subject to plastic materials and MPs pollution. As predicted by van Sebille *et al.* (2015), the highest MPs concentrations are in Mediterranean and in North Pacific zones, while the largest microplastic quantity is in the North Pacific. The total quantity is much smaller in Mediterranean Sea compared to other cited zones because of the very small average particle size and much smaller basin size. It has been estimated by Eriksen *et al.* (2014) that of the 268 940 tons of plastics particles floating on the surface of the world's oceans, about 14.1 quintals of particle

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size between 0.33-1.00 mm and 53.8 quintals of particle size 1.01-4.75 mm have been found in the Mediterranean Sea.

In the field of environmental policies, the EU Marine Strategy Framework Directive (MSFD, 2008/56/EC) establishes a framework within which EU Member States shall act to achieve or maintain good environmental status (GES) of their marine waters. In particular it includes, among the eleven key descriptors of marine environmental status quality, the Descriptor #10 "*The properties and quantities of marine litter do not cause damage to the coastal marine environment*" focus on marine litter and its impact on the marine environment and biota (Galgani *et al.* 2013). About MPs, in Italy the related monitoring protocol drawn up by the SNPA (the National System for Environmental Protection) aims to determine the abundance and the quality of microplastics into the water column. In Italy, this monitoring protocol is performed at regional scale by the ARPAs (Regional Agencies for the Prevention and Protection of the Environment). ARPA Puglia performed a quantitative and qualitative analysis collecting data on MPs during 2015-2017 monitoring program. The aim of this study is to provide a first assessment at regional scale of microplastics into Apulian sea waters, to give an estimation of their abundance and quality in Southern Adriatic and Western Ionian Sea off the Apulian coast.

Materials and Methods

Puglia region is located in the south of Italy and it is the easternmost region. It overlooks two seas, the Southern Adriatic Sea to the north-east and the Western Ionian Sea to the south-west. The total coastline length is 985 km (Regional coastal plan – Puglia Region, 2011), representing the 14 % of the Italian coast overall development.

Six survey areas, representative of the Apulian marine waters, were chosen for the monitoring activities (CA, Foce Capoiale; FO, Foce Ofanto; BA, Bari Trullo; CB, Capo Bianco; PC, Porto Cesareo; PN, Punta Rondinella). In each survey area, a coastal-wide transect was identified. For each transects, three sampling stations were chosen at progressive distances from the coastline: 0.5, 1.5 and 6 nautical miles (NM). The planned survey areas with the relative transect and the coordinates of the three sampling stations are reported in Figure 1 and Table 1.

The sampling activities were performed during 2015-2017. The sampling was carried out twice in 2016 and 2017, in spring season (February-April) and autumn season (September-November), while in 2015 a single campaign was performed during the autumn season, for a total of 5 campaigns in three years. The MPs were sampled using a manta net with a mouth opening of 25 cm height and 50 cm wide. On the mouth of the manta net a flow meter was mounted, in order to measure the water volume filtered. At each sampling stations, the manta net was lowered slowly from the boat and towed for twenty minutes across a linear transect, in the opposite direction to the surface current and the wind. The linear transect starting point coincides with the sampling stations coordinates, as reported in Table 1. The end position was recorded with portable GPS in WGS 84 UTM 32 as DD°, DDDGG. The boat speed was constant and slow, around 1 or 2 knots, never exceeding 3 knots. The collected samples were fixed adding 70 % alcohol and stored in a refrigerator. A total of 90 samples were achieved during the five campaigns. The laboratory analysis of MPs was performed on the whole sample. As a first step, the sample was sieved through two sieves, of 5000 μm and 300 μm respectively, rinsing the container several times.

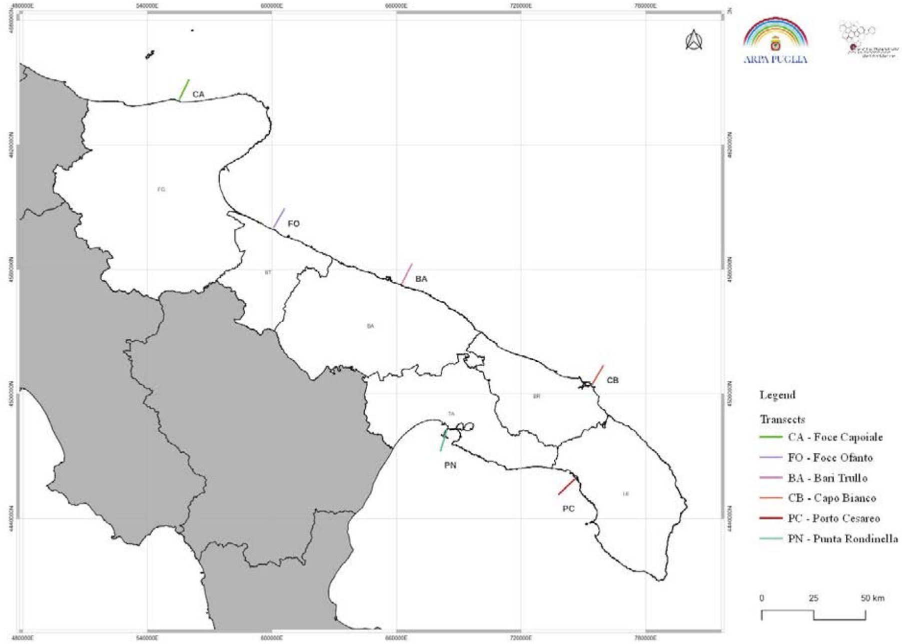

Figure 1 – Mapping of the six transects along the Apulian coasts.

Table 1 – Transects and sampling stations: identification code and geographical position.

Transects	Linear transect starting point	Lat.	Long.
CA	1CA01M	41.92963	15.67001
	1CA02M	41.94462	15.67997
	1CA03M	42.01132	15.72471
FO	3FO01M	41.36730	16.20593
	3FO02M	41.38175	16.21734
	3FO03M	41.44593	16.26803
BA	4BA01M	41.11583	16.93854
	4BA02M	41.13009	16.94867
	4BA03M	41.19636	16.99582
CB	6CB01M	40.65287	18.00848
	6CB02M	40.66689	18.02016
	6CB03M	40.73072	18.07377
PC	8PC01M	40.24308	17.88828
	8PC02M	40.23204	17.87222
	8PC03M	40.18166	17.79905
PN	9PN01M	40.47170	17.17270
	9PN02M	40.45584	17.16604
	9PN03M	40.38413	17.13597

Then, in a glass beaker the floating fragments were moved on a Petri dish with counting grid. The sorting phase involves the selection of the plastic materials only, separating for first organic residues (algae and plants, wood, etc.) with the aid of tweezers. Finally, MPs in the sample were counted and divided according to the shape (sphere, filament, fragment, sheet).

The MPs density was expressed as the number of particles per m^3 of sea water (n/m^3), according to different shape.

Most of the studies use a manta net for sampling, sometimes with mesh opening and vacuum of different sizes, pulled to the surface for a defined time and the samples are in all cases sieved in the laboratory in order to collect the microplastics (Frias *et al.* 2019, Suaria et al., 2016, Cózar et al., 2015, Zeri et al., 2018). In most of the studies the manta net is equipped with a flowmeter, however the GPS position of the beginning and the end of the transect is recorded. Consequently, some researchers show the data as the number of particles per m^3 of sea water (n/m^3; Fossi et al., 2016) while others as number per m^2 (n/m^2; Fossi et al., 2012). The data returned in the different articles are comparable to each other and with this study by standardizing them with mathematical formulas. Therefore, in order to compare the obtained results with the literature ones, MPs data were expressed as number per m^2 (n/m^2) also (Table 2).

The differences in the density values of MPs (n/m^3) were tested using the non-parametric Kruskal-Wallis rank sum test.

Results

MPs average number calculated for the entire dataset was 0.469 +/- 0.06 n/m^3. MPs average number for the Southern Adriatic Sea, calculated for 4 of the 6 transects (CA, FO, BA, CB), was 0.529 +/- 0.08 n/m^3 while the Western Ionian Sea transects (PC, PN) one was 0.348 +/- 0.07 n/m^3 (Figure 2). Nevertheless, although the average number of MPs is lower in the Ionian Sea than in the Adriatic Sea, the difference is not statistically significant (KW χ^2= 1.3656, df = 1, p-value = 0.2426).

The transect CA shows the highest average number of MPs per m^3 (0.702 +/- 0.25 n/m^3) in the three-year period, followed by FO, BA and transects (Figure 3). PC and PN show similar values. No statistical differences were detected among transects (KW χ^2= 6.8738, df = 5, p-value = 0.2302)

Considering MPs average number for each survey (Figure 4), the 2015 campaign highlighted the highest value (Autumn 2015: 0.646 +/- 0.21 n/m^3). Lowest mean value resulted for the 2016 Spring campaign (0.325 +/- 0.09 n/m^3), while Autumn 2016, Spring and Autumn 2017 mean values ranged from 0.430 ± 0.2 n/m^3 (Autumn 2017) to 0.501 +/- 0.10 n/m^3 (Autumn 2016). No statistical differences were detected among sampling periods (KW χ^2= 2.1424, df = 4, p-value = 0.7096)

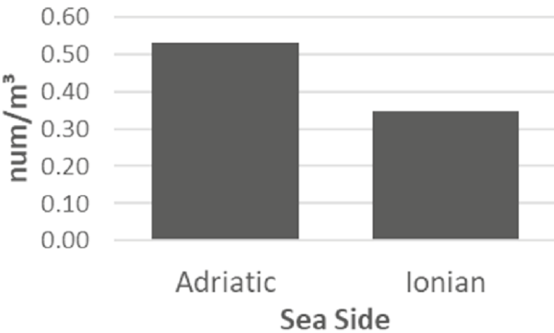

Figure 2 – MPs' average number calculated for the Southern Adriatic and Western Ionian Sea (+1 Standard Error).

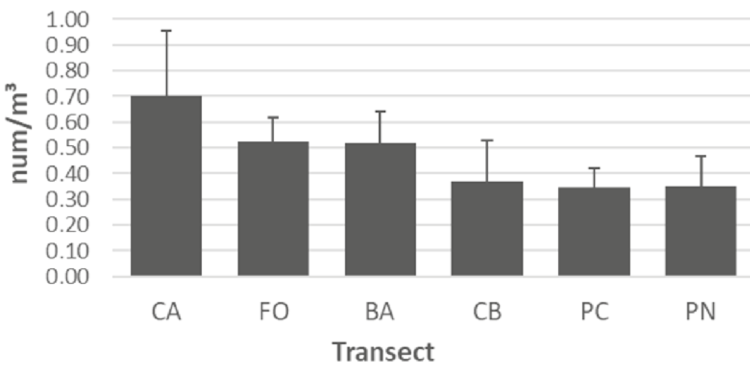

Figure 3 – MPs' three-year average number calculated for each transects (+1 Standard Error).

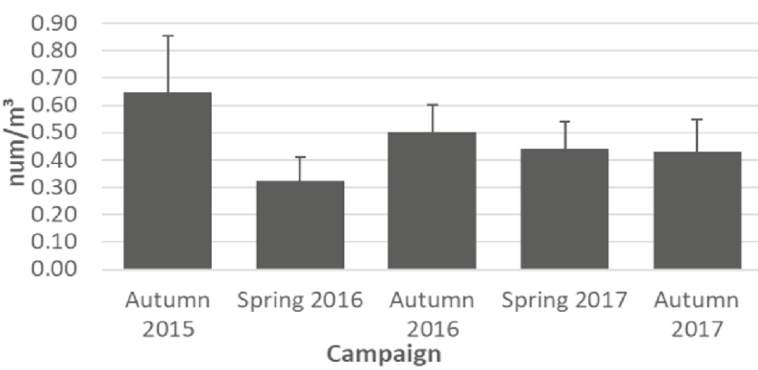

Figure 4 – MPs' average number calculated for each the five campaigns (+1 Standard Error).

MPs average numbers per transects and surveys are reported in Figure 5. The highest MPs average number was recorded in 2015 campaign along CA transect (0.331 ± 0.72 n/m³). None distribution pattern was highlighted. Since the samples were taken at 3 different distances from the coast (0.5, 1.5 and 6 NM), the possible distribution of microplastics as a function of this factor was investigated (Figure 6). Although highest value of MPs average number was detected close to the coast (0.5 NM, 0.520 ± 0.13 n/m³) no statistical differences were detected among coast distance (KW χ^2= 1.2733, df = 2, p-value = 0.529). Figure 7 shows average number of MPs per transects and surveys, as a function of distances from the coast. CA and BA transects show a decreasing gradient from the coast offshore, while FO transect don't show any trend. Instead, CB shows the highest values at the greatest distance from the coast (6 NM), PC at the lowest distance (0.5 NM) and for PN the highest value was found at the intermediate distance of 1.5 NM.

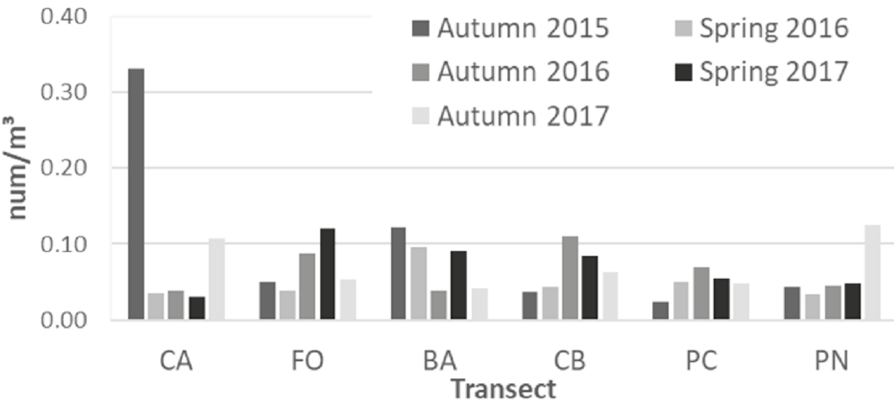

Figure 5 – MPs' average number for the 6 transects during the five campaigns (+1 Standard Error).

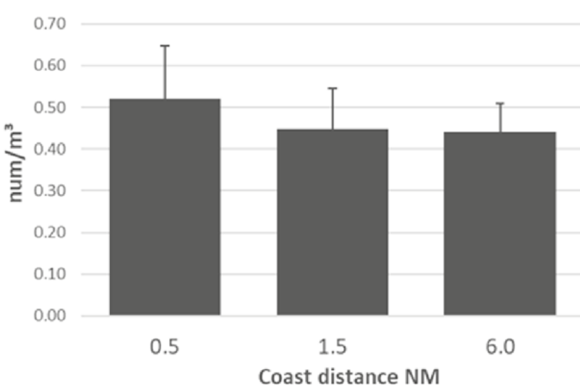

Figure 6 – MPs average number in the 6 transects as a function of distances from the coast (0.5, 1.5 and 6 NM) (+1 Standard Error).

With regard to the MPs qualitative analysis, the most common shape detected during the three-year monitoring program was “fragment” (68.9 %) followed by “sheet” (23.5 %), “filament” (4.9 %) and “sphere” (2.6 %) (Figure 8). In the end, the comparison among the results of the present study and the data from literature is reported in Table 2.

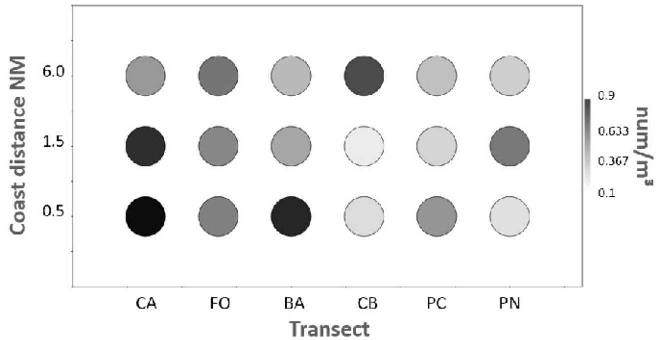

Figure 7 – MPs average number as a function of the distance from the coast per transects and campaigns.

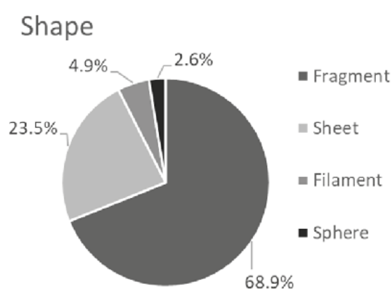

Figure 8 – Most common shape detected during the 2015-2016-2017 campaigns.

Table 2 – Literature data on floating microplastic densities for the Mediterranean Sea.

Source	**Region**	**Year**	**n. or item/m³**	**n. or item/m²**
Fossi et al., 2016	Ligurian Sea	2011-'12-'13	0.310	
Panti et al, 2015	NW Sardinia	2012-'13	0.170	
de Lucia et al., 2014	W Sardinia	2012-'13	0.150	
Suaria et al., 2016	W & Central Med. Sea	2013	1.000	0.400
Fossi et al., 2012	Ligurian/Sardinian Sea	2011		0.310
Ruiz-Orejón et al., 2016	W & Central Med. Sea	2011–'13		0.147
Cózar et al., 2015	Med. Sea	2013		0.243
Pedreotti et al., 2014	Ligurian Sea	2013		0.103
Gajšt et al., 2016	Adriatic Sea	2014		0.472
Zeri et al., 2018	Adriatic Sea	2014–'15		0.315
This study	Apulian sea waters	2015-'17	0.469	0.117

Discussion

As evidenced by recent studies (Cózar *et al.,* 2015), the Mediterranean Sea is a potentially accumulation zone at global scale but the patchy plastic distribution suggests that the variability of surface circulation hampers the formation of stable plastic retention areas into the basin. Regardless, the Mediterranean Sea is one of the marine regions in the world most impacted by plastic waste and it present a gradual increase in the concentration of marine litter mainly due to its basin conformation (van Sebille *et al*., 2015).

Within the Mediterranean Sea, Adriatic Sea is a semi-closed basin, with a limited recirculation of water and with highly anthropized coasts (by tourism and industry), with the presence of numerous rivers and streams that can be a path of contamination of coastal waters. In this study, the MPs average number calculated for the entire dataset was 0.469 n/m^3 and 0.117 n/m^2, values comparable with those previously reported for the Adriatic and Mediterranean waters (Fossi et al., 2016; Panti et al, 2015; de Lucia et al., 2014; Suaria et al., 2016; Fossi et al., 2012; Ruiz-Orejón et al., 2016; Cózar et al., 2015; Pedreotti et al., 2014; Gajšt et al., 2016; Zeri er al., 2018). As far as the Ionian Sea is concerned, only the portion relating to the Gulf of Taranto was taken into consideration. Nevertheless, in this study the average number of MPs is lower in the Ionian Sea than in the Southern Adriatic Sea, but the difference is not statistically significant.

As concern the investigated areas, no significant statistical differences were detected among transects, campaigns and coast distance, but the obtained results need to be confirmed in the next monitoring surveys. However, considering the whole Apulian sea waters, data from 2015/2017 three-year monitoring highlighted the highest value for the CA transect.

Although not confirmed by the statistical test, CA and BA transect shows higher values close to the coast while FO transect shows similar value at different distances from the coast. Since CA and FO are close to river mouths, it could indicate the presence of important plastics flows from land to the sea. The different position of the two transect, respectively in the north and in the south of Gargano promontory, can suggest the influence of such a geomorphological structure as a driver for the distribution and circulation of plastics in the Adriatic.

Conclusion

The results from the 2015/2017 three-year monitoring of microplastics (MPs) in the Apulian sea waters give first scientific data on distribution and relative density of MPs for the Southern Adriatic and the Western Ionian seas.

Although not significant differences have been found among the sampling sites and periods, some signals suggest the continuation of monitoring in order to achieve a larger data set to be analysed.

Nevertheless, the information now available can be useful for the implementation of predictive circulation models in order to estimate the fate of plastic litters released at the sea.

Acknowledgements

We would like to thank all the collaborators of ARPA Puglia who took part in the monitoring campaigns.

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CITIZEN SCIENCE BASED MARINE ENVIRONMENTAL MONITORING. THE MOANA60 EXPERIENCE

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Abstract – Sea water quality monitoring is an extremely important activity that following traditional methods is extremely demanding and expensive. This results often in the sea being largely under-sampled while scientific models are increasingly hungry of high resolution and high coverage data. A different approach needs to be pursued that could complement what is already available within the traditional practices with new data. The National Institute of Oceanography and Applied Geophysics - OGS developed innovative technologies that can be used within a citizen science or crowdsensing approach to monitor marine environmental parameters. These technologies consist of an acquisition and transmission device that sends data to the central OGS data collecting facility. The simultaneous installation of multiple such devices on boats of opportunity allows to create a network of mobile monitoring platforms and data management infrastructure able to acquire, store, process, validate and display in quasi-real-time georeferenced data on a web portal. This allows to share information on the quality of seawater with the scientific community but also with the public at large. If this allows the improvement of the environmental awareness of this latter and in particular of volunteers that are involved in the specific activity of data collection, at the same time this can dramatically improve spatial and temporal coverage of data. So far, the system has been installed mainly on recreational ships that covered restricted coastal areas, in the Gulf of Trieste (Northern Adriatic Sea); this work will report, instead, on an extension of the system done in collaboration with the Moana 60 Lab initiative that took place in the summer of 2021 and where it was possible to cover a large transect in the Tyrrhenian Sea between the Aeolian islands, the harbour of the city of Trapani and the Aegadian islands protected area. Recordings were accurate and highlighted interesting features especially when compared with satellite data. In addition, in the area of the Aeolian islands, the system was able to map with great precision the submarine hydrothermal vents insisting in that area.

Introduction

The United Nations Sustainable Development Goals (SDG) 2030 agenda (https://sdgs.un.org/goals) highlighted the importance of studying the sea and in particular of the coastal areas since they are key to understanding climate change and human pressure on the environment.

At the same time the costs of current technologies aiming at studying the sea can be prohibitive or at least not within reach for most scientific research institutions in particular in developing countries, so that eventually the sea remains largely under-sampled both

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geographically and temporally. Models and theories developed using a limited set of data can be problematic, so that a different perspective needs to be introduced, where the actual measurement is done by volunteers.

This can take the form of 'citizen science', where laypeople are directly involved in the acquisition process while growing their awareness of the natural phenomena they are observing, or crowdsensing, where measurements take place in an 'opportunistic' fashion enrolling volunteers mostly as platform drivers.

Citizen science initiatives are rather common in many scientific fields [1] but only few can be tracked in the case of marine environmental monitoring [2]. This is strange considering that several authors such as for example [3] highlighted that this field is very promising and following [4] it is an efficient way to avoid researchers' bias to be possibly projected on the data.

In [5] it is reported the application of a solution that covers both citizen science and crowdsourcing approaches within the MaDCrow project while focussing on the area of the Gulf of Trieste (Northern Adriatic Sea).

In that case, the slightly different perspectives of citizen science and crowdsensing were eventually bridged by the availability of data and information, while, if necessary, they can be separated depending on the availability of volunteers to take part in person to the measurements or not. In this sense crowdsensing is to be preferred when the active participation of volunteers interfere with their routines, risking being demotivating.

Within MaDCrow it was important to avoid disturbing boat owners' holidays; in this sense the crowdsensing approach was preferable and recreational boats were used as carriers of the acquisition devices only.

Putting aside the differences, the outcomes of the two approaches are similar. In both cases, in fact, the main result is to improve geographic and temporal coverage of observations.

At the same time, both approaches also have the same weaknesses that are related essentially to sensor quality and deployment. In fact, since it is not possible to provide expensive top end sensors to multiple volunteers otherwise the costs of the initiative would rise exponentially and eventually contradict the inner sense of the invoked paradigm, it is necessary to revert to cheaper sensors with lower accuracy and precision.

To partially overcome these latter problems, redundancy of data and statistical methods can help converging to reasonable values that can be further corrected if high level reference observations are available [6].

Another problem is the deployment of the sensors. Operating them manually can be problematic because they can be damaged and there is no guarantee to obtain consistent measurements. The option we chose was to install them secured to the hull of the boat in order to have the sensors at a fixed depth of approximately 1 metre from the sea surface. Of course, this depth can vary depending on several external factors such as the conditions of the sea, the draught of a boat's hull, meteo conditions or boat's roll, pitch and yaw. All this can introduce outliers in the data that, in our experience, are easy to be recognized (See figure 8) and less relevant than when sensors are operated manually.

In addition, another problem that has been reported in [5] is the effect of the speed of the boat on measurements.

Notwithstanding all issues described, with the help of some simple statistics and careful installation, the system is able to produce a large amount of data that can be very helpful both to the scientific community and the general public.

In this work the system has been mounted on the Moana60 boat during a cruise in the Southern Tyrrhenian Sea, extending therefore the range of the surveyed area from coastal only, as done in the previous project, to the open sea. This allowed us to understand how it behaves in rather different environments, and to identify other possible limitations and weaknesses.

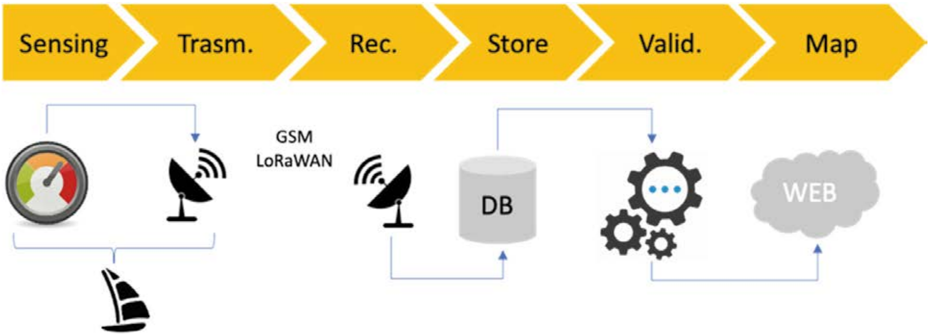

Figure 1 – The schematic workflow of the system developed to perform the study.

Materials and Methods

The system installed on the Moana 60 boat is a revised version of that used for the MaDCrow project.

As in figure 1 the schema of the system can be simplified in 6 blocks and namely:

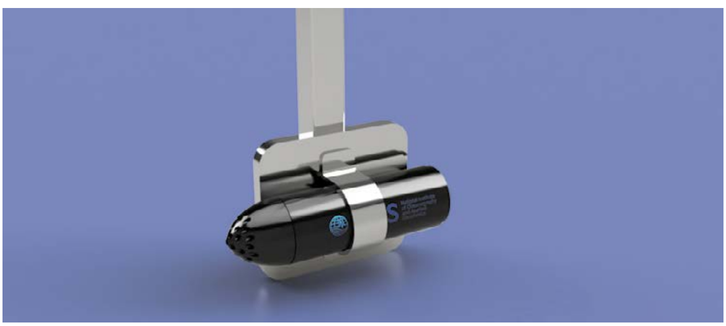

Figure 2 – The torpedo containing the sensors and how it is deployed on an aluminium arm fasted to the boat.

- ***The Sensing system.*** It is composed of the immersed container and sensors, while the acquisition electronics is located on the deck of the boat. In the previous experiences the former was not secured to the hull because it was intended to be used during short day trips in coastal areas only; in the case of this work, instead, since the system is required to be underwater during long periods of time and also in bad sea conditions, a torpedo containing the sensors was designed (figure 2) to be fastened to an aluminium arm that is secured to the hull of the boat. Sensors are located inside the torpedo in a revolver shaped structure (figure 3).

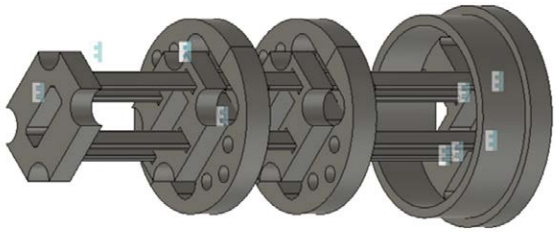

Figure 3 – The revolver shaped structure that hosts the actual sensors. The structure is then inserted into the torpedo of figure 2.

The selection of the sensors needed to achieve some characteristics defined in advance to address the crowdsourcing / Citizen Science paradigm: (i) be low-cost (less than a hundred euros per sensor), (ii) provide information about water characteristic to measure water quality, (iii) easy to use with same communication protocol with the embedded system, (iv) be small, robust and with the possibility of remain submerged in salt water for a long period of time, (v) provide easy calibration to users.

After a huge market research we individuated low-cost off-the-shelf devices produced by Atlas Scientific. They manufacture a kit with Temperature, pH, Salinity and Dissolved Oxygen probes and I2C boards. Every sensor makes use of a different operating principle (e.g.: pH probe uses the difference in concentration of hydrogen ions between a glass membrane to create a small amount of current proportional to it), an electronic board translates the sensor output to an isolated digital value with I2C communication. The advantage of this protocol is that all the sensors can be connected in parallel to the embedded system using a bus with 2 wires.

The selection of these sensors accomplish all the requirements mentioned before but other producers and technologies could also satisfy them. By the time we started this project it was hard to find another set of sensors that fulfil all the requirements, we found higher price solutions, closed proprietary systems or probes that are hard to integrate with the Cocal acquisition system. But in the future, with new technologies emerging, other models from other companies can replace Atlas Scientific sensors.

The system currently hosts Temperature, pH, Salinity (EC) and Dissolved Oxygen (DO) senses. As mentioned before, the pH sensor uses a difference in concentration of hydrogen ions between a glass membrane. Salinity instead uses an AC voltage applied to two electrodes, more free electrolytes the water contains more electrical conductivity is measured. On the other hand, galvanic dissolved oxygen uses a polymeric membrane to defuse oxygen molecules and produce a small amount of voltage in a cathode inside the sensor. The temperature sensor is a platinum RTD rod which has a linear correlation between resistance and temperature. Every probe is connected to a specific board through an SMA connector with I2C output. The sensors are calibrated at the -Oceanic Calibration and Metrology Center of OGS which is certified and using calibration liquids provided by the manufacturer.

The torpedo outlet allows the connecting wires to be fastened to the aluminium arm and to reach the deck where the acquisition and transmission circuits are located in a box (Figure 4) which is connected to the boat power supply. Other sensors can be used with small modifications of the revolver container. Each single measurement is georeferenced using the GPS embedded in the system. Previous experiences [5] suggest that the maximum speed for sensing pH values correctly is 13 km/h. When the vessel exceeds this speed measurements are flagged. The maximum speed allows to set the maximum sampling distance which is approx 200 metres since the sampling rate is 1 minute. Every half an hour we make a temperature correction to EC, pH and DO sensors and a conductivity correction to the DO sensor.

This low-cost system does not have a fault detection system or a redundant acquisition block, this would increase costs and consumption in the acquisition and transmission box, but we are studying how to solve this problem in the database side to provide a solution.

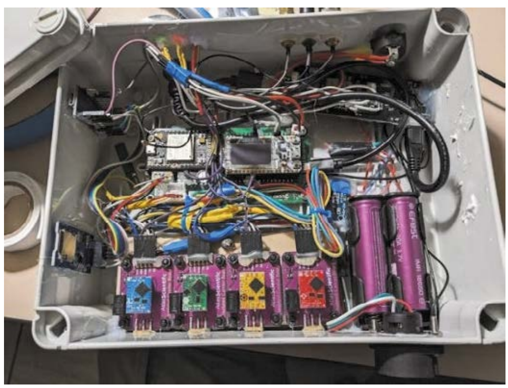

Figure 4 – The acquisition and transmission box. Measurements can be read in real time from the LCD display and are sent via mobile telephone and LoRa connectivity.

- *Transmission*. The transmission system is hosted in the box containing also the acquisition circuits. In this work, since the distance from the coast is supposed to be larger than in the previous experiences, together with standard GSM communication, the transmission system was also redesigned in order to use LoRAWAN technologies that allows it to cover longer distances. To store data, GSM creates an HTTP request to an influxDB database, while in the case of LoRa a LoRaWAN infrastructure is provided by The Things Network. Encrypted data are accessible by MQTT and a server agent called Telegraf.

  As indicated before measurements take place every minute, georeferenced and timestamped data is sent to the database using GSM and LoRa transmission, for a data backup we added an internal data logger using an SD card, this allows to have data stored in case of missing transmission.

- *Storage*. Once received the data are stored into an InfluxDB database running on a virtual machine that is regularly mirrored in a back-up site outside OGS. InfluxDB is a dedicated Internet of Things (IoT) time series database for real time data processing.
- *Validation*. Data is further subject to a validation process. Outliers and positioning errors are automatically identified, and the relative measurements Flagged in the database. It is not possible for the system to identify when a sensor is at fault, as mentioned before, out of range data is flagged. To avoid the above-mentioned issue of velocity biassed measurements all values corresponding to velocities above 13 km/h are also flagged as problematic and do not reach the production dataset. When reference measurements are available, for example when the boat passes close to an oceanographic buoy, the system corrects the values for the possible drifts of the sensors [6].
- *Visualization*. Data uploaded in the database can be visualized in real-time using the Grafana dashboard, from where it can be freely downloaded within an open data perspective. Data can be seen on a map and simple interactive statistics tools are also made available via the dedicated portal.

Moana60 Spirit of Community A.P.S is a non-profit organization born in 2020 (www.moana60.com). The association is named after the sailboat *Moana 60*, an eighteen-meter boat built in 1992 by Vittorio and Franco Malingri to participate in the Vendée Globe, a non-stop, solo round-the-world race. *Moana 60* has been engaged in numerous regattas around the world and later adapted to crewed sailing. Since 2020, with the establishment of the Moana 60 Spirit of Community association, it has been engaged in projects aimed at carrying out social, cultural, environmental and sustainable nautical tourism activities.

Figure 5 – Moana 60 Lab sailing boat.

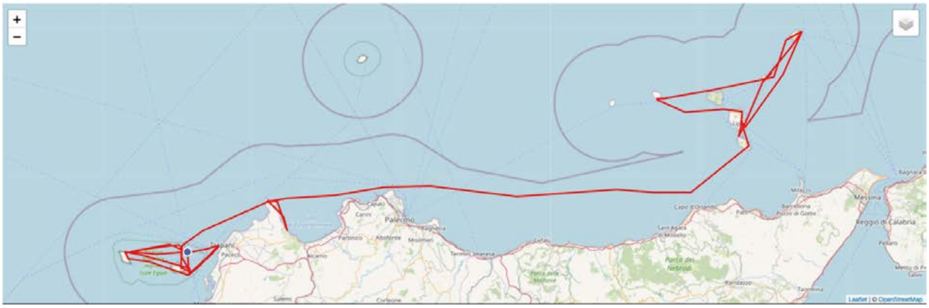

Figure 6 – The survey of the Moana 60 boat started on 28/7/2021 in the area of the Aeolian island and proceeded westward until the Aegadian islands were met on 17/8, after this, several short trips were made between Aegadian island and the city of Trapani. On august 30 the system was disassembled.

Results

After an initial phase of preparation that has been severely influenced and unfortunately reduced by the COVID pandemic outburst, we were able to focus on a research cruise in the sector of the Tyrrhenian Seas corresponding to the northern part of the Sicily Island starting from the Aeolian Island sailing westward all the way towards the Aegadian Islands.

The covered area comprised several stopovers in various ports, both commercial and touristic, populated areas and marine protected areas. An overall map of the survey can be seen in figure 6.

As a first result of the experience, it was possible to understand that the developed system can be applied also for long cruises at open seas and that the new deployment of structure is sufficiently robust. We experienced a couple of malfunctions of the electronics that were solved simply rebooting the system. In some areas the GSM coverage was very poor but also LoRaWAN coverage in that area was minimal, since satellite communication cannot be considered for the costs it can have, we have already developed a new version of the system with local storage of data that allows to avoid missing any measurement. Some outliers have been recorded and are visible in figure 8 (yellow boxes). It is to mention that, since the sensors were always active, these artefacts were mostly recorded while harboured and are probably related to human activities or maintenance.

Discussion

The Tyrrhenian basin is bounded by Corsica and Sardinia, on the west, Sicily on the south, and the Italian peninsula to the east and north. It is the result of the retreat of the Apennines-Calabrian subduction system that started in the Late Miocene and that lead to the back-arc extension and magmatism located in the basin [7]. The Tyrrhenian basin reaches 3600 m of depth while the bathymetry of the basin restricts circulation to two main channels:

the wide Sardinia Channel between Sardinia and Sicily and the Corsica channel to the north. The circulation through the Sardinia Channel is part of a complex exchange of water masses between the central basin of the Western Mediterranean, the Eastern Mediterranean, and the Tyrrhenian Sea. Although they tend to be modified in the basin and are not separated by clear high-gradient boundaries, the water masses of the Tyrrhenian Sea are commonly classified by their temperature, salinity and are named after their place of origin.

The water masses that are significant for this study are the Atlantic Water masses that can be found in the first 200 m from the surface and that originate through the Strait of Gibraltar [8]. Its hydrographic properties are modified by evaporation during its path along the North African coastline [8] and when in the Tyrrhenian sea follows its cyclonic circulation. Other water masses are very important in the area but cannot be sampled by the system we propose because generally can be found only at depths below 200 m.

Temperature recordings show an excellent match with sea surface temperature available from Copernicus Marine Service (Figure 7) while our system is able to provide much higher resolution both in time and space. It shows to be able to follow diurnal trends and to clearly highlight an increasing temperature trend from West to East that is coherent with satellite data and the literature

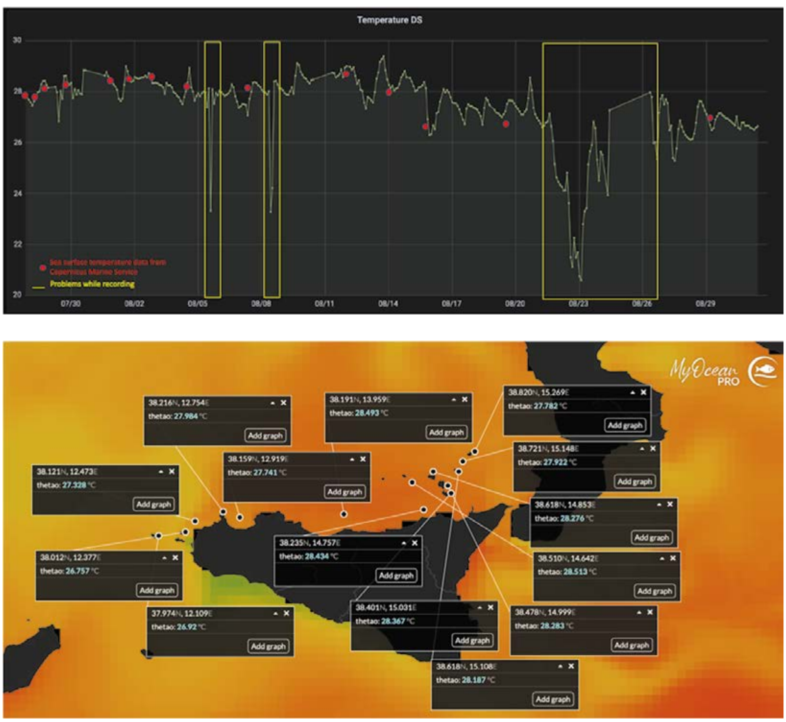

Figure 7 – (Upper) Graph of the temperature recorded by the system with comparison (Lower) with the sea surface temperature available from Copernicus Marine Service showing very good.

Another interesting result has been drawn in relation to hydrothermal vents in the Aeolian island area. There, the calc-alkaline volcanism and the connected hydrothermal systems resulting from the subduction of the African plate under the Eurasian plate, is active from 1 Ma up to now [9]. From the recordings, a clear decrease in pH and rise in temperature can be mapped that can be associated with the intense hydrothermal activity reported for example by [10].

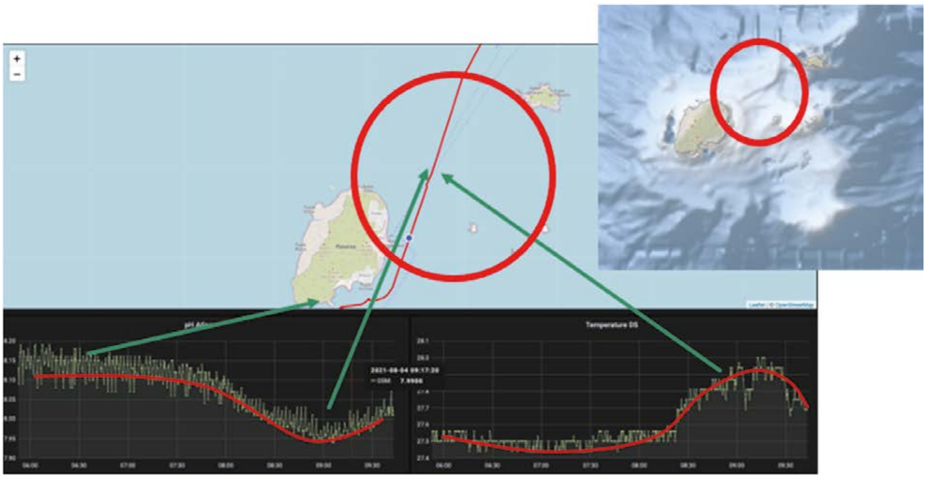

Figure 8 – (map on the left) highlights an area where pH values decrease (bottom left) while temperatures rise (bottom right); (upper map) bathymetry of the area.

Conclusions

In this work we demonstrated that a well-designed low-cost citizen science/crowdsensing system can effectively monitor the most common marine water quality parameters and that such a system can identify both regional trends and local anomalies, which makes it reasonably eligible to be used for environmental studies. In the example here reported the system was used during its recreational route to identify hydrothermal vents in the area of the Aeolian islands and demonstrated to be highly efficient and to provide data with very high resolution. At the same time the experience allowed us to focus on several issues such as the deployment of the acquisition system on private sailing boats, which of course is a very complicated topic since owners are very careful not to ruin the hulls of the vessels and generally do not want to be bothered by cumbersome instruments on deck. The developed solution allows to minimize the impact of the sensors and maximize the results that can be obtained. Starting in spring 2022, the boat will follow a route from Venice to Crete, passing through Croatia, Montenegro, Albania, and the Greek Islands in the Ionian Sea and will again use the system described here to collect an even larger dataset of marine measurements.

Acknowledgements

We thank the company Transpobank that within the MaDCrow project contributed to the design of the first version of the system.

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ASSESSMENT OF THE CHEMICAL QUALITY OF SEDIMENTS IN THE MARITIME PORT OF REUNION

- Concentrations in trace metals and natural geochemical backgrounds -

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Abstract – The analyzes carried out in the marine sediments sampled in the port and coastal areas of Reunion show, for certain metallic trace elements, significant variations in their contents and regular overruns of the regulatory thresholds for the management of dredged sediments.

Several studies show that the volcanic nature of Reunion Island is the cause of high concentrations of metals in the soil.

The objective of this study is to define, based on existing data, whether the observed exceedances of the management thresholds for dredged sediments (N1 and N2) are due to the geology of the island or to contributions of anthropogenic origin.

Introduction

The analyzes carried out on the marine sediments collected in the port and coastal areas of Réunion show, for certain metals, significant variations in their content and regular exceedances of the contamination levels set by the regulations governing the management of dredged sediments.

Several studies relating to the geochemical context of Réunion show naturally high metal contents due to the geology of the island. However, given the high variability of the results, the cause of the exceedances is not systematically due to the volcanic origin of the sediments.

The objective of this study is, on the basis of existing data, to define to what extent the observed exceedances of the dredged sediment management thresholds (N1 and N2) are due to the volcanic environment of the island or to anthropogenic inputs.

Methods

The analysis of the metal contents of sediments in Réunion is based on the following data:

- Port sediment quality monitoring network;
- sediment analyzes carried out by the Grand Port Maritime de La Réunion;
- measurement campaigns carried out under the implementation of the Water Framework Directive;

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- results of the CARTOMAR program [1];
- monitoring instituted by the water law decrees and impact studies produced in Reunion Island.

In order to avoid grain size variations, the measured concentrations were normalized with respect to an aluminum content of 5 % [2]:

$$[M]_{5\%\ d'Al} = [M]_{mesuré} \times \frac{5}{[Al_{\%}]_{mesuré}}$$

Port activities and different releases may generate heavy metal intakes were identified: careening area, stormwater discharges, refueling stations…

To determine the natural part and the anthropogenic part of exceeding the dredged sediment management thresholds, the measurement results were analyzed using two indices: the enrichment factor and the geo-accumulation index [3]:

Table 1 – Interpretation of sediment enrichment factor values.

Enrichment factor	Interpretation
< 1,5	Natural geological composition
1,5 à 3	Low enrichment
3 à 5	Moderate enrichment
> 5	Important enrichment

Table 2 – Interpretation of sediment geoaccumulation index.

Classe	Valeur	Intensité de la pollution
0	Igeo ≤ 0	Unpolluted
1	0 < Igeo ≤ 1	De non pollué à modérément pollué
2	1 < Igeo ≤ 2	Modérément pollué
3	2< Igeo ≤ 3	De modérément pollué à fortement pollué
4	3 < Igeo ≤ 4	Fortement pollué
5	4 < Igeo ≤ 5	De fortement pollué à extrêmement pollué
6	5 < Igeo	Extrêmement pollué

Finally, the concentrations of elements for which an anthropogenic contribution is suspected were correlated with the concentrations of contaminants of exclusively anthropogenic origin (TBT, DEHP...).

Results

Data from the Cartomar program [1] correspond to analyzes of sediments taken off the coast of Réunion. Considering that anthropogenic inputs are limited there, the results of these analyzes were used to define indicative levels of geochemical backgrounds for trace metals:

Table 3 – Indicative levels of geochemical backgrounds.

mg/kg	Cadmium	Mercure	Chrome	Cuivre	Nickel	Plomb	Zinc
Background (quartile 1)	**0,07**	**0,02**	**215,10**	**15,55**	**138,80**	**1,75**	**219,17**
N1	1,20	0,40	90,00	45,00	37,00	100,00	276,00
N2	2,40	0,80	180,00	90,00	74,00	200,00	552,00

According to the various analyzes of the results, the nickel and chromium concentrations are mainly of natural origin. The indicative levels of the geochemical background for these metals exceed the N2 levels, and they show no correlation with anthropogenic contaminants. Some peaks in concentrations may however be due to anthropogenic inputs.

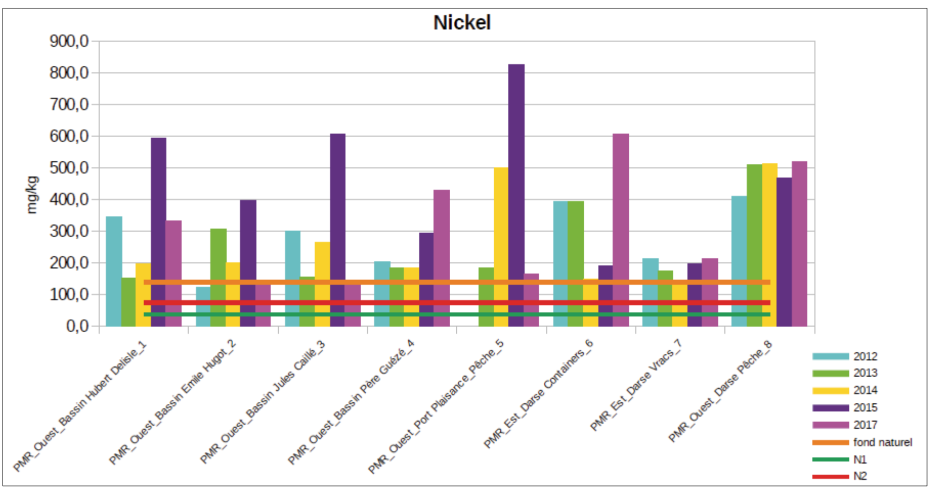

Figure 1 – Variation in nickel concentrations in the sediments of the maritime port of Reunion.

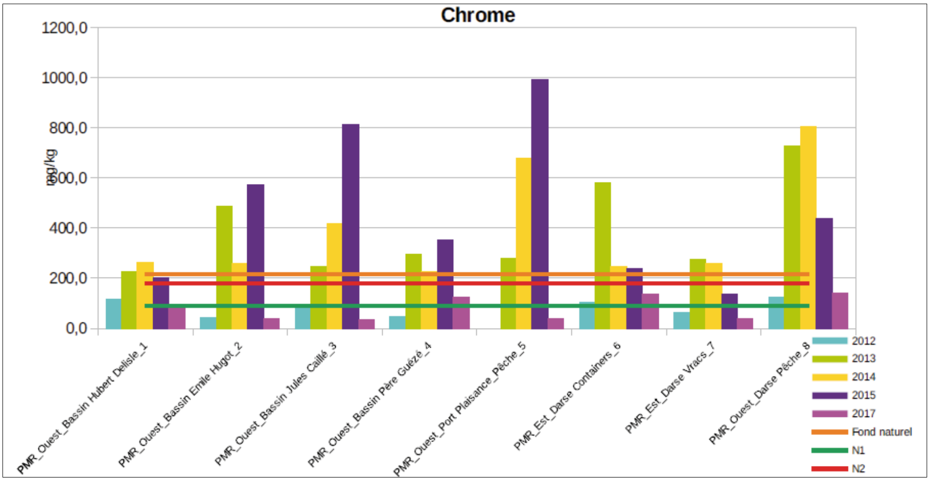

Figure 2 – Variation in chromium concentrations in the sediments of the maritime port of Reunion.

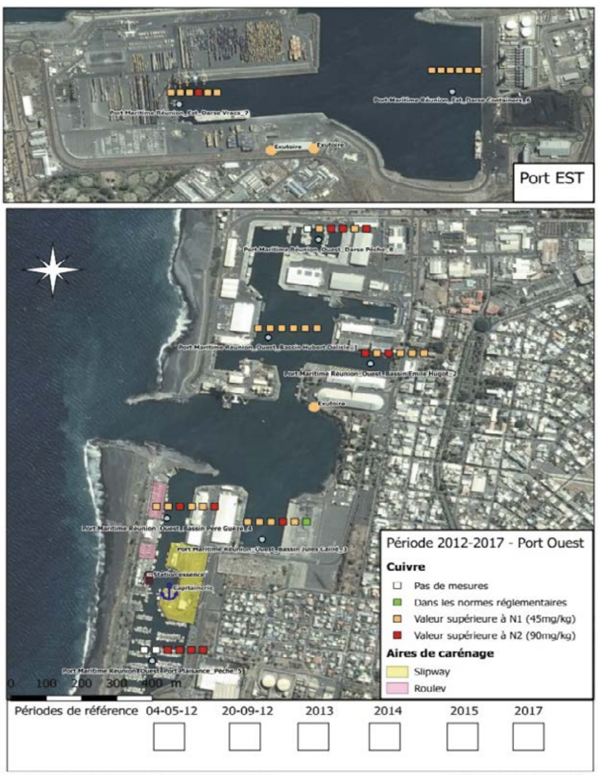

Figure 3 – Variation in copper concentrations in the sediments of the maritime port of Reunion.

For other metals (copper, lead, mercury, and zinc), the indicative levels of natural geochemicals are lower than level N1. The copper, mercury and lead concentrations only occasionally exceed the N1 or N2 levels. However, enrichment factors and iGeo indexes show significant anthropogenic inputs on the entire port area. In addition, the concentrations of these metals are positively correlated with certain anthropogenic contaminants.

Discussion

Regarding the quality of the dredged sediments, the high concentrations of nickel and copper may be due to anthropogenic inputs.

These high levels can lead to sediment management difficulties. An environmental diagnosis of the port area could make it possible to identify the origin of the anthropogenic inputs observed in the different basins and to target the actions to be implemented.

Acknowledgments

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ENVIRONMENTAL INVESTIGATIONS IN THE GULF OF POZZUOLI (NAPLES) IN RELATION TO PAHs CONTAMINATION

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Abstract – The Gulf of Pozzuoli (GoP) is a marginal sub-basin of the SE Tyrrhenian Sea, characterized by a strong anthropogenic impact, due to high population density and intense commercial and tourist traffic. Historically, the GoP is dedicated to the farming of bivalve mollusks, and mussels are constantly subject to chemical and microbiological monitoring to protect the health of consumers. Data from this monitoring show high levels of polycyclic aromatic hydrocarbons (PAHs) in mussels from the Lucrino area during the winter season. This study reports the activities carried out to investigate the levels and sources of contamination by PAHs in this area focusing also on the different PAH profiles and on the sea surface currents of the Gulf of Pozzuoli (Naples).

Introduction

The Gulf of Pozzuoli (GoP) is a marginal sub-basin of the south-eastern Tyrrhenian Sea (TYS), that is semi-enclosed by the Cape Miseno in the northern part of the GoP, and by the Island of Nisida in the southern part. This area is characterized by a strong anthropogenic impact, due to high population density and intense commercial and tourist traffic [Arienzo et al., 2017].

Historically, the GoP is dedicated to the farming of bivalve mollusks which are constantly subject to chemical and microbiological monitoring to protect the health of consumers. The monitoring plans detected high levels of polycyclic aromatic hydrocarbons (PAHs) in the mussels collected in the Lucrino area [Esposito et al., 2020].

PAHs are a large group of organic compounds comprised of two or more fused benzene rings arranged in various configurations. These compounds are widespread pollutants all over the world characterized by hydrophobicity, thermostability and highly persistent in the environment. PAHs have been determined to be highly toxic, mutagenic, carcinogenic, teratogenic, and immuno-toxic to various life forms.

The analysis on seasonality shows that PAH concentrations tend to be higher in specimens sampled in cold months (October–March), and this trend is statistically significant as reported in other studies [De Giovanni et al., 2022; Esposito et al., 2017].

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Figure 1 – Sampling station in the Gulf of Pozzuoli.

Literature studies suggest that contamination could be associated to the pyrolytic source of PAHs from the brownfield site of Bagnoli [Arienzo et al., 2017]. The area of Bagnoli located in the southern side of the GoP hosted important industrial plants (steel mills, cement factories, production of asbestos and fertilizers) until the end of the 20th century. These anthropogenic activities caused high levels of environmental pollutants and potentially hazardous chemicals, which affected the quality of marine ecosystems and, as a consequence, the human health. Toxic and potentially toxic metals, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) are the main contaminants found out in the soil and along the shoreline area [Ausili et al., 2020].

This study presents a set of multidisciplinary activities carried out to investigate the levels and sources of contamination by PAHs in the area of Lucrino basing on data from different scientific fields and samples including sediments, biological data and sea surface currents. In particular, data on the presence of PAHs in marine sediments along the entire coast of the GoP from Bagnoli to Baia, including the low depth areas next to the shoreline, are used as shown in Figure 1.

Sea surface current pattern during specific periods is obtained through oceanographic datafrom the modeling system ROMS (Regional Ocean Model System).

The GoP is in the Northwest area of the Gulf of Naples (GoN). The latter, inlet of the TYS, has a superficial circulation which is partly influenced by the large-scale circulation of the TYS. The circulation of the GoN is dominated by the complex interaction between factors acting on different spatial and temporal scales. Two classes of forcers have been identified that act on the pelvis and influence its circulation: remote and local [Gravili et al., 2001]. The main remote forcing is represented by the southern Tyrrhenian Sea, whose circulation can guide the movement of the water mass inside the GoN [Gravili et al., 2001]. Among the local factors, the main factor that gives the surface circulation of the Gulf the greatest spatial and temporal dynamic variability is wind stress [Moretti et al., 1976-1977; de Maio, 1985; Menna et al., 2007]. By virtue of this differentiation, it is possible to identify different circulation pattern developing in the GoN, each representative of the combination of specific seasonal and dynamic conditions [Cianelli et al., 2011].

Materials and Methods

Specimens of *Mytilus galloprovincialis* were collected from sea farms located along the coastal area of the GoP (Fig.1) The samples were transferred to the laboratory of Istituto Zooprofilattico Sperimentale del Mezzogiorno. Mollusks were washed with ultrapure water to remove any sludge or adhering particles, and the soft tissue of the shells was excised with a plastic knife. The PAHs analysis was performed by using a method developed in accordance with the criteria performance fixed by Regulation EU 836/2011; the method involves the saponification of the sample followed by extraction, purification and analysis by HPLC-FLD. The method allowed the quantification of four PAHs required by European legislation: benzo[a]anthracene (BaA), chrysene (CHR), benzo[b]fluoranthene (BbFA), benzo[a]pyrene (BaP). PAH concentrations and sum of BaA, CRY, BaP and BbFA (PAH4) were expressed in $\mu g\ kg^{-1}$ wet weight (ww). The limit of quantification (LOQ) of the method was 0.2 $\mu g\ kg^{-1}$ for each PAH analysed.

The sediment samples were collected and analysed from the Agenzia Regionale Protezione Ambientale della Campania (ARPAC). Twenty sampling stations were identified along the GoP coastline, from Bagnoli (Naples) to Baia (Bacoli), where surface sediment samples were taken. Additionally, three stations in correspondence of higher depth and at larger distance from the coastline were selected in the framework of Legislative Decree 152/06. Depth, geographical coordinates and distance from the coast are reported in Table 1.

Table 1 – Sampling stations along the Gulf of Pozzuoli.

Code	LAT. Nord	LONG. Est	depth (m)	distance from the coast (m)
CRIPA 1	40.80294	14.17031	5	245
CRIPA 2	40.80715	14.16724	6	340
CRIPA 3	40.80959	14.16558	5	280
CRIPA 4	40.80800	14.16101	13	690
CRIPA 5	40.80647	14.15863	20	955
CRIPA 6	40.81110	14.16373	5	195
CRIPA 7	40.81375	14.16012	4	254
CRIPA 8	40.81631	14.15332	5	170
CRIPA 9	40.81689	14.14820	8	170
CRIPA 10	40.81919	14.13053	5	148
CRIPA 11	40.81901	14.12191	7	167
CRIPA 12	40.81949	14.12158	5	155
CRIPA 13	40.81979	14.12167	3	188
CRIPA 14	40.82022	14.12107	3	230
CRIPA 15	40.82782	14.09512	3	370
CRIPA 16	40.82816	14.08759	5	229
IT15-LC036	40.80032	14.10533	70	3600
IT15-PZ	40.80907	14.12087	40	1200
IT15-BG039	40.80417	14.15083	55	1500

The extraction of PAHs from sediment samples was carried out with cyclohexane/acetone solution in ultrasonic bath. The organic solvent was removed by means a rotary evaporator and the dry residue was redissolved in n-hexane and injected in a GC-MS system. All samples were analyzed for the 16 US EPA priority PAHs.

To study the variability of surface currents, output of Regional Ocean Modeling System (ROMS) implemented by the marine and meteorological forecasting and observation center of the Dipartimento di Scienze e Tecnologie of the Università degli Studi di Napoli Parthenope, was used.

ROMS is a free surface hydrostatic model, widely used by the scientific community for a set of applications for the observation of surface sea currents, cryosphere dynamics, sediment transport, tidal cycles, biogeochemical cycles, and dispersion of pollutants. ROMS uses vertical terrain-following coordinates (they allow greater resolution in areas of main interest such as, for example, the thermocline or the friction layer on the bottom) and orthogonal curvilinear horizontally on a staggered Arakawa C calculation grid. Thanks to this characteristic, it was possible to increase the vertical resolution of the model in special interest areas as the layer depth where the mussel farms are located (between 5- and 25-meters depth). The ROMS circulation model presents a single computation domain with a spatial resolution of about 160 m and for 11 depth levels (from 0 to 10). In this study, only surface variables have been used

Results and Discussion

The results of the monitoring PAHs in mussels collected in the GoP, show a very different situation for the sampling stations.

In the Monte di Procida and Lake Fusaro plants, the concentrations of Benzo[a]pyrene (BaP) and other PAHs were almost always lower or slightly higher than the quantification limit, regardless of the withdrawal season. The area near the Island of Nisida may also be considered at low risk, since no non-compliant value was found and concentrations were generally low. On the contrary the areas of Punta Terone and Punta Pennata at the north end of the Gulf, showed appreciable concentrations of PAHs without exceeding the maximum limit (ML), except for three samples. It should be noted that these cases always occurred in the winter season (years 2016, 2019, 2020). Moving towards the center of the GoP, in the area of Lucrino, the concentrations of PAHs in mussels were significantly higher than those measured in the other sites. In particular, during the winter season, the levels of Bap and PAH4 exceeded the ML in 17 samples out of 100 and the average concentrations of Bap and PAH4 were 3.1 and 14.0 μg/kg, respectively.

The seasonal variability in the PAHs concentration in mussels has been previously related to the seasonal variability of the circulation in the Gulf of Naples [Perugini et al., 2007]. In particular, it has been suggested that the presence of a northward current outside the Gulf of Naples might favour the increase in PAH levels in mussels through remobilization, suspension and transport of contaminated sediments.

Previous studies on sediment samples in the GoP show that the concentrations of Σ16PAHs in all sediment samples from the Bagnoli brownfield site were above the limit values [Albanese et al., 2017]. In our study, the percentage distribution of PAHs in the GoP shows large variability according to the different sub-areas or stations. Figure 2 and 3 show the percentage of each congener in relation to the total PAHs, and for each station, percentages are show along concentric rings. Then, each ring represents the PAHs of a station, and the arc of each PAH is proportional to its percentage. This representation allows to define a pattern characteristic of the type of contamination of each station.

The results of sediment analysis demonstrate that the first eight stations (CRIPA stations from 1 to 8) located in the Bagnoli area have the same pattern of contamination (Fig. 2). On the other hand, CRPA stations from 10 to 14, located around the northern part of GoP and around the town of Pozzuoli, are characterized by different PAH percentages and distribution (Fig. 3).

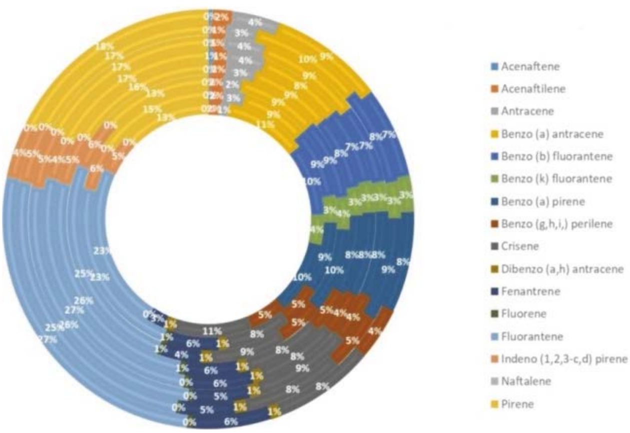

Figure 2 – Ring chart of the percentage distribution of PAHs in stations from CRIPA1 (innermost ring) to CRIPA8 (outermost ring).

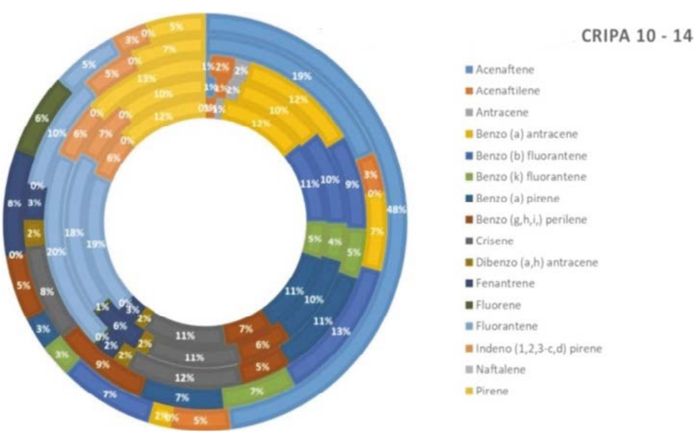

Figure 3 – Ring chart of the percentage distribution of PAHs in stations from CRIPA10 (innermost ring) to CRIPA14 (outermost ring).

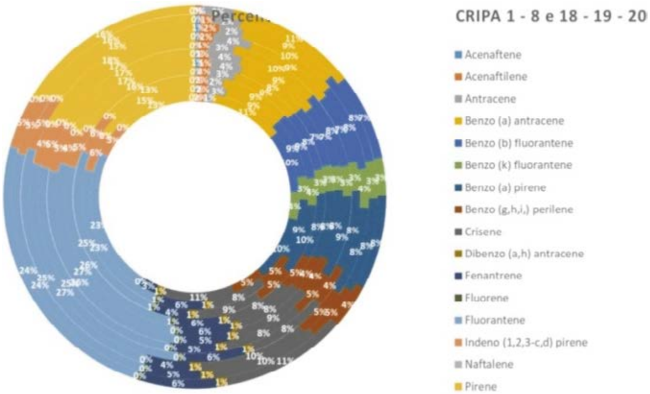

Figure 4 – Comparison ring chart between CRIPA 1-8 (innermost ring) and CRIPA 18-20 (outermost ring) stations.

Finally, the results, in terms of percentages of individual PAHs from sampling stations next to mussel farms in Lucrino area of GoP (CRIPA 18-19-20) show almost the same PAHs distribution of Bagnoli stations (Fig.4).

These similarities seem to suggest a common source of contamination between the sediments from the Bagnoli area and those collected close to the mussel farms.

To investigate the possible effect of marine currents on the transport of PAHs from the Bagnoli area to the Lucrino Mussels farms, the output of the ROMS have been analyzed for a limited number of events from 2018 to 2021. Figure 5 shows the surface current pattern that was modelled for three days before the biological sampling of 14th January 2021, when the concentration of PHAs (BaP:16,5 μg/kg; Σ16PAHs: 71,8 μg/kg) in the biological samples of Lucrino exceeded the law limits.

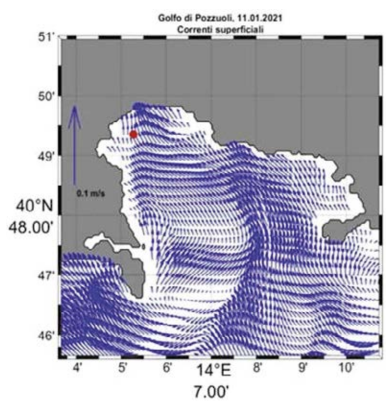

Figure 5 – Surface currents map 3 days before the exceeding event on 14th January 2021. The red dot indicates the position of the mussel farms, in the Lucrino area, where the samples were taken by the ASL.

The same scheme (Fig. 6) has been adopted when the concentration of PHAs in three mussel samples of Lucrino (BaP= 12.6- 14.2- 33.4 µg/kg; Σ4PAHs= 42.1- 49.3- 99.2 µg/kg) exceeded the law limits. The time step of three days was defined on the basis of the dimension of the GoP (average depth of about 60 m, maximum depth of 110 m, surface of 33 km^2) and of the mean surface currents (about 6 cm/s) modelled on hourly basis from 2019 to 2021.

To highlight the difference in the pattern of currents between events of exceeding the legal limits and events of not exceeding the legal limits, the map of the surface currents was made 3 days before a sampling in which no values of BaP above the LOQ were recorded. Figure 7 shows the map of the currents three days before 27th July 2021 when the concentration of PAHs in mussels was low (BaP= <0.2 µg/kg; Σ4PAHs= 2.7 µg/kg).

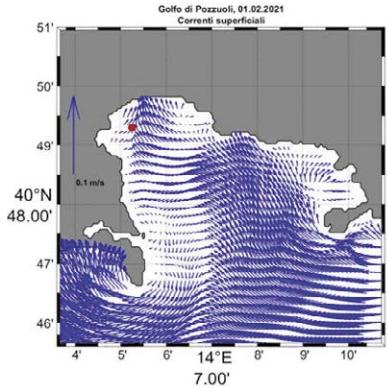

Figure 6 – Surface currents map 3 days before the event of exceeding legal limits on 04th February 2021. The red dot indicates the position of the mussel farms, in the Lucrino area, where the samples were taken by the ASL.

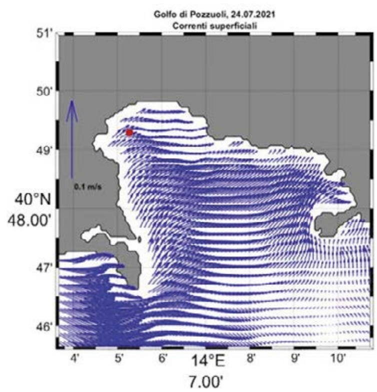

Figure 7 – Surface currents map 3 days before the event of not exceeding legal limits on 27th July 2021. The red dot indicates the position of the mussel farms, in the Lucrino area, where the samples were taken by the ASL.

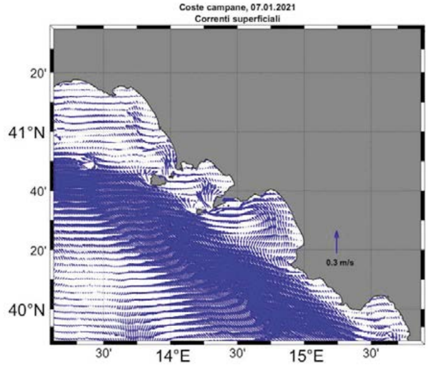

Figure 8 – Map of the Campania coasts with surface currents 7 days before the event of exceeding the legal limits of 14th January 2021.

As the surface circulation of the Gulf of Naples is influenced by the Tyrrhenian offshore currents, maps of the surface currents of the Campania coasts have been made for the same events. Sea surface currents during the winter period, when the concentration of PAHs in mussels is higher, are mainly directed from Bagnoli area to Lucrino mussel farm in the coastal area of the GoP. While the open sea area (i.e. the external limit of the GoP) is mainly influenced by a northward current [Iacono et al., 2013] of the area of the Tyrrhenian Sea focused on the Campania Coasts (Fig. 8).

During 27th July 2021 the sea surface currents in the Gop there are no direct currents from East to West, as for events in which the concentration of PAHs exceeded the law limits, but direct currents from West to East. This condition contributes to the non-accumulation of contaminants in the area where the mussel farms are located. In the same period the circulation of the Tyrrhenian Sea is characterized by a coastal current towards the south and outgoing from the Gulf of Naples (Fig. 9).

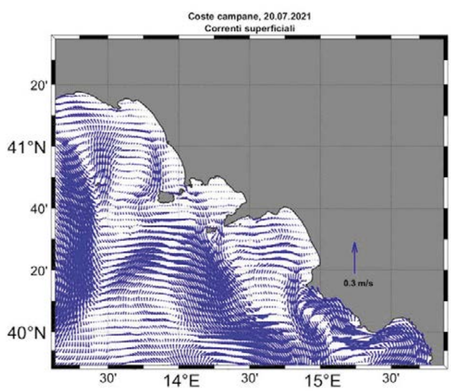

Figure 9 – Map of the Campania coasts with surface currents 7 days before the event of not exceeding the legal limits of 27th July 2021.

Accordingly, we suggest that during winter, when the East-West circulation pattern is more often verified, the contamination of mussels is favoured by the possible transport of PAHs from the Bagnoli area toward the Lucrino mussel farms. This is in agreement with previous studies, showing that the main remote forcing is represented by the southern Tyrrhenian Sea, whose circulation shows a large seasonal variability [Aulicino et al., 2016; Iacono et al., 2021] and that can guide the movement of the water mass inside the GoN [Gravili et al., 2001]. Here, when the dynamics of the surface currents depends on the offshore Tyrrhenian currents, two different scenarios can be outlined the Tyrrhenian current is directed towards the Northwest or towards the Southeast. In the first case an intense flow almost parallel to the Bocca Grande which enters the GoN from the Bocca Piccola and moves towards the island of Ischia. At the basin scale, when the current enters the GoN it creates a cyclonic structure while in the Gulf of Castellammare an anticyclonic structure is formed [Castagno et al., 2020, Aulicino et al., 2016].

According to the studies by de Ruggiero et al., 2020, in winter and autumn the main remote forcing is the offshore Tyrrhenian current directed towards the north-west. If the Tyrrhenian current moves south-east, the external part of the GoN has a cyclonic structure, while the Gulf of Naples and the Gulf of Castellammare have anticyclonic structures.

Conclusion

This study confirms the use of bivalve molluscs as good bioindicators to assess levels and trends of seawater contamination, due to their filter-feeding behaviour and sedentary life, that lead to the accumulation of pollutants in their tissues.

The results of sediment analysis seem to confirm the hypothesis that the contamination of molluscs raised in the Lucrino area of the GoP could be attributed to contaminated sediments of the Bagnoli area. Moreover, the seasonality of the phenomenon may be related to the recurrence of specific surface current patterns that could transport pollutants from the source area (Bagnoli) toward the mussel farms area of Lucrino.

Further efforts are necessary to confirm our hypothesis. In particular this study highlights the need for in situ current data along the water column, in order to test the model performances as well as the need for a higher frequency of the biological sampling.

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FIRST INVESTIGATION OF MICROPLASTIC POLLUTION IN MONASTIR SEA SURFACE WATER (EASTERN TUNISIA)

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Abstract – Microplastic pollution in the environment is a worldwide concern, as proven by the growing research interest on this issue. Almost all the world's oceans and seas are currently contaminated with microplastics, but the Mediterranean Sea has been identified as a target hotspot of the world, with a microplastic concentration four times that of the North Pacific Oceanic threats across the globe and is becoming a topic of intense study for environmental researchers. This study is the first to investigate the microplastic abundance and composition in Monastir Sea water. In the framework of COMMON MED-project, a sampling campaign was carried out during the month of December 2020 along two radials located in front of two tourist areas with different characteristics. The first radial (T1, Palmiers Beach) is distinguished by an intense tourist activity while the second radial (T2, Marina Beach) is characterized by the presence of a marina in addition to a high rate of urbanization. Microplastics were characterized by size, type and colour using a stereomicroscope and polymers were identified using Fourier Transformed Infrared (FT-IR) spectroscopy. The results showed that the particles of microplastic (MPs), ranging between 0,31 and 4,9 mm have larger average sizes in radial T2 than those of radial T1 (2.2 mm and 1.7 mm respectively). For all the stations surveyed, white particles were the most frequently observed colours, while the most dominant type was fragment. Of all the MPs identified, High Density Polyethylene (HDPE) and Polyethylene (PE) were predominant in the water. MPs concentrations varied between 62,095.032 and 260,979.12 items / km² with a density of 4 times greater in the T2 radial compared to the T1 radial, which shows the influence of urban and marina origin on plastic contamination among seaside tourist one. In addition, the greatest concentrations were recorded at the level of stations S2 and S5 which are closest to the coast (62,095.032 and 260,979.12 items / km² respectively). This preliminary study should be consolidated by other surveys in time in order to study the effect of the season and in the space with the objective of covering the whole area and mapping the distribution of microplastics in the bay of Monastir.

Key words: Microplastic monitoring, Sea water, Polymers, Monastir, Tunisia.

1. Introduction

Among the various pollutants known to contaminate the marine environment, microplastics (MPs) are considered to be next-generation contaminants. In fact, since the

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1950s, with the skyrocketing rise in the production and consumption of plastic products, the plastic flow into the environment appears to have been unstoppable and accelerating. Plastic products have become ubiquitous in everyday life. With an estimated global production of 368 million tons [36], 4.8–12.7 million tons of plastic are estimated to be released into the marine environment every year [26]. MPs pollution has become an increasing environmental issue, particularly in marine coastal systems [29].

The Mediterranean Sea was reported to host the highest concentrations of floating plastics in the world (Lebreton et al., 2012; Eriksen et al., 2014), and is therefore recognized as one of the most impacted regions in the world by plastic pollution [14; 41; 47; 5]. This situation has been exacerbated by the semi-closed nature of the Mediterranean Sea, its reduced surface waters flow, and the strong anthropization along its coasts and the resulting enormous quantities of litter ending up in the coastal environments [41].

Once in the aquatic environment, due to a combination of chemical, mechanical, and biological processes, plastic debris tends to break down into smaller micrometric debris, namely microplastics (MPs). Most commonly, MPs have been defined as synthetic organic polymer particles, less than 5 mm in size that may differ in shape, colour and chemical composition [18]. Microplastic pollution has been reported worldwide, in different environmental compartments, including water, soil, air, and biota [10;49]. Owing to their small size, MPs are potentially bioavailable to a wide range of organisms, having the potential to interact across trophic levels. Although during the last years there has been a virtual explosion of research on MPs pollution, especially in the Mediterranean Sea, there is a significant data gap for the Southern part of the basin [3; 30; 46].

Very few studies have been conducted in the central region of the east coast of Tunisia despite being subjected to pressures of various origins. This area is located on the south of Cap Bon that forms the southern tip of the Strait of Sicily boarded by the Gulf of Gabes in the south. It is therefore an intermediate zone between low salinity and relatively cold waters in the North and high salinity and relatively warm waters in the south. Depending on the seasons and the daily weather conditions, marine dynamics are moreor less intense with a varying intrusion of the Atlantic water vein [2; 47; 5]. The bay of Monastir, located within this region, constitutes an area of major interest due to its high coastal population density [43]. It is a very important economic activity zone (industry, fishing, aquaculture, tourism …) that have created very strong pressures on the marine environment of this area [8].

Along the Tunisian coasts, only a few studies conducted on the contamination of waters by MPs, namely two studies conducted in the south of Tunisia, precisely, the Gulf of Gabes [47; 5] and one conducted on the surface waters of the Bizerte lagoon [46]. Within our area, few preliminary studies have been conducted so far on MPs in the sediments and biota of the Bizerte lagoon [30;9], but no study has been conducted on the contamination of its waters by MPs contamination of its waters by MPs. The present work was conducted in this regard and aims to determine the composition, distribution, and abundance of MPs in the surface waters of Monastir Bay. These preliminary data should contribute to the identification of potential local sources of this pollution. The results of this work will therefore contribute to the implementation of a management plan to reduce MPs pollution in this area.

2. Materials and Methods

2.1. Study area and samples collection

Microplastics water samplings were conducted onboard of fishing vessel during Winter 2020 within the framework of COMMON project. A total of six stations have been sampled (table 1), along two radials located in front of two touristic coasts with different characteristics in the Monastir Bay. The first radial (T1, Palmiers Beach) is distinguished by an intense touristic activity while the second radial (T2, Marina Beach) is characterized by the presence of a marina in addition to a high rate of urbanization in the area around the beach (figure 1). In each radial, three stations located respectively at 1.5: 3 and 6 miles from the coast (Table 1).

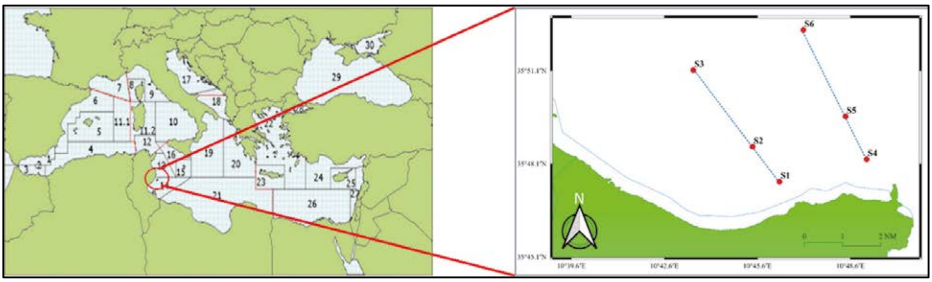

Figure 1 – Map showing the locations of the sampling stations in the Monastir Bay.

Table 1 – Sampling stations.

Transects	Sampling station	Longitude	Latitude
T1	Station 1	35°41’48	10°46’313
	Station 2	35°48’60	10°45’444
	Station 3	35°51’07	10°43’533
T2	Station 4	35°48’04	10°49’206
	Station 5	35°49’21	10°48’612
	Station 6	35°51’46	10°47’498

During the sampling campaign, a 200 µm Manta net (0.6 m width 0.2 m height) was towed at an average speed of 3 knots for 20 min for each sampling transect, yielding a total of 6 surface water samples. To gather all particles into the cod-end, the net was rinsed completely with seawater from the outside after each sampling operation. The samples were then transferred from the cod-end to 500 mL glass containers using a 0.3 mm mesh stainless steel sieve, fixed with 70 % ethanol, and transported to the INSTM laboratory for analysis.

2.2. Surface water samples analysis

The water samples were analyzed for their plastic content following the COMMON toolkit. For each sample a wet sieving is realized through a stacked arrangement of 5 mm, 1 mm, and 0.3 mm stainless steel mesh sieves. Accordingly, the litter items are classified in three size classes: small microlitter SML (300 µm – 1 mm), large microlitter LML (1 mm-5 mm), meso litter (5 mm-25 mm).

The presence of MPs was determined under a stereomicroscope (Olympus SZX7, 8x-56x) with attached digital camera. All potential particle items were manually sorted out from the sample and categorized by colour, shape (fragment, fiber, pellet, film and foam) and size. Then, each Polymer identification was carried out using a PerkinElmer Spectrum Two Fourier Transform Infrared (FT-IR) spectrometer. The number of MPs found in water samples was expressed both as items/km^2 where the area covered (km^2) was calculated by multiplying the width of the mouth of the net by the distance covered (km) during the tow.

2.3. Contamination Control

In order to avoid potential contamination during sample analysis, several precautions need to be taken account as recommended by scientific literature and guidelines [22; 7; 23; 31; 5]. All consumables were taken directly out from their packaging and all equipment was carefully rinsed with Milli-Q before and after use. Samples and equipment were covered with aluminium foil where possible. In addition, filter blanks were run in parallel to verify airborne contamination occurring during both water and fish sample processing. Particles or fibers detected on filter blanks were analyzed for colour and size and then compared to those found in the analyzed samples in order to avoid false results.

3. Results

3.1. Quality control

Analysis of the control membranes revealed the presence of fibers in different colors found in the samples collected during the Winter 2020 survey in different colors. Other microplastic typologies were never detected in the control samples. The final MPs content in the water samples was given subtracted from the blank values, to avoid overestimation.

3.2. Surface water sample

Throughout the first and the second radials, microplastic particles were found in all sampled stations (table 2). The recorded abundance at the level of the second transect is four times more important, it was around of 260979.12 items/km^2 than the first transect where the abundance was 62095.03 items/km^2.

As shown in the table below (table 2), for the first transect (T1), the abundance is ranged between 17098.63 (Station 1) and 26997.84 (Station 2). However, it ranged from 24298.05 (Station 4) to 166486.68 (Station 5) in transect 2. the greatest concentrations were recorded at the level of stations S2 and S5 which are closest to the coast (26997.84 and 166486.12 items / km^2 respectively).

Table 2 – Abundance of microplastics (items/km2) found in the samples collected along the two transects (T1 and T2) during the winter Campaign 2020 in the Monastir Bay.

Transects	Abundance (items/ km^2)	Stations	Abundance (items/ km^2)
T1	62095.03	S1	17098.63
		S2	26997.84
		S3	17998.56
T2	260979.12	S4	24298.05
		S5	166486.68
		S6	70194.38

All identified particles were categorized based on their shapes, colours, size class and polymer types.

Collected microplastic particles size ranged from 0.3 to 4.9 mm. According to COMMON protocol, items were categorized into three classes: Mesolitter (5 mm-25 mm); Large Microlitter LML (1mm-5mm) and Small Microlitter SML (300 µm – 1 mm). The Large Microlitter LML are the most abundant where the percentage is 75.34 % along T1 and 94.17 % along T2.

The sizes of the particles identified range from 0.31- 4.7 mm in transect T1 with an average of 1.71 mm and from 0.31-4.9 mm with an average of 2.1 mm in the transect 2 (figure 2).

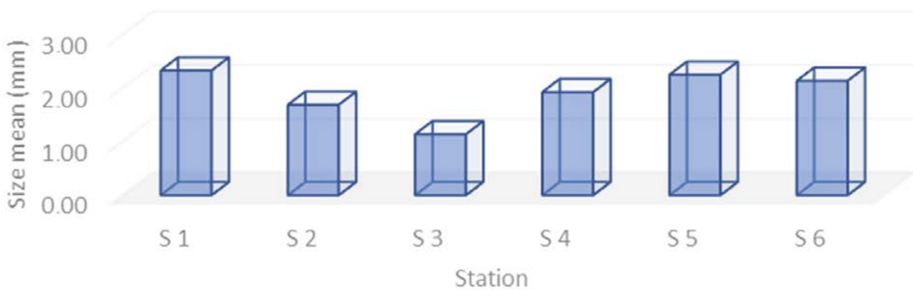

Figure 2 – Size means of particle extracted from water samples collected in the Monastir Bay per station.

Collected microplastics were sorted into five different categories: fragments, films and filaments. Fragments are dominant along both transects, with a percentage of 91.3 % 83.1 % followed by films with 8.69 % and 14.48 % for T1 and T2, respectively. The presence of filaments is recorded only in the stations of the second transect with a low percent of the order 1.18 % (Figure 3).

In this study, for all stations most of microplastics items were white opaque with a percentage of 51 %, of which 29 % in the first transect and 60.68 % in the second transect. While other colours (including, yellow, orange, blue, grey, brown), green, red and black items accounted on percentage for 32 %, 1.1 %, 11.1 and 3.9 % of total microplastics, respectively (Figure 3).

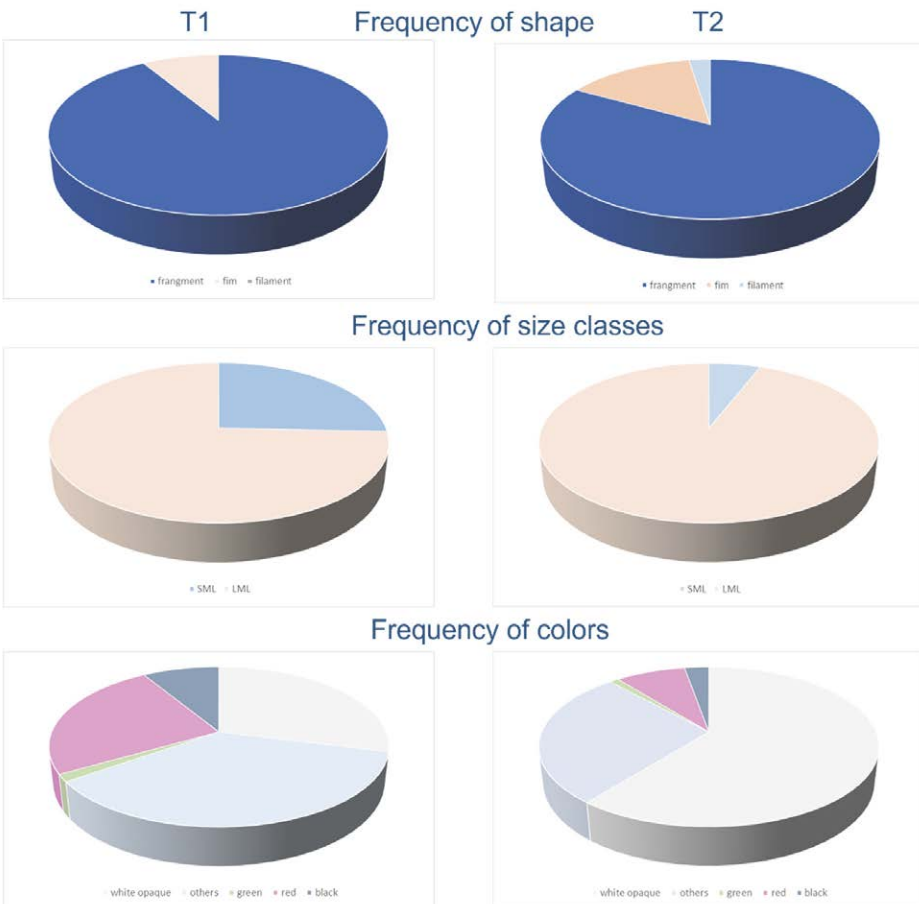

Figure 3 – Frequency (%) of particle shape, size classes and colors extracted from water samples collected in the Monastir Bay along the two transects T1 et T2.

The chemical composition of sorted items was confirmed by FT-IR analysis. Throughout both transects, 07 different polymer typologies were identified. Polyethylene high density (PEHD) made up the majority of microplastics, with 43.47 % (T1) and 63.77 % (T2), respectively, followed by Polyethylene (PE) (39.13 and 16.66 % from samples of the first and second transect, respectively), Polypropylene (PP), with 13 % (T1) and 19.5 % (T2). Less frequent polymers included (<6 %), polystyrene (PS), polyvinyl alcohol (PVA), polyamides (PA), ethylene-vinyl acetate (EVA), Cellophane (figure 4).

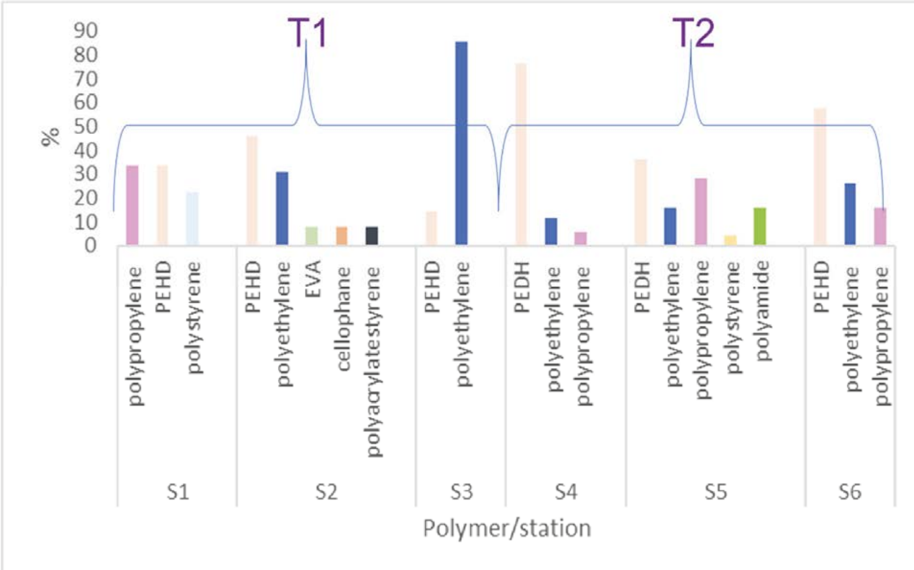

Figure 4 – Frequency (%) per station per transect of particle polymers extracted from water samples collected in the Monastir Bay along the two transects T1 et T2.

4. Discussion

Studies on MPs in seawater along the Tunisian coasts are scarce, as they are in other southern Mediterranean regions. In Tunisia, the quantification and characterization of microplastics in water is limited to a few studies: in 2020, [47] provided preliminary results on abundance in the Gulf of Gabes. Furthermore, a study published in the same year, conducted to define the effects of environmental factors on the distribution and abundance of microplastics in the waters of the Bizerte lagoon [46]. Recently, a study that aims to conduct a characterization of the level of pollution by microplastics in the Gulf of Gabes [5]. Here we provide for the first time the investigation of microplastic abundance and composition in Monastir Bay Sea water. Our study area, constitutes an area of major interest due to its high coastal population density [43]. It is a very important economic activity zone (industry, fishing, aquaculture, tourism …) that have created very strong pressures on the marine environment of this bay [8].

The results of this study showed a significant presence of microplastics in all surface water samples along both radials with an abundance of 62095.03 items/km^2 at T1 and a 4-time higher concentration at T2, around 260979.12 items/km^2. Several factors can explain the high concentrations of microplastics observed along the study area. Among these, plastic pollution sources most likely play a major role, given that the city of Monastir is highly anthropized, with several urban, industrial, aquaculture and tourist coastal concentrations that can generate a lot of plastic litter that ends up in the sea.

The highest concentration is recorded at station 5, located 3miles from the Marina Monastir. During the sampling campaign we noted bad weather as well as the wind direction of NE during the sampling campaign can explain the fact that the concentrations of microplastics follow an upward gradient from coast to shore for both radials.

By reviewing the literature on studies conducted in the Mediterranean, we noted that several sampling methods are used, such as the mesh size, the sampling time, the unit of measurement, etc. [47; 5]. Overall, the abundance found in this study remains high compared to other concentrations found in the Mediterranean basin.

Table 3 – Microplastics abundance values found in surface waters from Mediterranean Sea.

Area	Abundance ±SD	References
NW Mediterranean	0.116 (0.892) items/m^2	[13]
Ligurian/Sardinin Sea	0.31±1.0 (4.83) items/m^2	[21]
Bay of Calvi (Corsica)	0.062 (0.688) items/m^2	[12]
W Mediterranean	0.135 (0.42) items/m^2	[20]
W Sardinia	0.15 (0.35) items/m^3	[15]
Ligurian Sea	0.103 (0.36) items/m^2	[34]
Ligurian Sea	21 000 – 578 000 items/km^2	[35]
NW Sardinia	0.17±0.32 (1.69) items/m^3	[33]
Central W Mediterranean	40 000 – 9 230 000 items/km^2	[41]
Coast of Turkey	16 339 – 520 213 items/km^2	[24]
Central and Western Mediterranean Sea	8 999 – 1 164 403 items/ km^2	[38]
Northern Ionian Sea (Greece)	0 – 1 610 000 items/km^2	[17]
Gulf of Lion	6 000 – 1 000 000 items/km^2	[39]
Southern Mediterranean/ Gulf of Gabes	25 471 – 111 821 items/km^2	[47]
Southern Mediterranean/ Bizerte lagoon	453.0 ± 335.2 items /m^3	[46]
Eastern Mediterranean Sea	0.12–0.72 items/m^3	[1]
South-Western Mediterranean Sea	1.01 $*10^5 \pm 3.8 *10^4$ items/km^2	[40]
Southern Mediterranean/ Gulf of Gabes	312 887 – 77 110 items/ km^2	[5]
Southern Mediterranean/ Monastir Bay	62 095.032- 260 979.12 items / km^2	Actual Study

Our findings identified fragment as the most predominant plastic particles in the water samples which is in agreement with several other works [25; 20; 38; 42; 5; 47; 44]. Some studies linked the predominance of fragments to the decomposition of larger plastic objects (secondary sources) than to primary inputs of MPs, such as MPs directly released from treated wastewater effluents [47; 5]. Color can be considered a good indicator of the residence time of plastic particles in the ocean and its degree of weathering as well [32]. More than 50 % of the microplastics particles collected during our campaign are opaque white in color and had fading hues, indicating that they have undergone various weathering processes over a long period of time.

In addition, the results of this study reveal the predominance of small particles, with an average size of 1.71 mm and 2.19 for the two transects T1 and T2 respectively. At the level of station 3, we recorded the smallest average size, it is of the order of 1.14 mm.

The size distribution of MPs may be related to their origin and could also reflect their degree of weathering. It has been suggested that the plastic weathering process and meteorological forcing contribute to breaking large marine plastic debris into smaller pieces, resulting in a decrease in size (Pan et al., 2019). Our results showed that along the first transect T1 a dominance of large particles in coastal stations (S1 and S2) while along T2 large particles are found in the open ocean (S6). This may infer that the particles in the first transect were of the same origin while the particles in the second transect were of different origin.

According to [16] the identification of plastic polymer types does not define the origin from which the plastic litter originates, but it does identify potential sources of plastic particles. During this study, seven types of microplastic polymers were identified (HDPE, PE, PP, PS, PVA, PA, EVA, Cellophane), allowing to deduce that the sources of plastic contamination in Monastir Bay are diverse. All these types of polymers are known to be derived from various packaging materials, consumer goods, fibers and textiles, automotive applications, building and construction, and medical applications (https://www.plasticseurope.org/). The majority of these applications can be observed along the coast of Monastir, in urban, industrial, tourist and aquaculture areas.

The prevalence of HDPE, PE and PP in the surface waters of the study area indicates the multiple uses of these types of polymers and confirms that they are the most used in the region [4]. In fact, it is well known that HDPE, PE and PP can be derived from various household plastic wastes such as crates, trays, bottles, caps food packaging, cans, bulk containers and various products used in personal care and cosmetics [11; 28; 48].

The present study assessed the density levels of microplastics in surface waters in Monastir Bay for the first time, which gave us an idea of the nature of the waste and the levels of microplastic pollution in this area.

5. Conclusion

This study reported a high level of microplastics in the surface water samples.

Given the multitude of pressures on the study area from anthropogenic, industrial, aquaculture, and severe fishing, further work is recommended to define the levels of plastic pollution in the area and the threat it poses to marine ecosystems and to establish effective management measures to address this emerging global threat.

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CHEMICAL COMPOSITION OF MICROPLASTICS FLOATING ON THE MEDITERRANEAN SEA SURFACE

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Abstract – The Mediterranean Sea is one of the most studied regions in the world in terms of microplastic (MP) pollution. With an estimated input of plastic of approximately 100 kt per year, it is considered as one of the largest hotspots of plastic litter accumulation in the world [1]. However, the observation of a consistent distribution and concentration pattern is difficult. Indeed, microplastic investigations in the Mediterranean Sea surface often concern localized areas. Moreover, the different studies are uneasy to compare due to the heterogeneity of the Mediterranean Sea environment and the variety of methodologies used. In addition, only a few studies have analysed the chemical composition of microplastics at the Mediterranean Sea surface. In this context, the main objective of the present study is to describe the chemical composition of MP collected in the surface waters of the Mediterranean Sea, as well as the size of the particles [2].
Our results pointed to a certain homogeneity at the Mediterranean Sea scale. The main polymers collected were polyethylene (PE) (67.3±2.4 %), polypropylene (20.8±2.1 %) and polystyrene (3.0±0.9 %). Nevertheless, discrepancies, confirmed by the literature, were observed at a mesoscale level. Thus, in the North Tyrrhenian Sea, the proportion of PE was significantly lower than the average value of the Mediterranean Sea (57.9±10.5 %). In congruence with the current state of knowledge, different hypotheses are proposed to explain these discrepancies: anthropic sources, rivers, horizontal and vertical distribution phenomena.

Introduction

The Mediterranean Sea is a semi-enclosed sea with densely populated coasts that concentrates miscellaneous intensive marine and terrestrial activities and receives water from important river catchments (e.g. Nile, Ebro, Rhône and Po). It is therefore no coincidence that it has been reported to be one of the largest hotspots of plastic litter accumulation in the world with an estimated input of plastic of approximately 100 kt per year [1], [3].

These plastic particles are composed of large proportions of microplastics (MP) ranging from millimetre-sized to micrometre-sized particles [4]. MP are found to be present

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in every studied Mediterranean shoreline and island from 18 coastal countries [5]. Despite an important spatial and temporal variability, highest microplastic concentrations are found to be near the more densely populated coastlines [6]. Statistical calculations have estimated that more than 75% of floating plastics reside in the 50 km near-shore waters [7]. Moreover, a segregation of plastic types with increasing distance to shore has been observed [6]. The detected plastic types are diverse but some are predominant on the sea surface because of their widespread use and their buoyancy: polyethylene (PE), frequent in food packaging (e.g. in films and bottle caps); polypropylene (PP), used as packaging material and plastic parts in various industries; polyamides (PA) and polystyrene (PS) [8].

Despite a growing number of papers, knowledge is still lacking to fully understand the distribution and concentration and chemical composition of MPs on the surface of the Mediterranean Sea [9]–[14]. Furthermore, the different studies are uneasy to compare because of the heterogeneity of the Mediterranean Sea environment (hydrodynamic features, seasonality) and the variety of methodologies used (e.g. sampling, microplastic extraction, analysis, sizes considered, concentration units) [10].

In this context, where a global vision at the scale of the Mediterranean Sea was missing, the Tara Ocean Foundation, a French non-profit organisation dedicated to the study of the world's oceans, carried out microplastic samplings for 5 months in 2014 across the entire Mediterranean Sea. This expedition thus made it possible to map various areas using the same methodologies.

This poster and proceeding are an excerpt from our work recently published in the Marine Pollution Bulletin journal [2]. This publication aimed to quantify (concentrations in mass and in number) and qualify (size and chemical nature) microplastic pollution at the surface of the Mediterranean Sea. Here, only the results concerning the chemical composition and sizes of the collected microplastics are presented.

Materials and Methods

Microplastic samples were collected in Mediterranean Sea waters during the Tara Mediterranean Expedition between May and November 2014 (Fig. 1). Using a 333µm-mesh size manta net (net opening: 16x60 cm), samplings were carried out in surface waters in 124 sites across the Mediterranean Sea.

In the laboratory, plastic debris were carefully separated from the other components (plankton, wood, etc.) under a dissecting microscope. Plastic particles were counted and measured using a ZooScan digital scanner at the Laboratoire d'Océanographie de Villefranche-sur-Mer (LOV, Villefranche-sur-Mer, France) [6]. Plastic samples were then transferred to the Ifremer LERPAC laboratory (France) to be weighed before chemical analysis. A total of 15,654 particles from 54 selected sites were wet sieved by size class (]5-2 mm],]2-1 mm],]1-0.5 mm],]0.5-0.315 mm]), sorted and transferred to 96-well microplates and named with a unique identifier at the Institut de Recherche Dupuy de Lôme (IRDL, Lorient, France). A statistical approach based on a random draw of particles was used to limit the amount of work required to analyse the MP by infrared spectroscopy (ATR-FTIR). The aim of this method was to analyse only a statistically representative proportion of the total population of microplastics collected [15]. MP spectra were acquired using an Attenuated Total Reflection Fourier Transform Infrared spectrometer (ATR-FTIR Vertex70v, Bruker). All spectra were recorded in absorbance mode in the 4000–600 cm^{-1} region with a resolution of 4 cm^{-1} and 16 scans. All the spectra were then identified using the POSEIDON (Plastic pOllutionS ExtractIon, DetectiOn and aNalysis) software [16] which was developed with R i386 3.1.2.

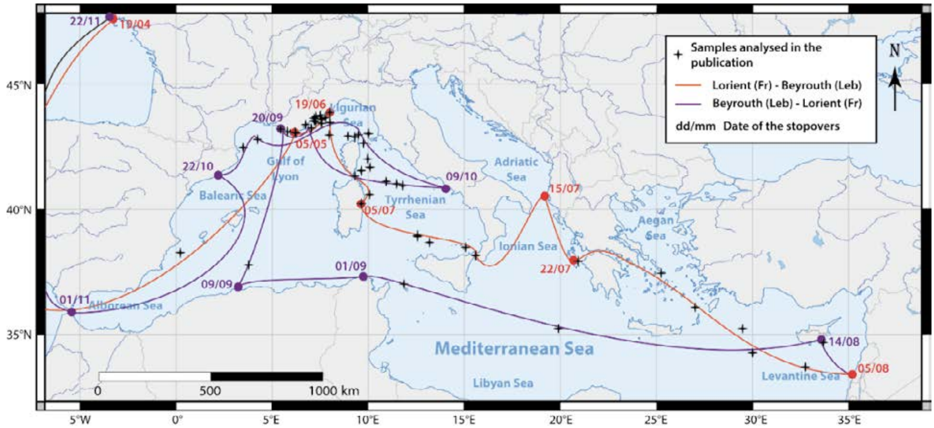

Figure 1 – Routes of the Tara schooner during the TARA Mediterranean Expedition in 2014.

Results

Overview of the microplastic pollution in the Mediterranean Sea and its sub-basins

At the Mediterranean scale, the collected particles were mainly PE (67.3 ± 2.4 %), PP (20.8 ± 2.1 %), and PS (3.0 ± 0.9 %) (Fig. 2.a.). The other identified polymers (i.e. polyethylene vinyl acetate, ethylene propylene rubber, poly(methyl methacrylate), polyamide, polystyrene, polyurethane, polyvinyl chloride, and polyethylene and polypropylene like) represented 6.0 ± 1.2 % of the total sampled particles. For the three sub-basins studied (Gulf of Lyon, Tyrrhenian Sea and Eastern Mediterranean basin) the distribution of polymer types was similar to the one observed at the Mediterranean Sea scale. Nevertheless, in the Tyrrhenian Sea, the PP rate was significantly higher than the average value of the Mediterranean Sea. In the Eastern Mediterranean basin, the data showed a significantly lower rate of the category “other polymers”.

The proportions of the different chemical natures highlighted in this study varied significantly according to the particle size range (Fig. 2.b). Thus, the PE content of the samples was 76.1 ± 7.0 % for particles between 2 and 5 mm, and fell to only 38.3 ± 6.4 % in the 315 to 500 μm particle size range. PS showed a similar tendency, with proportions of 7.7 ± 4.4 % to 0.5 ± 0.9 % respectively. Conversely, the PP content of the samples increased as the particle size range decreased. Indeed, PP represented 10.6 % of the particles for particles between 2 and 5 mm, and increased up to 49.1 ± 6.6 % in the particle size range from 315 to 500 μm.

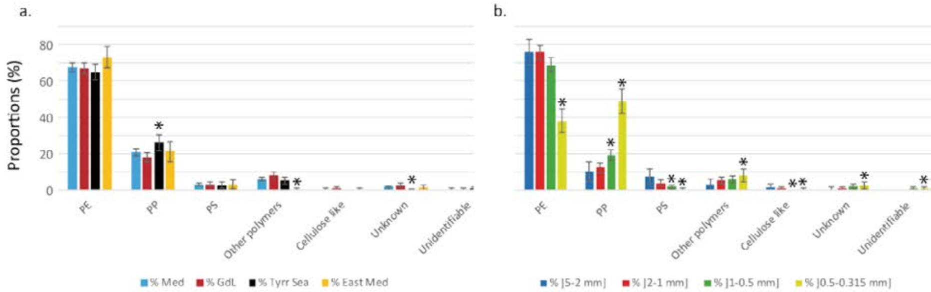

Figure 2 – Proportion of the chemical natures of the collected MP (±Interval of confidence). a. Proportions of the different chemical natures at the Mediterranean scale (Med) as well as for the three sub-basins studied: The Gulf of Lyon (GdL), the Tyrrhenian Sea (Tyrr Sea) and the eastern Mediterranean basin (East Med) (±Interval of confidence). The chemical composition varied little from one basin to another. Only the Tyrrhenian Sea had a significantly (*) higher PP content than the Mediterranean Sea. b. Proportions of the different chemical natures according to the size range of the collected particles (±Interval of confidence). Statistically significant variations (*) of the chemical nature were evidenced depending on the size range studied.

Discussion

Chemical composition of MP on the surface of the Mediterranean Sea
Comparison with previous work and limitations

Few studies have analysed more than a few hundred MP in the Mediterranean. Among them, Baini *et al.* (Tuscany, Italy) and Zeri *et al.* (Adriatic Sea) have shown chemical composition results very similar to those of our study [9], [17]: PE rates of about 66.0 ± 5.2% and 66.5 ± 2.6% respectively. On the contrary, other studies have shown different results, with notably lower PE rates: 41.2 ± 3.3 % in the south of the Adriatic Sea [18], 60.0 ± 1.9 % in the north of this sub-basin [12], 55.0 ± 1.7 % and 43.0 ± 4.6 % in the western basin of the Mediterranean Sea [11], [18]. The results of these two publications differ significantly from those of our publication. In contrast, two other studies have evidenced high percentages of PE in the range of 76 ± 3.9 to 79 ± 5.4 % on the southern coasts of the Mediterranean Sea [13], [14]. Nevertheless, these values are consistent with those found by the present study (73.1 ± 5.8 %) in the eastern Mediterranean Sea basin. Finally, it is interesting to note that the PE rate in the Mediterranean Sea is on average higher than in the Atlantic ocean (<60 %) [19].

However, the comparison of the data obtained between our study and these publications presents various limitations [2], [9], [11], [12], [17], [18]. The first is undoubtedly linked to a scale effect. Indeed, the smaller the sampling in terms of number of sampling points, the more sensitive it will be to local variations. Thus, it may be more prone to deviate from the average value for the Mediterranean Sea. However, the lack of data leads to the comparison of studies carried out at different spatial scales. The use of statistical calculations considering the number of particles analysed (i.e. calculation of the interval of confidence, proportion test) allows to partially compensate this bias of geographical scale.

Furthermore, the lack of standardized sampling methods is a hindrance when it comes to comparing MP studies with each other [10]. The influence of the net mesh size is assumed to be crucial in MP size measurements. For example, sampling in the Seine River with an 80 µm net yields on average 30 times more MP (in numbers) than sampling with a 333 µm net [20]. As it can differ between publications, discrepancies in MP concentrations, but also in PE proportions, could be induced by this parameter.

Chemical composition and size range

Our results evidenced an increase in the PP rate with decreasing particle size. A similar trend has been demonstrated in the Mediterranean Sea by Baini *et al.* [9], but also in plastic samples from different oceans [21]. In fact, this trend could be explained by a higher ageing sensitivity of PP than PE, enabling PP to fragment into small dimensions faster [22]. The PE/PP ratio therefore seems to be an interesting data to characterise plastic pollution and may be an indicator of a segregation phenomenon undergone by plastic pollution on the ocean surface.

Variations observed at smaller geographical scale: the case of the North Tyrrhenian Sea

If our study tends to highlight differences in polyethylene levels, the analysis of previous scientific publications also seems to show some similar trends.

In the North Tyrrhenian Sea, the PE and PP proportions were respectively abnormally low and high (Fig. 3) compared to other sampled areas in the North Mediterranean Sea (Fig. 3). This lower proportions of PE in the North Tyrrhenian Sea could imply the existence of local sources introducing MP pollution with low levels of PE (i.e. <65 % of PE). These MP can come from four main sources: rivers, cities, maritime traffic and sea currents [7], [23] (Fig. 3). There are currently no data for the Italian rivers flowing into the Tyrrhenian Sea. Based on data further away from this geographical framework, it appears that the composition of MP pollution in European rivers is generally poor in PE and rich in PP and PS. Indeed, PE proportions have been reported to be quite low in samples collected on the surface of lakes tributary of the Po and in the delta of the Rhône river (RR; Fig. 3) but also in north European rivers (without connection to the Mediterranean Sea) (<50 %) [1], [24], [25].

Furthermore, the relatively high average size of the MPs collected in the north of the Tyrrhenian Sea can possibly be interpreted as an indication of a source of microplastic relatively close to the sampling areas. Cities such as Rome, Naples or Livorno are other potential important sources of MP [7], [23]. However, data are very scarce in the case of Mediterranean cities and, more generally, in the case of this kind of proximal sources that therefore need to be better studied [11]. In other locations around the world, MP observed in cities (i.e. water and soils) are heterogeneous and have rather low PE contents [26]–[28].

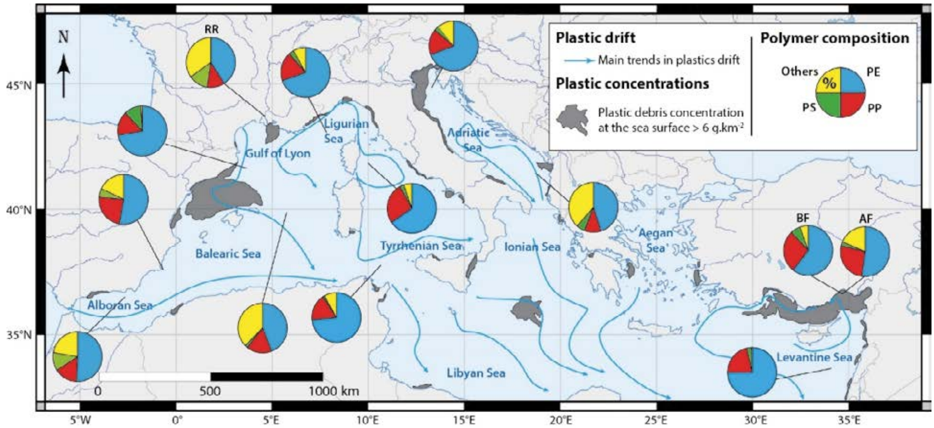

Figure 3 – Synthesis map of the sources, drift, concentration and composition of MP in the Mediterranean Sea. Data on concentrations and drifts of MP are based on numerical modelling [7]. The data on chemical types are taken from the current study and various other publications ([9], [11]–[14], [18], [29]). RR: Rhône river; BF: Before flooding; AF: After flooding.

Spectral variability of microplastics collected in the Mediterranean Sea: example of PE spectra

Many FTIR spectra of Tara samples presented additional bands, in particular between 1200 and 800 cm^{-1} (attributed to biofouling), and between 1800 and 1500 cm^{-1} (attributed to polymer weathering by oxidation). These bands are assumed to be induced by marine environment weathering [30]–[32]. These new bands can lead to errors when spectra of weathered polymers are compared in an automated way with reference databases of virgin polymers [32].

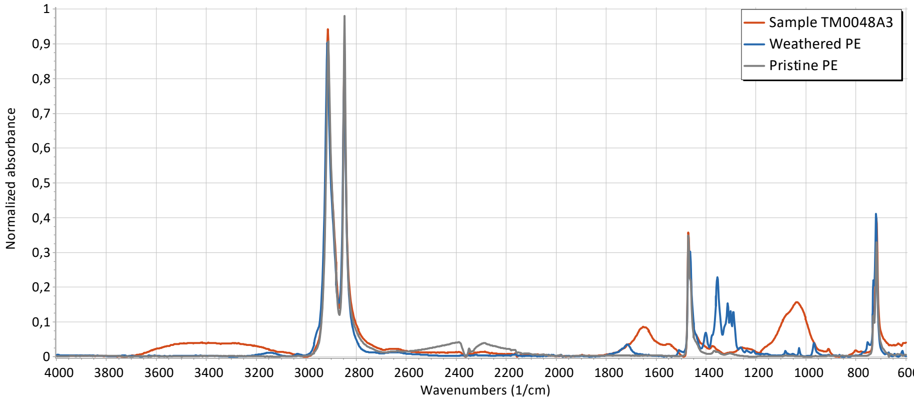

Figure 4 – Infrared spectra of pristine PE (gray), artificially UV-weathered PE (blue) and a PE microplastic from the Tara mission (TM0048A3) (orange). The band between 1100 cm^{-1} and 1045 cm^{-1} could reflect the presence of diatoms on the surface of TM0048A3.

For example, in the case of the TM0048A3 sample, a PE pellet, it was possible to observe on its surface areas of green colour (Fig. 5). SEM observation revealed the presence of diatoms (*Bacillariophyta*) that had largely colonised the anfractuosities (Fig. 5). Analysis of the FTIR spectrum showed that in addition to the band at 1045 cm^{-1}, a characteristic shoulder is visible at 1100-1060 cm^{-1}, reflecting the presence of diatom frustule silica (Fig. 5) [33]. This diatom fingerprint was visible on a very large number of PE spectra. Thus, from the point of view of FTIR spectra, diatoms could be a good marker of the plastisphere since the study of microalgae by FTIR is well established in the literature [33].

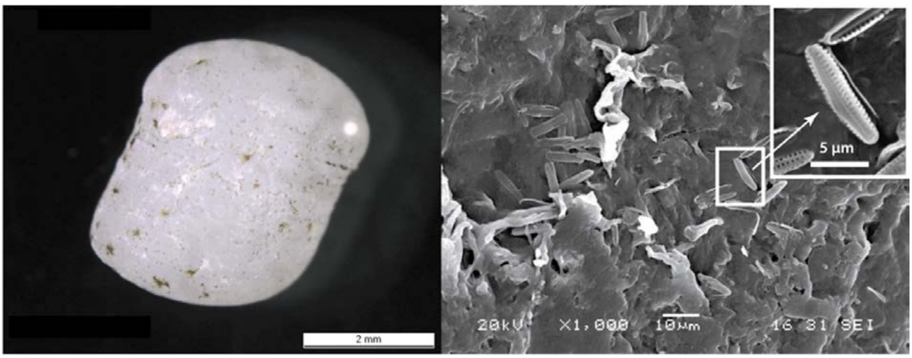

Figure 5 – SEM photograph of the surface of the sample TM0048A3. Diatoms are clearly visible.

Conclusion

The objective of this work was to evaluate the chemical nature of the microplastic pollution at the surface of the Mediterranean Sea. The samples were collected by manta net during the Tara Mediterranean expedition, carried out between June and November 2014. Microplastics from 54 sites were analysed by FTIR spectroscopy, and size, concentrations in mass and in number were measured. At the Mediterranean scale, the collected particles were mainly PE (67.3 ± 2.4 %), PP (20.8 ± 2.1 %), and PS (3.0 ± 0.9 %). The results point towards a certain homogeneity of the chemical nature of microplastics in the Mediterranean during the sampling period. However, differences, confirmed by the literature, were observed at a mesoscale level. New studies involving more geographically targeted samplings, temporal monitoring or numerical modelling are needed to confirm, invalidate or refine some of the hypotheses made here. Finally, further investigations are needed to explore the potential of infrared spectroscopy to study the fouling of microplastics at sea.

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APPLICATION OF STATISTICAL ANALYSIS TO ESTIMATE THE COASTAL HAZARD. A CASE STUDY IN LIGURIA REGION

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Abstract – Liguria Region is totally exposed to the action of the sea storms and too the natural evolution of the profile of the shoreline. The modification along the time of the shape of the shoreface is measured from the official administrative and technical offices of the Liguria Region and Italian Environmental Ministry, this information is available in shape format starting from 1944.
The phenomenon of coastal flood produces a direct damage represented by the loss of soil and an indirect damage correlated to the impact on tourism activity, social aspects, and damage to heritage buildings. In recent years another type of damage source must be considered, and this is the phenomenon of the increasing of the mean sea water level, known as Sea Level Rise (SLR). It is necessary to introduce this phenomenon in the hazard analysis and this is a direct and known consequence of the climate change.
Results from the hazard index encompass both the relative magnitude of erosion and/or coastal flooding, and the probability that these hazards may occur based on the distribution of the index using different scenarios. The paper analyzes a Liguria case study in which the effects of SLR is particularly critical in terms of heritage and economic and social activities hazard.

Introduction

The Ligurian coast is classified as "beach" or "rock", and, generally, area classified as beach erosion and/or sediment deposition is often frequent. Phenomenon not due to the natural circulation of the littoral currents, as natural non-maritime phenomena or as consequence of anthropogenic actions, for example new offshore works can modify the circulation of sediments. The principal phenomenon that may be analyzed is the increasing of the mean sea water level, known as Sea Level Rise (SLR), mainly forced by the climate change. In the Mediterranean area this phenomenon produces a negative effect like loss of soil on the coastal area where the main percentage of the population is present, and the principal economical and touristic activities and heritage elements are located.

According to the international literature [1], [2], [3], [4] a general coastal hazard index is calculated considering the following variables: shoreline type, habitats, relief, SLR, wind exposure and surge potential.

In the Liguria Region the data used to evaluate the exposure of the coast to wave actions are available in shape format and with indications of intensity and direction of the

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dominant sea states on the web site relevant to the official cartography. Another important data is the evaluation of the percentage of loss of soil knowing the value of the Run Up for various periods of return time of the marine storms. For the estimation of these values the Ligurian Region has adopted the Van der Meer equation in which it is introduced the value of slope as cumulative value relevant both submerged and emerged beach. All of these values are available along the coast of Ligurian Region for each longitudinal section defined in the Protection Plan for the Marine and Coastal Environment, [5].

It is necessary to highlight that the data and results reported in the PTAMC are binding instruments for the Liguria Region to be respected in every new project and /or intervention to refurbish the coastal area.

Results from the hazard index encompass both the relative magnitude of erosion and/or coastal flooding, and the probability that these hazards may occur based on the distribution of the index using different scenarios.

Materials and Methods

The coastal area environmental definition

Although the coastal environment represents in the common sense a territorial and landscape context that is quite clearly identifiable and historically defined, its spatial delimitation appears as a rather complex problem [6] and, in substance, inevitably subject to different nuances and variations depending on the point of view from which the definition is attempted.

The physical-environmental component is, in any case, the one most used to attempt to trace the borders to the coastal area: the hydrological and sedimentary cycles represent the processes that, in fact, determining the forms and morphogenesis of the coastal areas [7], [8]. These cycles are used to delimit this area, which tends to be configured as a territorial area that includes, physically, the coastal strip and the catchment areas at least of the first interrelation with the coastline. The land border of the coastal area therefore coincides with the line of the first coastal ridge. This definition, geographically quite intuitive and of relatively simple identification, also meets important interpretative doubts in those coastal stretches characterized by the coastal plains resulting from the sedimentation action of the most important watercourses.

In literature [1] the physical limits are used to delimit the coastal area, defining an area of sensitivity with respect to the maritime-coastal dynamics frequently used in the ICM, and an example is shown in Figure 1.

Compared to the problems of the SLR, we provide a definition of a coastal area not only related to the aspects linked to the landscape components or, more generally, to those determined by the uses of the soil, but rather to identify that strip of land in strictly environmental terms emerged that is more exposed to the weather-marine dynamics. In this sense, we propose to utilize a “sensible maritime coastal area” that takes few but fundamental physical-morphological factors:

- the slope, which makes it possible to distinguish between the high coast and the low coast and, within the low coast, the flat areas that we could define as the "first exposure coastal plain";

- the altimetry that, in addition to better defining the differentiation between high rocky / low coast, allows the identification of the areas most exposed to the sea waves action. These areas may even have a depth of some tens if not hundreds of meters in some cases (e.g. watercourse beds and / or areas with coastal elevation depression).

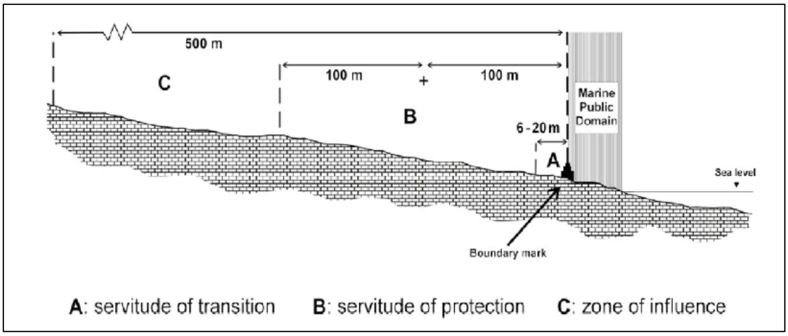

Figure 1 – Example of coastal area definition (from Belaguer, 2008).

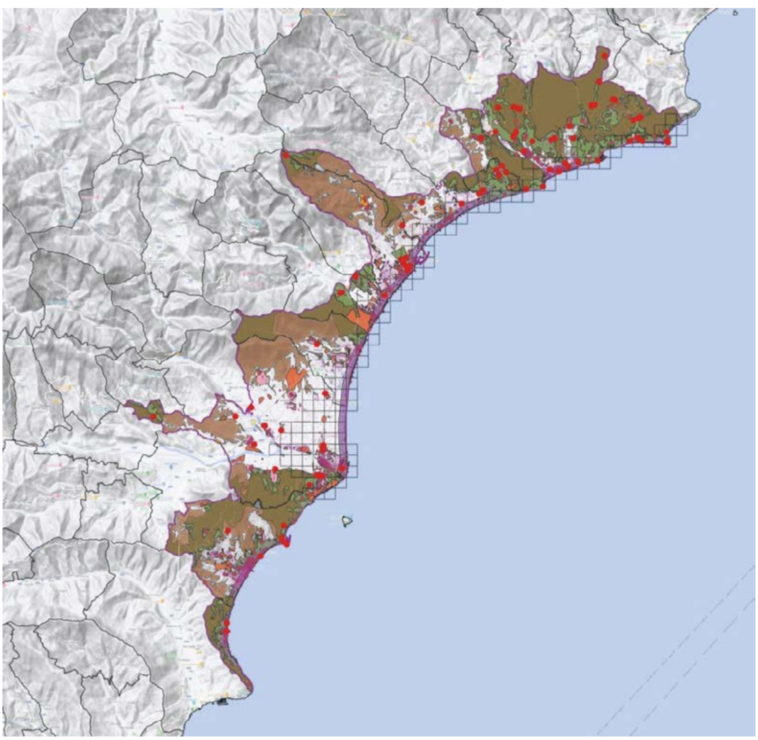

Figure 2 – The area of western Liguria under study.

The combination of these two morphological factors together with that of the coastal habitats allow to define a concept of exposed coastal plain that can be useful to introduce then the exposed elements of anthropic (and therefore patrimonial) nature that constitute the "functional" coastal area.

In this paper, the sensitive coastal maritime area is the result of the combination of flat areas (and therefore differentiated with respect to the stretches of rocky costs, where the cliff prevails) located below the 5 meter altitude. These are areas exposed to the risk of exposure, since climate change is progressively raising the average sea level and therefore, in the event of storm surges, the area of penetration of marine waters towards land (i.e. potential flooding) tends to increase.

In order to synthetically represent the anthropogenic (and therefore patrimonial) elements present in the coastal area (following a similar method already adopted by Koroglu [9]), we then tessellated the area under study with square cells oriented north-south of 500 meters on each side.

The settlement structure of coastal area

From the settlement point of view, coastal areas are often characterized by discontinuous uses in space and time: the maritime zone is increasingly characterized by fragmentation, porosity and discontinuity. On the other hand, the sea and the resources that can be traced in the coastal area are seen from an exploitation point of view in which the conditions external to the coastal territories themselves are increasingly preponderant and tend to reduce the "local production" processes to residual factors during the long historical duration. For these reasons the delimitation of the coastal strip under the settlement profile must considered, in addition to the physical morphologies, also the economies and the areas of influence generated by the functions that have been progressively localized there [10]. These economic conditions, in turn, influences the legal one, since the concentration of functions that are so different and with such significant impacts of human activity on an environment, that is somewhat delicate by its very nature, determines obvious problems of territorial governance.

Data utilized

The data utilized in the proposal analysis are available in the cartographic website of Liguria Region [4]. We have utilized the information relevant to the shape of the inland, the location of the principal line of communication utilized for the civil and public transport, the classification of civil structure according to their use public or private and, finally, the economic information relevant to the private enterprises. Important information utilized to estimate the hazard in each cell are extracted from different source areal or individual and relevant to the heritage elements.

Once the coastal maritime area was defined and the risk area delimited, the characteristics of the settlement were identified by calculating an index that expresses the patrimonial value present in each cell of the previously constructed grid.

In order to reach a synthetic value that expressed the territorial and patrimonial value of each cell, the presence (or non-presence) of some elements grouped into three main categories was analyzed: a) physical elements; b) specific elements that express functions or uses of the land of public interest and c) elements that represent a patrimonial value (normally linked to characteristics of landscape value recognized by planning tools).

The first category of variables includes: the presence of roads or linear infrastructures of territorial scale (example: railway lines); coastal defence works. The second category includes the historic centers, the areas of archaeological value, the areas recognized as areas of high landscape value. Finally, the third category includes punctual or public access services and private (such as rental points) and public services on a neighbourhood scale (essential for daily life).

Results

Coastal hazard

The risk is defined using the following relationship [11]:

$$R = H*V*E \qquad 1$$

in which H is the hazard correlated to the probability that the event occurs, V is the vulnerability of the system involved in this event and E is the value of the elements present in this system and exposed at this event.

Then it is necessary first to define the system in which you wish to estimate the different components of the risk equation, and then the typology of the event and its return time. Our analysis started from the approach of Kantamaneni [12], Benassai et al. [13] and Gallina [14], and we have divided the shore line in square grid with side of 500 m, to produce an estimation of vulnerability and exposure for each grid realized.

Approach proposed to estimate of coastal hazard

Coastal hazard refers to flooding and erosion caused by storms and sea level rise acting upon shorelines. In literature the most used methods for assessing coastal vulnerability are based on the Coastal Vulnerability Index (CVI) [15], which combines the changing susceptibility of the coastal system with its inherent response to a changing environment.

The variables usually taken into account to evaluate the CVI are mean elevation, geology, coastal landform, shoreline, wave height and tidal range. In the area under examination, we don't consider the tidal effect because it is not present and in general the effect of the erosion is not significant.

Obviously now it is important to develop a CVI to specifically assess the impacts induced by SLR, knowing the values for the future climate change scenario.

The habitats present along the coast can provide different level of coastal protection (erosion and coastal flood), the hazard index ranks the habitats based on differences in their morphology and observe ability to provide protection from erosion and flooding by dissipating wave energy and/or attenuating storm surge. Using a GIS it is possible to identify if some part of the coast has or not a "natural protection" and if this buffer overlap the land in which are present vulnerable elements.

Generally, wave exposure is calculated using a numerical model and the input data are the intensity and dominant direction of wind and the bathymetry of the region analyzed. In Liguria Region these data are available for part of the territory in shape format.

In literature are available technical descriptions of different methods to evaluate the extension of coastal flood area, both as the effect of run-up of sea waves and of the sea-level rise as direct consequence of the trend of climate change.

In this paper we apply a static approach, that it develops starting from the following the knowing variables as Run_Up for 50 year of return period and of structural protection of the coast.

The Run-Up values are available on the WebGIS system of Liguria Region and are official data [5]. For the values of the SLR we have adopted the maximum projection relevant to the condition described and correlated to the RCP 8.5, that represent the scenario with the increase of global sea mean surface temperature of 2 °C and the highest future pathway that will produce a radiative forcing of 8.5 W/m^2 in 2100. Models available in literature [16] indicates that for the Mediterranean Sea at 2100 the maximum values of SLR corresponding to the scenario of RCP8,5 is 0,8 meter, values that will be used in the following.

In the following Figure 3 we shown the part of cell submerged in presence of the actual Run Up indicated as red cells (4.00 meters) and the future scenario of SLR indicated as yellow cells (4.80 meters).

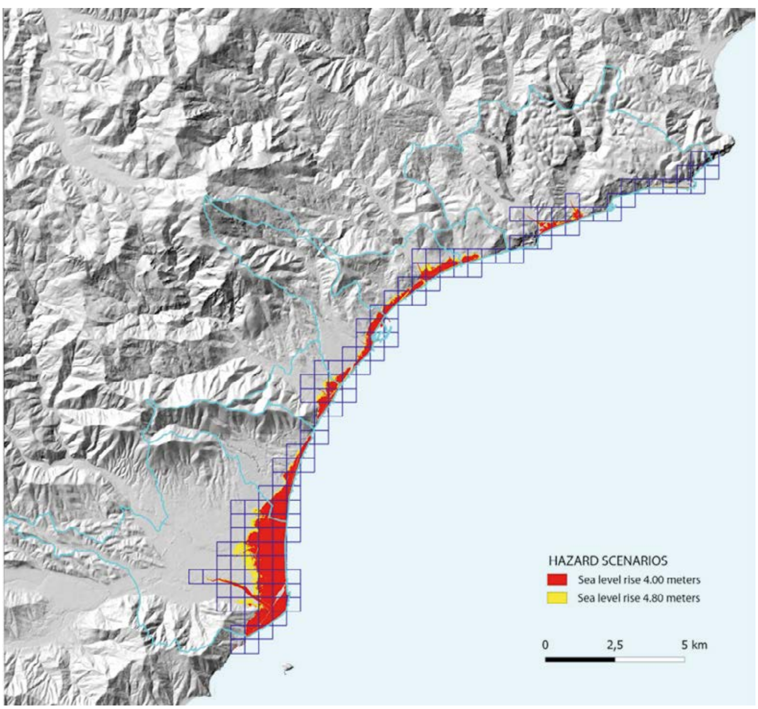

Figure 3 – Hazard scenarios in the study area.

We have assigned a different value of hazard and vulnerability at each cell according to the percentage of surface submerged from sea storm now and in the future scenario applying SLR value. The following step is to apply the sea-level rise and to evaluate, always using a GIS system, the loss of soil and the hazard for the different elements exposed on the part of the territory analyzed. The variables here proposed are indicated in the following Table 1:

Table 1 – Variables considered in the estimation of hazard.

Coefficient	Variable	Criterium	Vulnerability Index
a	Submerged area of cell	0 %	0
		50 %	1
		100 %	3
b	Erosion	Present	3
		Not present	0
c	Structure to protect the coast	Present	0
		Not present	3
d	Heritage elements	Present	3
		Not present	0
e	Communication way	Present	3
		Not present	0
f	Commercial structures	Present	3
		Not present	0
g	Private and public structures	Present	3
		Not present	0

Using this approach, the minimum value of vulnerability/hazard of the coast is 0 and the maximum value is 21, considering that we apply the following equation for our proposal CVI (pVI), relative to the values of Run Up for a return time of 50 years:

$$pCVI = a+b+c+d+e+f+g \qquad 2$$

Then we can classify the coast in the usual range from very low to very high pCVI, using a classical semaphore color, as indicated in the Table 2:

Table 2 – Vulnerability values.

Classification	Very low	Low	Mean	High	Very High
pCVI	< 4	4 -8	9- 12	13-18	>18

The same approach can be applied in the condition of presence of the maxim values of SLR in the area examined and the result can be indicated as future proposal CVI (fpCVI), relative to the scenario correlated to the Rappresentative Conventrate Pathway 8.5 (in the following RCP8.5) [17].

Discussion and conclusions

The vulnerability is represented in the territory submerged by the analyzed scenarios by the different elements as streets, civil and public buildings and enterprises present.

The area examined is a part of the Liguria Region, in West part (see Figure 2) and in Figure 3 it is shown the results for the actual situation, relevant to the estimation of the hazard along the coast examined and the future considering the effect of SLR.

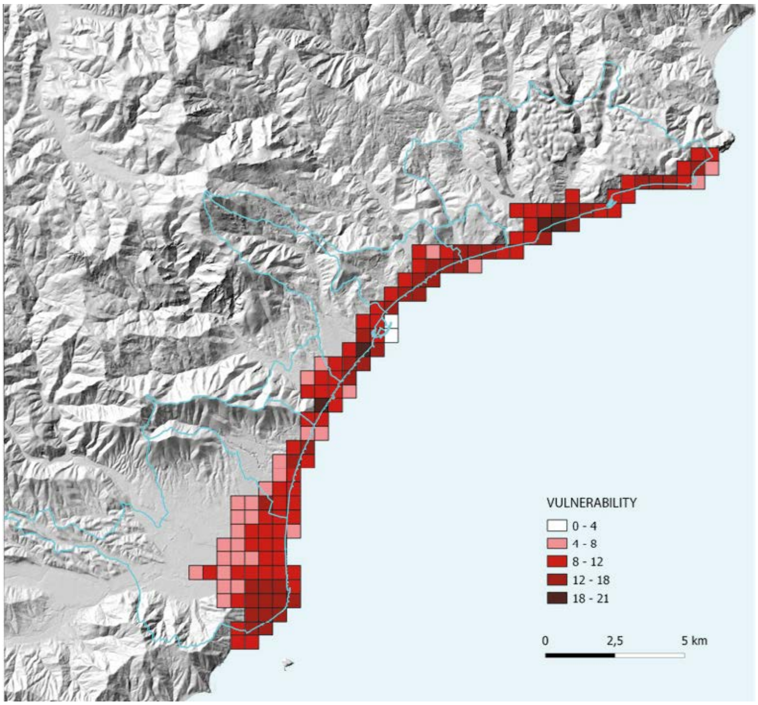

Figure 4 – Vulnerability in the 4.00 meters scenario.

By adopting the proposed static approach, the first result is the estimation of the loss of soil without taking into account the value of the elements exposed to the flood phenomenon as consequence of the SLR, for the scenario of 0.8 m of SLR the loss of soil is equivalent to 40 % of total coastal area considered in the 4.00 meters scenario. This value becomes 45 % in the 4.80 scenario.

What emerges from this first study is the impact that the rise of mean sea level caused by climate change (even in the most conservative assumptions), that is significant for the coastal area analyzed. In fact, Liguria, as well as numerous other regions of the Mediterranean area, has been affected in the past decades by an intense process of urbanization, which has concentrated not only a large amount of physical elements on the coast (roads, railways, buildings), but also an important component of the regional economy. On the other hand, the coastal area itself is the one where the highest density and frequency of elements of patrimonial value (linked above all to elements of historical-archaeological value and above all to coastal landscapes) is found. This concentration in the space of a few hundred meters from the coastline, determines a strong exposure of values with respect to the risk induced by coastal floods. The areas most at risk are those where urbanization has pushed to the seashore and, in order to prevent what could be significant economic losses, expensive adaptation programs will have to be set up in the coming years. Finally, we must consider how the most exposed element obviously consists of low and flat beaches. These constitute one of the fundamental bases that support the entire tourism value chain and the fact that they are extremely vulnerable leads to a more general vulnerability also to the general economy of coastal activity.

The development of the present work will have to consider the action of the wave motion run-up starting from the new mean sea water level modified by the expected SLR as a consequence of the climate change.

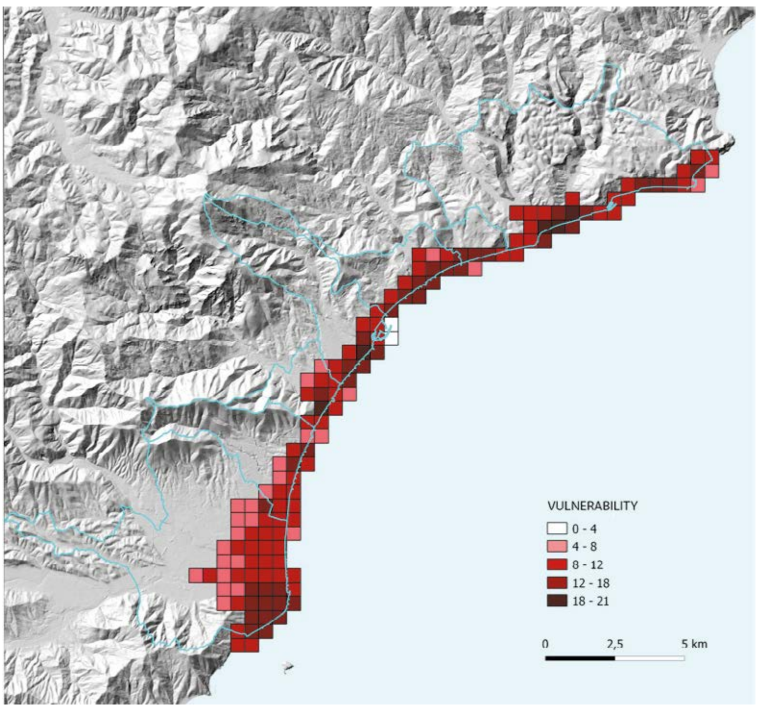

Figure 5 – Vulnerability in the 4.80 meters scenario.

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BIODIVERSITY SMART MONITORING GUIDED BY HISTORICAL ANALYSIS OF COASTAL EVOLUTION

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Abstract – Environmental monitoring is aimed to measure biological, chemical, and physical parameters that characterize the environmental components. Recently, smart environmental monitoring has gained much attention from the technical and scientific community as it is recognized as a crucial tool for gaining insight into the state of the environment when the protection of biodiversity and ecosystems must be pursued. Indeed, it is one of the best means to understand the dynamics that develop, and any changes induced by anthropic activities upon the various environmental components/factors.
This paper is aimed to describe the architecture of the smart environmental monitoring system to be installed within the frame of the project BEST (Addressing joint Agro and Aqua-Biodiversity pressures Enhancing SuSTainable Rural Development) funded by the INTERREG VA Greece-Italy 2014/2020 Program, as well as the data analysis needed to synthesize the collected data. Particular attention is paid to the criteria behind the scene: the selection of the locations of monitoring stations, as well as the identification of the instrumentation and type of sensors. The use of low-cost sensors while keeping the smart features of the system management (i.e. the minimization of the role of human presence at the sensing stations) is also investigated.
The analysis of the evolutionary dynamics of the coasts, starting from a robust definition of the initial state based on previous studies and new analyses and monitoring activities, has been firstly carried out to characterize the areas and to inform the monitoring strategy. The latter is aimed to get a real picture of biodiversity (i.e. habitats and species) and to relate its spatial and temporal evolution to environmental parameters. Then, measurement of physical parameters (e.g. air temperature, air and soil humidity, atmospheric pressure, wind direction and speed, precipitation, etc) has been foreseen.

Introduction

Biota has exhibited worldwide steep declines in the years, largely due to human activities, and is also expected to change in number and distribution as the impacts of climate change play out in coming years. To meet the global challenges in monitoring and conserving biodiversity, scientists and resource managers must evaluate changes in species composition,

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distribution, abundance, and response to anthropogenic impacts [8]. This has traditionally been performed via standard surveying [5], [6], even if observation remains limited, especially in areas that are physically challenging to access, or when the focus is night-time behaviour [11].

With recent advances in technology, reductions in cost, and increased interest in wildlife images and sounds as an outreach and education tool, the use of remote cameras, microphones and hydrophones has grown exponentially for the past 10–15 year [1], [9]. However, modern remote monitoring stations carry out the automatic recording of audio and video but not the automatic detection of the species, based on the manual study of these recordings. With the current state of the art, the use of machine learning, albeit limitedly widespread, has shown great skill in monitoring biodiversity. Machine learning workflows use a "training set" of data from which the algorithm "learns," a "validation set" used to determine when the learning has achieved a satisfactory level, and then a "testing set" which is used for the actual evaluation to estimate the algorithm's typical performance on unseen data [10].

Remote sensing has become increasingly widespread for analyzing the effects of environmental changes on biodiversity, integrating in situ local data on biodiversity with environmental data available globally. However, in situ sensing of biodiversity provides insight into the levels of genes, species, and some ecosystems that remain hidden from remote sensing. It can also generate urgently needed time series of biodiversity observations, complementing remote-sensing time series of measures such as land cover and sea surface temperature that now span several decades [2]. The result is an interaction between the global scale of conservation needs and the localized availability of ecological data [3].

The environmental monitoring to be implemented within the frame of BEST project is intended over the years to be smart (Smart Environmental Monitoring – SEM). Indeed, this approach has been identified as an effective tool to solve both the spatial and temporal resolution of standard methods (i.e. [4], [11]) to be used to identify structural and environmental issues and the best management strategies to conserve as well as to restore biodiversity.

This paper discusses a new community engagement paradigm for the development of low-cost and smart environmental monitoring system and presents the latest developments for the BEST project from a physical and technological perspective. We review and refine the key goals for inexpensive biodiversity monitoring and propose the core hardware and software systems as well as the monitoring strategy informed by the evolutive dynamics of the coasts.

Materials and Methods

Within the frame of the BEST project, a specific analysis of the evolutionary dynamics of the beaches belonging to an Adriatic coastal stretch and the implementation of a smart monitoring system, to be extended to a nearby enclosed basin, are foreseen. The project, as a whole, aims to protect the natural and cultural heritage and restore biodiversity and rural and coastal natural habitats. It involves local stakeholders in cross-border projects and joint pilot actions also through the use of new technologies with low environmental impact, with the final goal of improving the quality of life of the citizens of the regions concerned. The activities concern two main aspects, mutually correlated and analyzed in detail in the following, i.e. (i) monitoring of the areas, and (ii) analysis of the evolutive dynamics of the coasts.

The project has identified a series of pilot areas for the implementation of a monitoring network aimed at the protection and conservation of biodiversity. As part of the activities related to the development of a smart network, the preliminary recognition of existing knowledge aimed at defining the initial "zero point" reference framework plays an "information" role in the monitoring strategy. This activity concerned (i) the analysis of the biodiversity of habitats and species present in the pilot areas, concerning particularly the data available in the European network of NATURA 2000 sites, (ii) the identification of environmental factors, with particular regard to abiotic ones, to be monitored both in the terrestrial and in the aquatic environment, (iii) the definition and mapping of the areas and environments of greatest naturalistic importance in the pilot areas of the project.

The considered coastal areas fall within the Apulia Region, south Italy, respectively (i) the territory of the municipalities of Polignano a Mare, Monopoli, Fasano, and Ostuni on the Adriatic coast (hereinafter referred to as Area 1.1, Fig. 1), (ii) the territory included in the proposed perimeter for the establishment of the "Mar Piccolo" Regional Natural Park, Taranto (hereinafter referred to as Area 1.2, Fig. 1). A further area, where three natural parks are present, affected by the *Xylella fastidiosa* will be monitored.

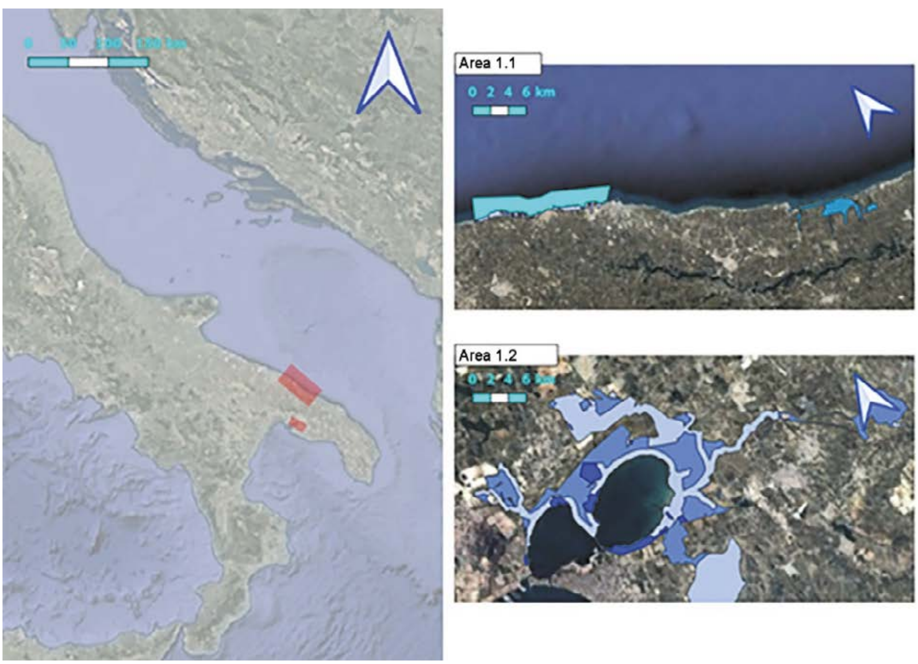

Figure 1 – Localization of the selected Areas 1.1 and 1.2. The shaded zones on the right panels refer to the Regional Parks in the areas.

The territory of Area 1.1 is located on the Adriatic coast of the Puglia Region (Figure 1) and includes (i) the Regional Natural Park called "Coastal Dunes from Torre Canne to Torre S. Leonardo" (hereinafter referred to simply as "Coastal Dunes"), and (ii) the Regional Natural Park called "Costa Ripagnola", located in the municipalities of Polignano a Mare and Monopoli. The coastal stretch extends almost parallel to the NW-SE direction for a length of approximately 35 km, and is mainly rocky, with few sandy beaches, and some pebbly beaches. The rocky coast becomes high in correspondence with the built-up area of the Municipality of Polignano a Mare. Along this stretch, there are evident signs of erosion at the foot of the cliff and some cave collapses have also been recorded, on which a large part of the historic center of Polignano stands. The sandy beaches are affected by erosion due to the strong anthropogenic pressure. There are numerous habitats of community and priority interest, according to NATURA 2000 network. There are also numerous species of community interest and priority established based on the Habitats Directive and the Birds Directive of the EU. Other features of the site concern the landscape, consisting of weak hilly undulations that degrade towards the coast, with a substratum of Cretaceous limestone. The thermo-xerophilic climate favors the presence of vegetation along the slopes. The quality and importance reside in the area of recent coastal dunes, with the presence of Mediterranean scrub vegetation. The pseudo-steppe areas are rich in orchids, including some endemic ones.

The territory of Area 1.2 is located in the Mar Piccolo of Taranto. It consists of a confined water basin subject to fluctuations in the average level and surrounded by a coastline that is substantially fixed over time. There are two regional natural parks in the area, i.e. the "Palude La Vela" Regional Nature Reserve and the "Mar Piccolo" Regional Nature Park. It is observed that Area 1.2 is not characterized by a real evolutionary dynamics of the coasts (substantially lacking a morphodynamic modification of the boundaries of the water basin), therefore the study essentially concerns the analysis of sea levels that can influence biodiversity in the area. Likewise Area 1.1, in this area there are numerous species of community interest and priority, according to NATURA 2000 network, the Habitats Directive and the Birds Directive of the European Union. The site is also characterized by coastal depressions with water stagnation and high halophilia. The substrate is mainly made up of Pleistocene clays and silts. It is also characterized by the presence of coastal humid depressions with halophilous vegetation, by salt flats, and by a watercourse belonging to the group of short but characteristic Ionian rivers.

To complete the monitoring network covered by the BEST project, additional stations have been identified in three natural parks in the territory included in the Area 2. The first park is "Bosco delle Pianelle" Regional Nature Reserve, a protected natural area belonging to the wider Site of Community Interest "Murgia di Sud-Est". The reserve was established to conserve natural biodiversity and promote sustainable economic and fruition activities from an environmental point of view. The second one is "Le Cesine" Nature Reserve has been recognized as a Special Protection Area due to the nesting of various animal species and as a Site of Community Interest thanks to the presence in the area of habitats and animal and plant species listed in the Habitat Directive and the Birds Directive. The area also represents an extraordinary training ground for knowledge and respect for nature. Finally, "Aquatina" Coastal Basin Naturalistic Oasis is a humid coastal area. The basin of brackish water covers an area of 45 ha and extends for 2 km in a rear dune position. Among the plant species, there are shrubs of the Mediterranean scrub, the salt steppe, and various species of spontaneous orchids. Among the animal species, there is an abundant and valuable ichthyofauna.

The implementation of the smart biodiversity monitoring network has been the driving force of the whole study. The network does not require the presence of operators in the field, whilst it requires a remote transmission system of the acquired data, a monitoring system for the proper functioning of the stations for the definition of activities of maintenance, and a security system against vandal attacks. In identifying the configuration of the measuring stations for biodiversity monitoring, an attempt was made to identify the most appropriate strategy to define quality models of the instrumentation that at the same time can comply with the requirement of being low-cost.

Specifically, an attempt was made to frame the problem of quality by referring to solid and established cornerstones, in the context of the experience linked to decades of industrial software development activities. The modern vision has therefore been integrated which favors the culture of service over that of the product, considered more in keeping with the objectives set. The quality characteristics taken as a reference to determine the quality profile of the entire monitoring network are:

- usability, as the ability of the product/service to be understood, used, and appreciated (think of the quality of the data);
- functionality, as the product/service's ability to meet user needs;
- reliability, both as availability in absolute terms of the product/service and as fault tolerance to ensure product availability, through maintenance;
- the temporal efficiency, both in terms of product/service duration, and the ability to respond promptly to requests or response time (for example, the speed of intervention of a maintenance service activated due to an error message sent by a certain acquisition system).

The needed features of the network motivated a careful choice of monitoring stations components, considering different possibilities, compared in particular with maintenance costs. No matter how smart, the network needs management activities that are expressed in "monitoring the monitoring network" and with "ordinary maintenance" (with a frequency of 1-3 months depending on the growing season) and "extraordinary maintenance".

The aforementioned strategy was applied at the level of the individual components, managing to define different configurations of measuring stations (e.g., low cost controller, high cost sensor, medium cost power supply). Thus, an attempt was made to give the entire monitoring network a "fair" cost, which balances the choice of any higher cost components with maintenance costs, without ever interfering with the aforementioned quality parameters. In the next section, the details of the network architecture are detailed.

Results and Discussion

The present work focuses on the preparatory phase of the design of the biodiversity monitoring network. The preliminary results of this first phase are then presented, starting from the formation of a cognitive framework based on previous knowledge of environmental parameters, the definition of sampling stations, areas, and detection points depending on the characteristics of the territory, the presence of any sensitive areas (Natura 2000 sites, wetlands, protected natural areas, etc..). At the same time, the results of the analysis of the evolutionary dynamics of the coasts are shown in the light of the new analyses and new measures, which, together with existing data, aim to inform the monitoring strategy.

To describe the system architecture of the monitoring network, the OSI (Open Systems Interconnection) model was used: the separation of the levels is not sharp, on the contrary, the layers overlap each other to create efficient, light, capable communication protocols, to support advanced energy-saving features and flexible to changes in the network itself.

A simplified scheme of the structure defined for the biodiversity monitoring network consists of the following basic components (Figure 2): (i) a group of spatially distributed sensors for monitoring biotic and abiotic parameters (for a total of 27 measuring points and 75 monitoring stations), (ii) a transmission infrastructure for transmitting data to a server, (iii) a server for collecting data (images, video, audio and data related to environmental parameters), (iv) a collection of computational resources with medium-high performances on the data collection server's end aimed at archiving data, verifying data consistency, managing station malfunctions, data correlation analyses, data elaboration, biodiversity monitoring.

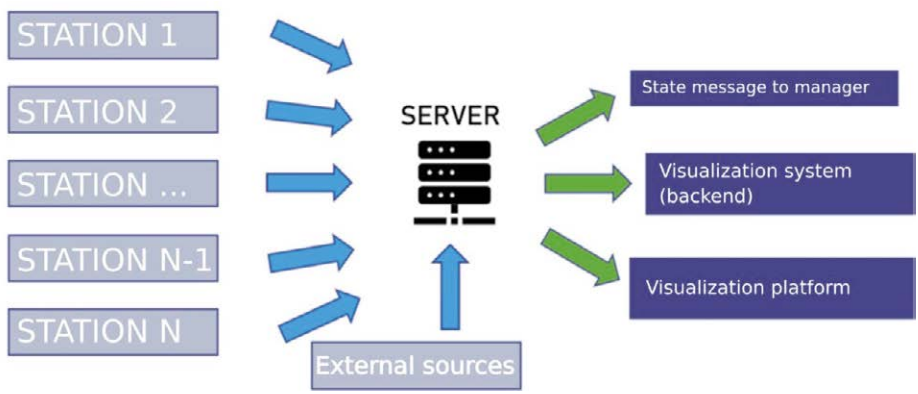

Figure 2 – System architecture of the smart ecosystem monitoring system.

The type of data depends on the type of station, function of the biotic or abiotic parameter under investigation, i.e. birds, mammals, insects, reptiles, flora, weather, water (Table 1).

The main and common characteristics of the planned components of each measuring point are described in Table 2.

The management of each subsystem is foreseen to allow the following minimal functions:

- integration of data flux management for data ingestion, addition, and configuration of new data source and related services;
- functionality and integrity control for the geospatial server through the resource and usage log;
- management of users and their access rights to services and resources;
- monitoring the proper functioning of the monitoring network and management of maintenance interventions.

Table 1 – Type of data associated with the type of station.

Type of station	Type of data
Birds monitoring	Images Audio track
Mammals monitoring	Images Audio track
Insects/reptiles monitoring	Images Numerical values
Flora	Images Numerical values
Weather	Numerical values
Underwater monitoring	Images
Underwater monitoring with water parameters measurement	Images Numerical values
Underwater monitoring with water parameters measurement and hydrophone	Images Numerical values Audio track

Table 2 – Characteristics of components for each measuring point.

Component	Characteristics
Power supply	photovoltaic panel with buffer battery, connection cable, solar charge controller, mounting brackets, installation box, assembly.
Data transmission	the measurement management system of one of the stations installed in the measurement point will act as an access point for all the others (installed in the same measurement point) consisting of an integrated circuit system, case with heat sink, gsm-gprs module, power supply for fans, sim subscription (flat rate, 2 years), assembly.
Installation	labor, equipment, any support structure compatible with the environment and with the relative constraints of the installation point (the structure must ensure the installation of the instruments up to a maximum height of 7.0 m, base and thickness adequate to support all the instruments anchored to it), possible foundation construction of the support structure.

For the analysis of biodiversity over time, which can be carried out as the final result of the monitoring through the network subject of this project, the algorithms must be reliable. Therefore, an experimental period is required during which the results obtained by the virtual operator (the algorithms) will be compared with those obtained by specialized operators.

To achieve this goal, monitoring protocol must be set up. It must be noted that pre-existing literature and legislation regarding biodiversity monitoring generally refer to in situ measurement techniques. The monitoring network discussed herein is smart, i.e. it will allow automated acquisition and cataloging of data which will then be further elaborated for providing useful information, comparable to what current legislation requires. In short, automated elaboration can be interpreted as the monitoring performed by a virtual operator.

Smart samplings through cameras/microphones/hydrophones are foreseen. All animals and vegetal species will be sampled through cameras (as will be sampled all animal species recognized through the use of microphones/hydrophones), taking special care of animals and vegetal species listed in the annexes to the Habitat Directive (Directive n.92/43/CEE) and the Birds Directive (Directive 79/409/CEE), especially noting non indigenous/alien invasive animal and vegetal species recognized by EASIN (European Alien Species Information Network).

As far as the environmental parameters are concerned, the temporal evolution of the monitored parameters will be crucial for the analysis of correlation with the results of the monitoring of biodiversity.

For the sampling of animal species (birds, mammals, reptiles, insects), algorithms will be implemented in order to identify, among all recorded video and audio on the server, samples that actually document the presence of animal species and a machine learning approach will be used to make the challenging attempt to define the type of animals so that they can be categorized. During the experimental phase for the system, results of unsupervised analysis of acquired data (obtained through algorithms) will be compared to those obtained in a standard way (through specialized biologists) with the goal of validating/improving/train the implemented algorithms.

For the sampling of vegetal species, long-term analysis of video footage is more effective to assess the variation of the specific composition (qualitative analysis) and variations in the extension of formations (quantitative analysis by employing well established parametric analysis, e.g. visible normalized difference vegetation index, vNDVI).

For the sampling of environmental, land and water parameters, temporal analysis will be useful for highlighting evolutionary trends and possibly relate criticality conditions for other analyzed biotic parameters.

All data can be compared to qualitative and quantitative indicators, which will allow to determine the presence of possible critical issues related to biodiversity conservation and, above all, the their temporal evolution. The system will thus represent a powerful tool aimed to support decision-makers.

The analysis of littoral dynamic evolution is aimed to inform the monitoring strategy of the areas by guiding their observation strategy.

First, a wind climate study has been carried out. The data from ERA5 database, recently developed by ECMWF (European Center for Medium-range Weather Forecast), have been used. In particular, 71 years (1950-2021) of observations have been considered, concerning the point located at: 41.00°N, 17.50 °E. According to the wind analysis, the wind rose reveals the existence of a prevailing wind sector (i.e. Mistral, NW – 345°N) from which the most intense and frequent events originate and a secondary wind sector related to Levant-Sirocco winds (i.e. ESE, 100-135°N). The wind data have been then analyzed considering the wind speeds following a Generalized Pareto Distribution (i.e. GPD). For the prevailing wind direction, the wind speed ranges between 13.9 m/s (return period TR = 2 year) and 25.6 m/s (TR = 200 years).

Then, a wave climate study has been performed. At first, a calibration with the wave data coming from the wave buoy installed in Monopoli and belonging to the National Wave Buoy Network has been carried out. The wave rose confirms the presence of a prevailing sector (N-NW) and a secondary sector (ESE). An extreme value analysis has been then performed. In this context, for the prevailing wave direction, the significant wave height ranges between 2.9 m (TR = 2 year) and 6.9 m (TR = 200 years). For the secondary direction, the significant wave height ranges between 2.1 m (TR = 1 year) and 5.0 m (TR = 200 years).

Lastly, a tidal analysis has been performed based on the tidal gauges installed in Bari (at the Ferry Port, Pier 12) and Taranto (at the S. Eligio Pier of the Taranto Port) for the time range from 01/01/1999 up to 12/31/2020 (sampling time equal to 1h). According to the superposition principle, the meteorological component of the level (i.e. storm surge, [7]) has been estimated as the simple difference between the observed levels and the (estimated) astronomical component. The extreme value analysis of the meteorological component has been then carried out. The achieved results show how the storm surge ranges from 0.52 cm up to 0.65 cm for Bari and from 0.50 cm up to 0.58 cm for Taranto, for a return period TR = 100 years, depending on the selected probability distribution function (i.e. GPD or GEV).

The littoral characterization also included the assessment of the shoreline evolution [2]. Within this context, the 2018 shoreline position has been compared to the shoreline location collected during a recent survey (2022). The stretch of the analyzed coastline (see Figure 3) is between the municipalities of Torre Canne (Fasano, BR) and Rosa Marina (Ostuni, BR). The results inspection revealed that 59 % (3.2 km) of the littoral is in retreat, the 18 % (1 km) is stable and the remaining 23 % (1.3 km) is in advancement. The sediment balance is negative with a medium annual loss equal to 10000 m^3/year. According to the dominant wave direction, the sediment transport is directed toward S-E.

Figure 3 – Recent littoral evolution trend. Comparison between shorelines of 2018-2022.

Concluding remarks

This paper aims to describe the design of a low-cost monitoring system for abiotic and biotic parameters that collect data remotely in near real-time with the final aim to assess the temporal and spatial evolution of biodiversity in coastal areas located in South Italy. The strategy of monitoring and the architecture of the network has been defined also based on the results of in-depth hydrodynamics and morphodynamics analyses of the coastal stretches to be monitored. These analyses are intended to "inform" the monitoring strategy. The data, along with their analysis and synthesis, are intended to support decision-makers. Indeed, smart environmental monitoring has gained much attention from the technical and scientific community as it is recognized as a crucial tool for gaining insight into the state of the environment when the protection of biodiversity and ecosystems must be pursued.

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MANAGING WATER COMMONS USING MEDIATOR VARIABLES TO BRIDGE THE GAP BETWEEN ENVIRONMENTAL FACTORS AND ANTHROPOGENIC POLLUTION INDICATORS

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Abstract – Water is the lifeblood of all life, so population concentrates near potable sweet water sources. People also concentrate near the coastline for economic reasons. Much of the drinking groundwater resources in the Croatian coastal area is stored in karst aquifers. Because of its quick pass-through nature and nonpoint source pollution, its protection is challenging. There have been many monitoring and measurement challenges in the past. For example, there was no empirical confirmation of a conjectured link between precipitation and microbiologic pollution in the monitored coastal areas. Before the use of $\delta^{18}O$ as mediator for the analysis of groundwater dynamics in karst aquifer characterisation, the causal links between precipitation and aquifer- as well as marine pollution were elusive. Data analysis of groundwater dynamics required also some dynamic statistical modelling, as for example dynamic panel data modelling in form of a General Method of Moments with First Differences transformation to control for unobserved time-invariant individual effect heterogeneity in. Static statistical models that include $\delta^{18}O$ values successfully represent the microbial pollution variations within a closed system. We understand this to be a characteristic of a stock pollution. At an open sea location, the results of static microbial pollution modelling have not been as good. Dynamic modelling using first differences of $\delta^{18}O$ values indicate that in these circumstances we deal with flow pollution.
Whether a pollutant is a stock or a flow is not only dependent on the pollutant itself, but mostly on the medium, and its environment. Policies regarded as optimal for stock and flow pollutants are different. The question of stock or flow is of great importance to decide whether the regulatory body should use price or quantitative allocation mechanisms. There are circumstances where we would prefer the one to the other because of political and administrative reasons, but it is ultimately up to the marginal costs and benefits to use the one or the other. When supply and demand curves are flat, it is better to use quota-like quantitative methods for avoiding planning mistakes. For inelastic costs and benefits, a price system of regulation is optimal instead. Whether an ecological system produces elastic or inelastic costs and benefits depends on factors such as pass-through velocity and its sustainability. Stocks are common goods and prefer price mechanisms. Flows are common pool resources and prefer quantitative mechanisms.

Keywords – *economic institutions, water commons management, mediator variable, pollution measurement, stock pollutants, flow pollutants.*

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Introduction

Water is the lifeblood of all life, so people congregate near fresh water sources. People congregate near the coast for economic reasons as well. Dinaric karst covers nearly half of Croatia's land area (Fig. 1).

Figure 1 – Boundary of the Dinaric Karst (red dashed line).

A significant portion of Croatia's drinking groundwater resources is stored in karst aquifers. Because of its rapid passage through nature and nonpoint source pollution, karst protection is difficult. For any reasonable design of an institutional mechanism to control for pollution, the rate at which water flows through the system and its accumulation and degradation in the environment through which it travels determines whether a pollutant is a stock or a flow. There are times when we would prefer one to the other for administrative reasons, but it is ultimately up to the marginal costs and benefits to use one or the other. Ecological problems, as addressed in environmental economics and in the design of economic institutional mechanisms, are referred to as stock and flow problems. The rates of pollutant emission and depletion determine the sustainability of the system. According to Elinor Ostrom's classification of common goods into stocks or flows [9] we also classify water media into stocks or flows regarding their capability to retain pollutants. Stocks are better modelled with a static approach in form of an Estimated Generalised Least Squares causal mechanical inferential model of explanation. To account for the unobserved time-invariant variability of individual effects, aquifers with a higher degree of karstification are best modelled using a dynamic inferential causal mechanical method in the form of a General Method of moments with transformation of first differences [6,7]. Panel data statistical methods may also be used for hypothesis testing and coefficient estimation as well as direction of causality testing [4,8].

In this study, we present the results of observations using the $\delta^{18}O$ as a mediator variable between precipitation locations and human pollution at beach sites. Where other measurement and statistical techniques, as well as mediators had failed, have been prohibitively expensive or outright impossible to use, the $\delta^{18}O$, as a mediator variable, has provided statistically significant results.

Materials and Methods

With the help of formal logic, we can neither draw a deductive conclusion going from a description of the cause to the kind of the effect, nor are we able to conclude from a description of the effect about the kind of the cause. It is a common methodological problem to all empirical sciences: natural and social. In empirical sciences, a single consequence may have many different sources of causation. In addition to the problem of causation in natural sciences, which answers the question of how come, social sciences have the problem of grasping the reasons for certain human behaviour (teleologically rational or not), which answers the question of what for. Problems of anthropogenic pollution, its measurement, and ultimately abatement cannot be adequately addressed without resorting to human incentives, and social institutions in the form of rules and norms, as well as other institutions that have evolved to incentivize human behaviour in a certain social context.

In this paper, we firstly try to answer the question of measurement where some other techniques have failed in the past. Secondly, we try to use mediator indicator variables to try to understand the causal mechanics hidden within the black box of karstic aquifers. Finally, we present some unorthodox methods of inferential statistics that enabled us to test causal conjectures regarding the anthropogenic sources of pollution. The concept of causality is essential for scientific explanation. According to the Causal-Mechanical (CM) model of explanation, the fundamental causal mechanisms are causal processes and causal interactions [10, 11]. The most fundamental causal concept, according to Wesley Salmon, is that of a causal process. A causal process is defined by its ability to transmit a mark or its own structure in a spatiotemporally continuous manner. So, for all our practical intents and purposes, a pollutant ending up in an estuary, a spring, or on the beach, may have different sources or causes that may never precisely be identified. According to the CM model of explanation, to be able to claim that something is a source of pollution at a certain beach, one should be able to systematically and spatially continuously track the transmission of the pollutant from the source to the target location, a task that is neither feasible nor economical. This task is usually performed by some form of marker or tracer, usually a liquid of persistent colour, transmitting the colour downhill. At our measurement locations, and by using standard tracers and standard statistical methods, any attempt to find a direct link between precipitation or any other anthropogenic indicator variable gave spurious results [5,6,7]. When a mediator variable was introduced instead in the form of a delta value of the stable isotope ^{18}O, the puzzle finally fell into place: The tracer could serve as a mediator between rainfall in the hinterland and anthropogenic pollution on the beaches. In statistical terms, the

$\delta^{18}O$ is the mediator variable. The $\delta^{18}O$ is not perfect, because there is also the possibility of false correlation due to random mixing of precipitation with different content of stable isotope ^{18}O at all levels as an independent variable, which in the end leads to false positive results. Nevertheless, we consider such results very unlikely, especially if the measurements are repeated many times. According to the basic idea of methodological pluralism, there is as many explanations as there are alternative causes but also as many possible alternative methods to get to the scientific truth. One should pursue as many as possible of these paths. In this paper, we attempt to represent the Causal-Mechanical (CM) model of bacterial contamination in coastal bathing water by using mediator variables to bridge the gap between environmental factors such as total precipitation and anthropogenic pollution indicators such as *E. coli* or enterococci. Prior to the use of stable isotope ^{18}O as a mediator indicator variable for the analysis of groundwater dynamics in karst aquifer characterisation, the causal links between precipitation and aquifer- and marine pollution were elusive. Thus, we cannot overstate the importance of stable isotopes in completing the missing CM links as they stand for proxies of the particular water in the precipitation – groundwater – bathing water process. Another question needed to be answered for an effective governance of water commons is the speed at which water passes through the ground. We used isotopic content of the precipitation and groundwater samples as the primary mediator indicator variable (a naturally occurring tracer) to try to estimate the points of origin of the precipitation and the pass-through velocity of the groundwater. During the 2010 and 2011 bathing seasons, bi-weekly samples were collected from coastal bathing waters in the Kvarner Bay region of Croatia. Sampling sites included Bakar Bay and Kantrida Beach in the city of Rijeka. Four coastal springs were sampled weekly from April 2010 to April 2012. Only groundwater samples that coincided with sampling of marine bathing waters were included in the analysis of this study. The collected groundwater samples were stored in 50-mL double-capped polyethylene bottles until analysed by an isotope ratio mass spectrometer. We used the water equilibration technique to measure stable isotope ratios on a DeltaplusXP (Thermo Finnigan) isotope ratio mass spectrometer with an HDOeq48/24 (IsoCal) equilibration unit and a Dual Inlet system (Thermo Finnigan) as peripherals. The measurements were made against three laboratory standards ranging from -1.58 ‰ to -19.92 ‰ for $\delta^{18}O$, where $\delta^{18}O= R_{sample}/R_{standard} -1$, with R_{sample} and $R_{standard}$ representing the ratio of ^{18}O and ^{16}O in the sample and the standard respectively. The laboratory standards were calibrated against the primary standards VSMOW2, SLAP2, and GISP. The measurements were normalised and analyzed using the USGS Laboratory Information Management System (LIMS) and the IAEA SiCalib 2.14 program for stable isotopes in water. The precision of measurement was better than 0.1 ‰.

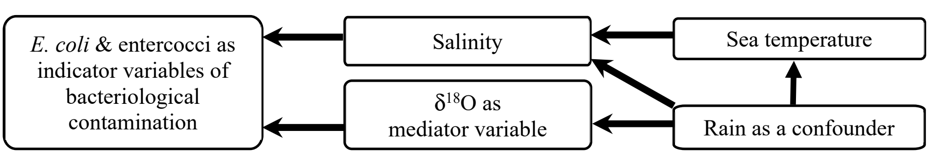

Figure 2 – $\delta^{18}O$ as a mediator variable between precipitation and indicators of anthropogenic bacteriological contamination of marine bathing water.

Panel data, also known as longitudinal data, are cross-sectional units observed over time. The use of both cross-sectional and time-series data allows for more accurate econometric model parameters and generalizations. The Generalized Method of Moments First Differences (GMM FD) is widely used in empirical research [2,3,12] and has numerous advantages over Ordinary Least Squares (OLS) and Estimated Generalized Least Squares (EGLS) Fixed Effects (FE) modelling. The GMM FD is unaffected by distributional assumptions such as heteroskedasticity, it produces the least bias and variance in parameter estimation and eliminates autoregression by explicitly including a time-lagged dependent variable into the model. Firstly, we used a static approach in the form of an EGLS model test to account for heteroscedasticity in the residuals and to incorporate spatiotemporal effects. We then performed dynamic panel data modelling in the form of a General Method of Moments (GMM) with First Differences (FD) transformation to control for unobserved time-invariant individual effect heterogeneity. The GMM estimators are consistent, asymptotically normal, and efficient because they use no information other than that contained in the moment terms. The differencing process eliminates the non-stationarity of the data, accounts for momentum and inertia, and removes the problem of location fixed effects, autocorrelation, and other time-invariant components [3,12]. As a result, Panel GMM FD is an excellent complement for EGLS estimation. Finally, to rule out autoregression as a cause of spurious correlations, we performed the Arellano-Bond test on the residuals [1].

Results and discussion

Our results are divided into two sections: static Estimated Generalized Least Squares (EGLS) Fixed Effects (FE) modelling and dynamic General Method of Moments (GMM) First Differences (FD) modelling. The latter is called dynamic because variables are differenced first to control for non-stationarity and autoregression, idiosyncratic heterogeneities, and heteroskedasticity, all problems in inferential statistics that lead to spurious correlation.

a) The static inferential analysis

First, we present the results of the static EGLS models. Static models explain well the interaction between precipitation, stable oxygen isotopes, and bacterial contamination at closed sites where seawater does not move much (Tables 1 and 2).

Table 1 – Panel EGLS for *E. coli* as a dependent variable at Bakar Bay.

Independent	Coeff.	S.E.	p	R^2
Total precipitation	0.043862	0.003372	<0.001	0.128

Total precipitation has long been used as an instrumental variable for predicting anthropogenic bacterial pollution in Croatian karst areas, since pollution is known to be washed out by rain, and rather quickly, within a few days [5]. However, it is clear from Table 2 that the $\delta^{18}O$ is a better predictor of bacterial pollution than pure information on total precipitation and also than any other indicator we could test. $\delta^{18}O$ is statistically not a determinant, but a mediator variable. Total precipitation is a confounding variable because it plays a role in the transmission of the independent variable (anthropogenic contamination in soil) to the dependent variable (bacterial contamination of coastal bathing water) but also influences the dependent variable (it lowers seawater salinity and decreases its temperature). In a CM model, it is necessary to use a mediator (for example, $\delta^{18}O$) to serve as a tracer in the transmission mechanism when there is no statistically significant relationship between the independent and dependent variables.

Table 2 – Panel EGLS for *E. coli* as a dependent variable at Bakar Bay.

Independent	**Coeff.**	**S.E.**	**p**	**R^2**
$\delta^{18}O$	7.918967	1.354843	<0.001	**0.525**
Salinity	-0.23324	0.048671	<0.001	

The model in Table 2 gives us a much better coefficient of determination (R^2=0.525). Unfortunately, combining the independent variables from Table 1 and Table 2 was not possible due to multicollinearity problems between total precipitation, $\delta^{18}O$, and salinity. Since *E. coli* is less resistant to salinity than enterococci, the salinity variable was statistically significant in the model with the *E. coli* as a dependent variable and thus was included in the model with the correct negative sign, as expected. The same could not be said for enterococci as a dependent variable, as the results did not show statistical significance for salinity at the $p<0.05$ level.

Table 3 – Panel EGLS for enterococci at Bakar Bay.

Independent	**Coeff.**	**S.E.**	**p**	**R^2**
Total precipitation	0.058916	0.005082	<0.001	0.122

Again, total precipitation and $\delta^{18}O$ were measured separately due to multicollinearity issues (Table 3). The main reason why salinity was not included in the model is the relative biological insensitivity of enterococci to salinity compared to *E. coli*, which makes it impossible to draw any statistically significant inferential conclusions regarding causal relations. The $\delta^{18}O$ outperforms all other variables in predicting enterococci in a closed bay environment (Table 4) with the coefficient of determination R^2=0.426.

Table 4 – Panel EGLS for enterococci at Bakar Bay.

Independent	**Coeff.**	**S.E.**	**p**	**R^2**
$\delta^{18}O$	11.88985	1.395156	<0.001	**0.426**

As stated earlier, enterococci are relatively more resistant to salinity and persist longer than *E. coli*. This is more exacerbated in a semi-enclosed bay such as Bakar Bay. We suspect that this is why we could not obtain statistically significant results for the conjecture that salinity reduces bacterial contamination by enterococci in semi-enclosed bays in the short term.

Table 5 – Panel EGLS for enterococci Kantrida (open sea).

Independent	Coeff.	S.E.	p	R^2
Total precipitation	0.195296	0.036986	<0.001	0.059

As shown in Table 5, total precipitation does not result in a large coefficient of determination, especially if one compares it to the model in Table 6.

Table 6 – Panel EGLS for enterococci Kantrida (open sea).

Independent	Coeff.	S.E.	p	R^2
$\delta^{18}O$	22.80015	10.54655	0.033	
Total precipitation	0.090819	0.022678	<0.001	**0.695**
Salinity	-3.36561	0.291998	<0.001	

In the open sea case at Kantrida shown in Table 6, again, the $\delta^{18}O$ oxygen isotope together with salinity and total precipitation in a common static panel EGLS model resulted in a very high coefficient of determination of 0.695.

b) The dynamic inferential analysis

Panel EGLS is a static modelling technique based on non-differenced data prone to give spurious correlations. Static EGLS modelling of bacterial contamination did not give any statistically significant results at open sea locations for short-lived and salinity non-resistant *E. coli.* Thus, it was not possible to get any meaningful statistically significant results for *E. coli,* similar to those for enterococci as shown in tables 3 to 6. This is the reason we had to change our methods to dynamic ones using first-differences of variables.

Table 7 – Panel GMM FD for *E. coli* at Bakar Bay.

Independent	Coeff.	S. E.	p	S.E.	J-stat.	AR(1) p	AR(2) p
$\delta^{18}O$	5.16	0.32	<0.001	7.31	19.14	0.05	0.796
Salinity	-0.46	0.11	<0.001				

Similar to the static EGLS model, the best results for a dynamic panel model GMM FD were obtained with the two variables $\delta^{18}O$ and salinity. In the case of the open ocean at the Kantrida site, we had to use the first difference of the oxygen isotope and precipitation data, which were one day ahead of the isotope sample data, indicating the need for careful dynamic modelling at open ocean sites that are susceptible to various dynamic influences. The most noticeable distinction between Bakar Bay and Kantrida is found in the enterococci modelling, where an autoregressive (-1) variable was required for Bakar Bay, confirming its more static nature (Table 8).

Table 8 – Panel GMM FD for enterococci at Bakar Bay.

Independent	**Coeff.**	**S. E.**	**p**	**S.E.**	**J-stat.**	**AR(1) p**	**AR(2) p**
enterococci(-1)	-0.49	0.01	<0.001				
$\delta^{18}O$	26.54	4.38	<0.001	19.80	40.34	0.061	0.538
Salinity	-0.26	0.02	<0.001				

Table 8 shows the null-hypothesis of the Arellano-Bond test statistics cannot be rejected at p=0.05 level indicating the constant presence of the enterococci autoregressive component (-1) even after being introduced into the GMM FD model. This is indicative of the static nature of the Bakar Bay but also of the resistance of enterococci. Table 9 shows cumulatively the dynamic panel model for *E. coli* at the open sea location at Kantrida. The models are separated by a straight line within the table.

Table 9 – Panel GMM FD for *E. coli* at Kantrida.

Independent	**Coeff.**	**S. E.**	**p**	**J-stat.**	**AR(1) p**	**AR(2) p**
$\delta^{18}O$	495.75	157.79	0.002	62.62	< 0.001	0.721
Rain day before	12.78	5.11	0.014	68.99	< 0.001	0.670
Salinity	-28.40	6.20	<0.001	57.62	< 0.001	0.684
$\delta^{18}O$	344.36	129.08	0.009			
Rain day before	17.05	7.89	0.033	47.82	< 0.001	0.654
Salinity	-30.49	8.01	<0.001			

The results of the panel GMM FD for *E. coli* at the open sea Kantrida location show the independent variables to be statistically significant at the p<0.05 level both individually as well as collectively in a model, and with correct signs.

Table 10 – Panel GMM FD for enterococci at Kantrida.

Independent	Coeff.	S. E.	p	J-stat.	AR(1) p	AR(2) p
$\Delta(\delta^{18}O)$	156.21	50.11	0.002	72.73	< 0.001	0.968
Rain day before	4.89	1.54	0.002	80.18	< 0.001	0.965
Salinity	-8.50	1.86	<0.001	69.05	< 0.001	0.844

Table 10 shows the variables in a Panel GMM FD for enterococci at Kantrida taken separately. Taken together, the standard error seems to be slightly lower, thus, giving a better model (Table 11).

Table 11 – Panel GMM FD for enterococci at Kantrida.

Independent	Coeff.	S. E.	p	J-stat.	AR(1) p	AR(2) p
$\Delta(\delta^{18}O)$	164.4491	43.11	<0.001			
Rain day before	7.135354	2.00	<0.001	54.71	< 0.001	0.785
Salinity	-8.24550	2.30	<0.001			

The dynamic panel GMM FD results for enterococci at the Kantrida open sea location give the best results when the three independent variables ($\delta^{18}O$, precipitation the day before bacteria measurement, and salinity) are shown together in a common model. We need to emphasize once again, that in a dynamic panel GMM FD model all variables are first differenced, and thereby loose the constant in the process. Although the coefficients were calculated as first moments, that is, the changes in the independent variables are calculated relative to the changes in the dependent variables, the coefficients in Table 7 represent nominal coefficients. The major shortcoming of the method concerns the elimination of the constant and the inability to compare the results to other methods due to the lacking R^2.

Conclusion

The pollutant's status as a stock or a flow is determined not only by the pollutant, but also by the medium and the environment through which it is propagating, as the medium propagating through the environment determines its pass-through velocity. Thus, the same medium, in our case the seawater, may travel slower or faster depending on whether it is a closed bay or open sea. As our panel data analysis of static $\delta^{18}O$ and dynamic $\Delta(\delta^{18}O)$ as well as of the *E. coli* and enterococci bacteria show, there is a statistically significant difference between closed bay and open sea environments. We analysed the precipitation $\delta^{18}O$ data from hinterland locations that might potentially coincide with the locations where anthropogenic pollution originates, and subsequently we analysed $\delta^{18}O$ data springs at several locations near the beaches. Without $\delta^{18}O$ as a mediator variable, no statistically significant results were obtained. With ^{18}O as a naturally occurring tracer as a mediator indicator variable, we were able to obtain acceptable and expectable results. The measures considered optimal for stock and flow pollutants differ. The amount of pollution that renders a water source (a spring) unusable might be at a point where the marginal benefit of an additional unit of pollutant discharge changes very rapidly. In such cases, it is not optimal to regulate prices or impose taxes, but instead to set total allowable quantities of pollutants with tradable permits or quotas. Mixed systems may be optimal in some situations.

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THE USE OF ^{2}H AND ^{18}O ISOTOPES IN THE STUDY OF COASTAL KARSTIC AQUIFER

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Abstract – Karst covers nearly half of Croatia's area. Croatian karst is part of the Dinaric karst and stretches from the Adriatic Sea to the Pannonian basin. Carbonate aquifers are the primary source of freshwater in karst part of Croatia and their protection is of the highest priority. Karst aquifers are sensitive to pollution since pollutants can easily enter the groundwater channel systems, often without prior self-purification process. Once pollutants enter the karstic underground they spread through the aquifer very quickly. Therefore, a thorough knowledge of the karst aquifer is essential for a timely and appropriate reaction to possible pollution incidents. Complexity of the karst landforms and groundwater networks requires implementation of a standard hydrogeological monitoring as well as unconventional methods of investigation.

Analysis of stable water isotopes ^{2}H and ^{18}O proved to be helpful complementing method to a standard hydrogeological karst studies. We present the results of the stable isotope composition analysis of the coastal karst springs in the Bakar Bay and rain water collected in the hinterland of the springs. The local water supply company supervises the examined springs. During two years, spring water samples were collected on a weekly basis and rain samples were collected once a month.

The stable isotope composition of the karst groundwater was modelled using autoregressive integrated moving average modelling. The study's main findings are: winter precipitation of Mediterranean origin dominates springs recharge, a dual porosity model that includes a fissure-porous aquifer and karstic channels is a fit for the studied systems, and autocorrelation function analysis revealed varying degrees of karstification in the hinterland of the studied springs.

Introduction

Karst aquifers are important sources of potable water not only in the Mediterranean region, but also globally [18]. They are recognized by their heterogeneous physical properties and complex flow patterns, which make investigation and description of their functioning challenging [5,14]. Many physicochemical parameters of groundwater could be used to characterize the hydrological behaviour of karst watersheds. However, in the case of non-stationary hydrological conditions, hydrochemical data should be supplemented with additional data such as environmental isotopes (e.g. water isotopes ^{18}O and ^{2}H) to provide a reliable interpretation of karst basin functioning [15]. Some applications of water stable

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isotopes in karst aquifer research include the analysis of recharge processes [8,13] and water reservoir mixing [12], as well as the determination of residence times [19] and mean recharge elevations [16].

Although stable isotopes are typically used to supplement traditional hydrological methods [6], it has been demonstrated that when conventional parameters are unavailable, a thorough statistical analysis of oxygen and hydrogen stable isotope time series could be used for description of karst system hydrological behaviour [7]. Stable isotope content of Bakar Bay springs (Perilo - PER, Dobra - DB, and Dobrica - DBC) are discussed in the paper. Since there is no data on discharges for these springs, in our analysis we had to rely entirely on stable isotopes and statistical modelling.

Materials and Methods

An element's isotopes share the same number of protons but differ in the number of neutrons in their atomic nuclei. There are two stable isotopes of hydrogen: ^{1}H and ^{2}H. The lighter hydrogen isotope accounts for ≈ 99.985 % of total stable hydrogen, with the heavier isotope ^{2}H accounting for the remaining ≈0.015 %. There are three stable forms of oxygen: ^{16}O, ^{17}O, and ^{18}O. The lightest one, is the most abundant, while ^{17}O and ^{18}O are less common in nature.

There are nine different stable water configurations, the most common of which are $^{1}H^{1}H^{16}O$, $^{1}H^{2}H^{16}O$, and $^{1}H^{1}H^{18}O$. The masses of various stable water configurations differ, as do their physical and chemical properties. These differences result in isotopic fractionation or changes in stable isotope abundances at the beginning and end of physical, chemical, or biological processes. Because of fractionation, stable isotopes are sometimes referred to as "fingerprints" used in determining the origin of water [20].

The stable isotope composition of water is represented by $\delta^{18}O$ and $\delta^{2}H$, with δ-value defined as the ratio of heavier to lighter isotope abundance in the sample (R_{sample}) and the standard ($R_{standard}$): $\delta(‰) = R_{samle} / R_{standard} - 1$. To express the stable isotope composition of water, the international VSMOW (Vienna Standard Mean Ocean Water) standard is used. Fresh water δ-values are typically negative, indicating a decrease in ^{2}H or/and ^{18}O abundance compared to the standard.

Evaporation and condensation have a significant impact on the isotopic composition of water (Fig. 1). Water vapour is depleted in heavy isotopes when compared to the evaporating body. In contrast, rain contains more heavy isotopes than residual vapour. Air temperature has a strong influence on precipitation isotope content, resulting in higher δ-values in the summer and lower δ-values in the winter [11]. There is a linear correlation between ^{2}H and ^{18}O values in natural waters that are not affected by evaporation ($\delta^{2}H = 8 \cdot \delta^{18}O + 10$ ‰), known as a Global Meteoric Water Line (GMWL) [2]. The calculation of regression lines for local precipitation (Local Meteoric Water Line - LMWL) and ground water (Local Groundwater Line - LGWL) is a standard procedure in isotope hydrology. If there is no further evaporation, the isotopic composition of the precipitation usually remains unchanged once it enters the underground [11]. Nonetheless, mixing of different water masses causes changes in the stable isotope composition of groundwater [10].

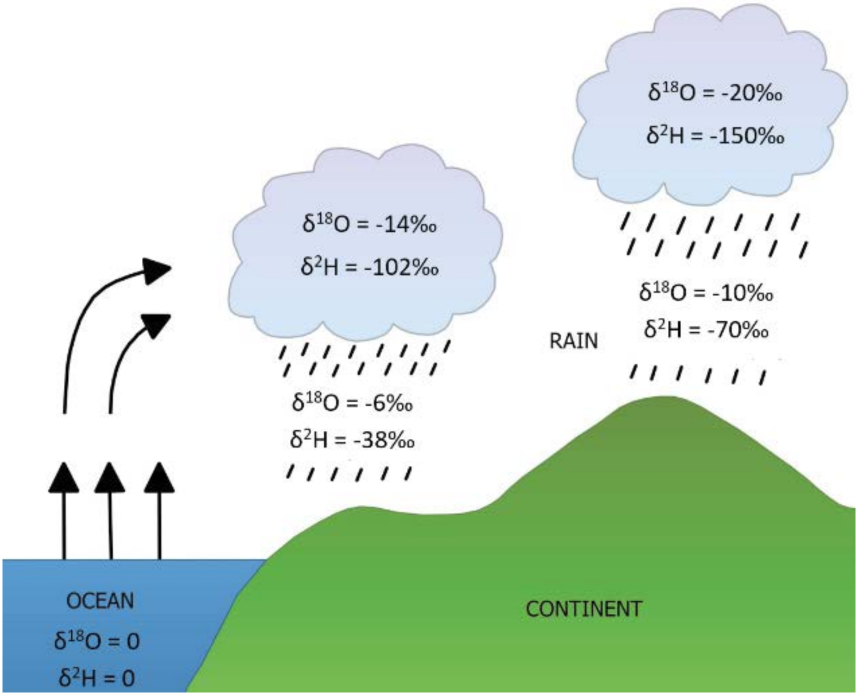

Figure 1 – The atmospheric part of water cycle and changes in stable isotope content caused by water evaporation and condensation.

In 1964, Dansgaard introduced the concept of d-excess, which is defined as follows: d-excess = $\delta^2H - 8\cdot\delta^{18}O$ [3]. D-excess values of around 10 ‰ indicate precipitation originating in the Atlantic Ocean, whereas values greater than 15 ‰ indicate precipitation originating in the Mediterranean [4].

The study area is the Bakar Bay spring discharge zone in western Croatia (Fig. 2).

For two years, weekly spring water samples were collected. We used a set of precipitation isotope data from the Kukuljanovo (KUK), Škalnica (SKAL), and Platak (PLAT) rain gauging stations to compare the isotopic content of precipitation and groundwater (Fig. 2). Some of these data have already been used in hydrogeological analyses of the Rječina River chacment [7, 8]. To prevent evaporation, monthly totals were collected in 3.5-litre rain gauges containing 100 ml of paraffin oil. After being separated from the oil, the precipitation samples, same as groundwater samples, were stored in double-capped HDPE bottles. A Delta^{plus}XP (Thermo Finnigan) isotope ratio mass spectrometer, with an HDOeq48/24 (IsoCal) equilibration unit and a Dual Inlet system (Thermo Finnigan) as peripherals, was used for the stable isotope measurements. For $\delta^{18}O$, measurement precision was better than 0.1 ‰, and for δ^2H, it was better than 1 ‰.

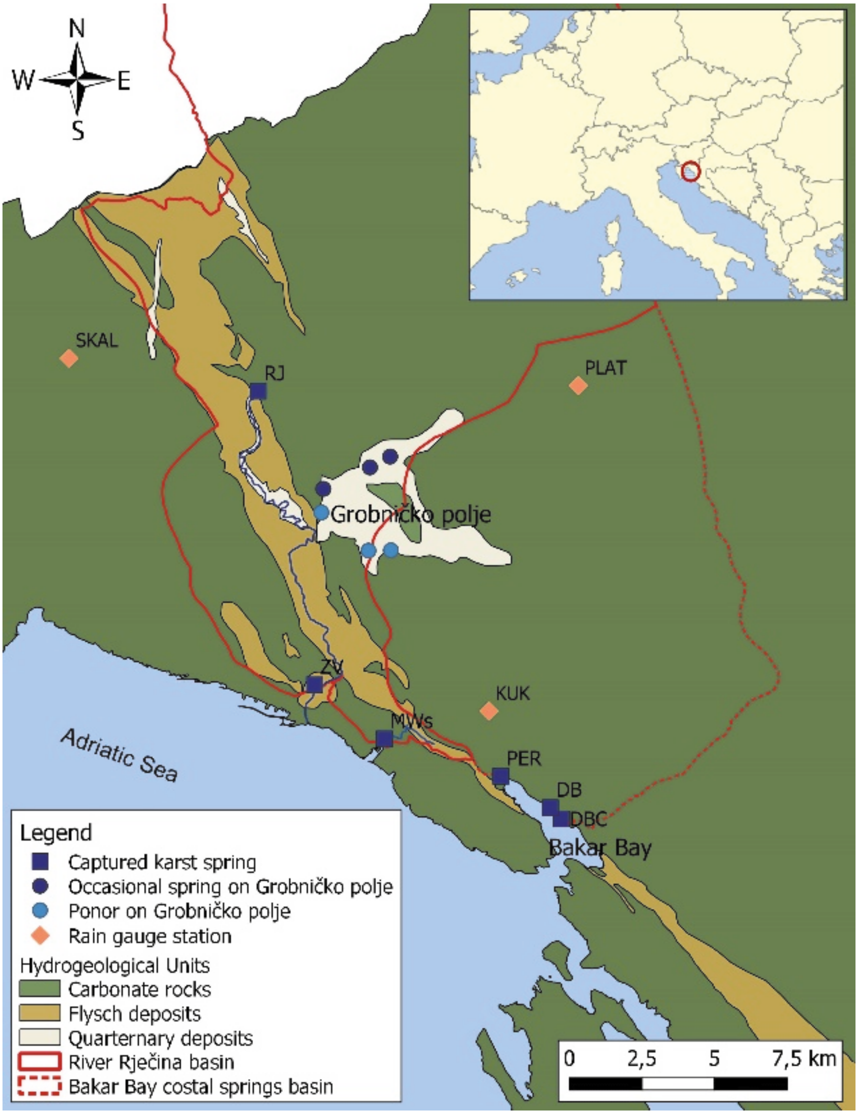

Figure 2 – The main map: a hydrogeological map of the study area showing basins of Rječina River and coastal springs in the Bakar Bay. The map also shows: the main karst springs (RJ – Rječina Spring, ZV – Zvir, MWs – Martinšćica wells, PER – Perilo, DB – Dobra, DBC – Dobrica), the Rječina River (blue line on the main map), and rain gauge stations for sampling cumulative monthly precipitation (KUK – Kukuljanovo, SKAL – Škalnica, PLAT – Platak). Upper right corner: the position of the study area in Europe.

To analyse the groundwater stable isotope series, we used univariate time series analysis methods such as autocorrelation function (ACF) and autoregressive integrated moving average modelling (ARIMA) [1]. We used graphical representations of ACF to draw a conclusions about aquifer's karstification and retention capabilities, as well as to select the appropriate ARIMA model. Prior to ARIMA, we used an additive component model ($\delta = l + s + sc$) to test the groundwater stable isotope time series for trends and seasonal variations, where l is a linear trend component determined by linear regression, s is a seasonal component determined by periodic regression, and sc is a stochastic component. The results were interpreted using the 0.05 level of statistical significance.

Results and Discussion

For the study area and period, LMWLs for the warm part of the hydrological year ($\delta^2H = 8.05 \cdot \delta^{18}O + 8.52$ ‰; R^2=0.89) and cold part of the hydrological year ($\delta^2H = 8.04 \cdot \delta^{18}O + 13.96$ ‰; R^2=0.99) were already presented in [7]. The division of the LMWL into summer and winter seasons was justified by previous studies. These have shown that the rainy season from October to April contributes more to groundwater recharge in the study area than the precipitation that falls during the summer season [7,8]. Figure 3 shows that the δ-values of all three springs (PER, DB, and DBC) agree well with the LMWL for the cold season, indicating that the groundwater is primarily fed by winter precipitation. LGWL for PER, DB, and DBC, as shown in Fig. 3 ($\delta^2H = 8.37 \cdot \delta^{18}O + 17.6$ ‰; R^2=0.95), further supports this conclusion.

Figure 4 shows large variations in the d-excess for rainwater: values in the winter months are significantly higher than values in the summer months of the hydrologic year. Since precipitation is generally lower in the summer months than in the winter months, a weighted average of d-excess was calculated: KUK (12.9 ‰), SKAL (14.71 ‰) and PLAT (14.66 ‰) [7]. Values for SKAL and PLAT correspond to the average values of groundwater d-excess for DBC (14.67 $\pm$ 0.73) ‰, DB (14.82 $\pm$ 0.73) ‰, and PER (14.53 $\pm$ 0.73) ‰.

Due to the strong and statistically significant correlation between $\delta^{18}O$ and δ^2H values (R=0.97, $p < 0.001$), only $\delta^{18}O$ values were used for time series analysis. The ACF of the groundwater $\delta^{18}O$ series was analyzed to obtain information about the system's karstification. Figure 5 shows the ACFs of the $\delta^{18}O$ series for PER, DB, and DBC.

The shape of the ACF discharge graph is commonly used to determine the retention capacity and degree of karstification of the karst aquifer [17]. The karst system's "memory effect" is the time required for auto-correlation coefficients $r(k)_{xx}$ to fall below 0.2 [9]. We used the same reasoning to interpret $\delta^{18}O$ ACFs (Fig. 5). The ACFs do not decrease continuously but exhibit two types of decline, supporting the interpretation of the aquifers' dual nature. Initially, all three ACFs drop rapidly with steep slopes. The gradients begin to decline after five weeks. The ACF for PER decreases more rapidly, and its autocorrelation factors become statistically insignificant after eight weeks; whereas the ACFs for DB and DBC decrease more gradually, and their autocorrelation factors remain statistically significant for eleven weeks. The slower declines in DB and DBC ACFs suggest that DB and DBC have a greater ability to retain water than PER. This could also indicate a more developed karst channel system in the case of PER versus DB and DBC.

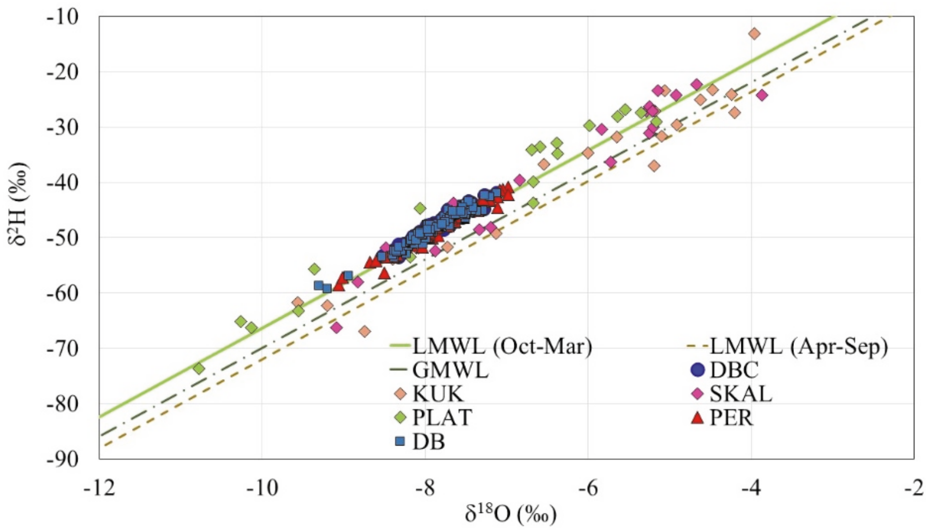

Figure 3 – Correlation diagram of δ^{2}H and δ^{18}O values for precipitation collected at Kukuljanovo (KUK), Škalnica (SKAL), and Platak (PLAT) stations, as well as groundwater collected at Dobrica (DBC), Dobra (DB) and Perilo (PER). Local meteoric water lines (LMWLs) for precipitation in the warm and cold seasons of the hydrological year, as well as a global meteoric water line (GMWL) are also presented.

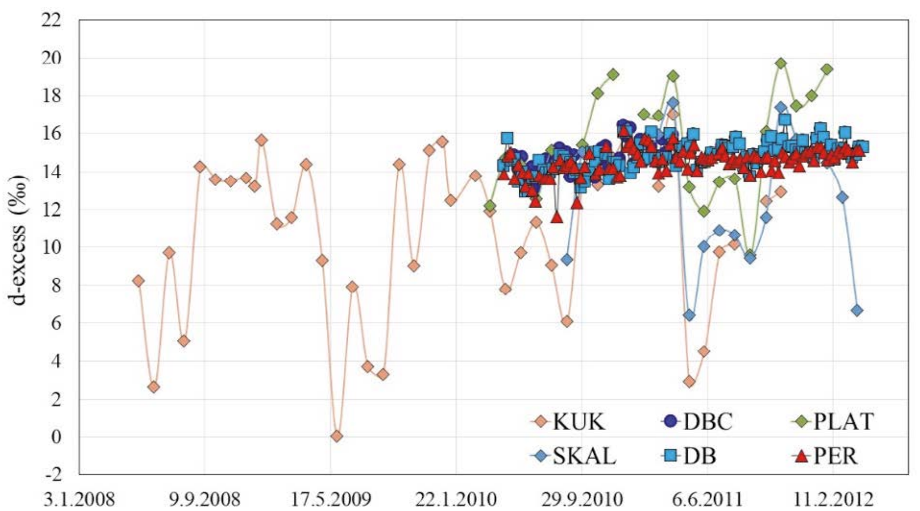

Figure 4 – D-excess values for precipitation collected at the stations Kukuljanovo (KUK), Škalnica (SKAL), and Platak (PLAT), and spring water from Dobrica (DBC), Dobra (DB) and Perilo (PER).

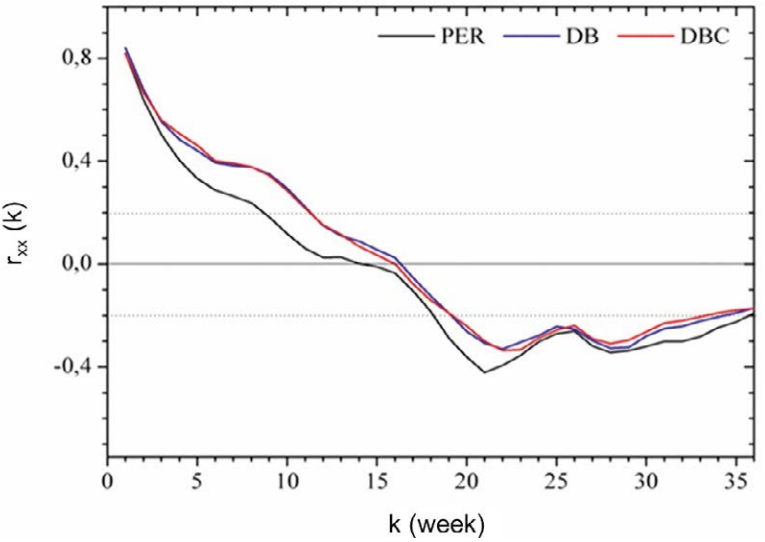

Figure 5 – Perilo (PER), Dobra (DB), and Dobrica (DBC) autocorrelation functions for $\delta^{18}O$ time series.

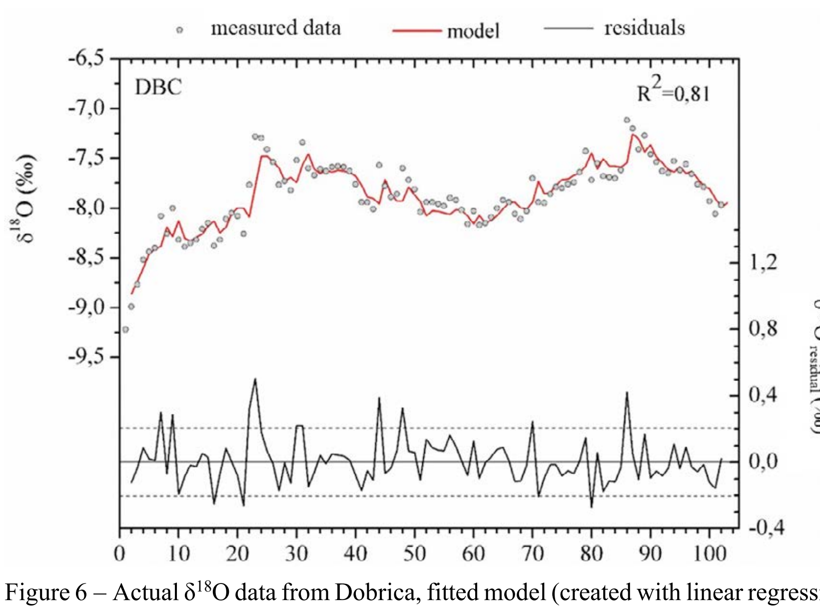

Figure 6 – Actual $\delta^{18}O$ data from Dobrica, fitted model (created with linear regression, periodic regression, and ARIMA (1,0,0)), and residuals. The circles in the upper part of the graph represent the measured data for $\delta^{18}O$ in water. A red line represents the fitted model. Deviations from the fitted model are represented by a black solid line in the lower part of the graph.

Since ARIMA results for PER and DB have already been published [8], this paper includes only DBC results. Significant linear and seasonal trends were observed: $\delta^{18}O = -8.07 + 0.004 \cdot t - 0.32 \cdot \cos((2\pi/52) \cdot t + 2.32))$ (R^2=0.65), where t is a time period (a week). There were no seasonal changes in the $\delta^{18}O$ values of the monthly precipitation samples observed during the study period [7,8]. As a result, we conclude that seasonality in groundwater $\delta^{18}O$ time series is caused by aquifer characteristics such as rapid infiltration and discharge of heavy rain, as well as the predominance of winter precipitation in replenishing groundwater reserves. Indeed, the strongest $\delta^{18}O$ shifts to higher values were observed during the cold part of the hydrological year at the time of the heaviest precipitation. This indicates that precipitation infiltrated rapidly into the subsurface and reached springs in a short time. In contrast, groundwater had the lowest delta values during the warm part of the hydrologic year and these were without significant fluctuations. There were no heavy rain events during this period and we can conclude that the water sampled at the springs during this period came from the aquifer water reserves. The low delta values indicate that snowmelt probably plays the most important role in recharging the aquifer. This situation suggests that the systems analyzed are best described by the so-called dual porosity model. Such a model includes a fissure porous part of the aquifer characterized by baseflow whose activity is most evident during dry seasons. The second part of the model consists of a developed network of karst channels that respond rapidly to intense precipitation events.

ARIMA modeling of the $\delta^{18}O$ series was performed after seasonal and linear trends were removed from the series and stationarity of the residual series was achieved. AR (1) (i.e., ARIMA (1,0,0) model) proved to be the best model for all three springs. The actual data, fitted data, and $\delta^{18}O$ DBC residuals are shown in Fig. 6. The largest deviation from the statistical models was found for samples collected during heavy rainfall. For PER they were up to 1.2 ‰, while for DB and DBC they were not higher than 0.5 ‰. This difference in residuals could be explained by the greater karstification of the hinterland of PER compared to DB and DBC. The good agreement of measured and modelled values (R^2 = 0.81) obtained by ARIMA (Fig. 6), also supports the idea of the DBC hinterland having a lower karstification degree and higher retention capability than PER (R^2 = 0.76).

Conclusions

To protect drinking water sources and use them sustainably, we need to understand how aquifers work. Karst aquifers are well-known for their complexity and research difficulty. Scientists have long agreed that multidisciplinary research is essential, and isotopic hydrology is an excellent example of multidisciplinary karst aquifer research.

This paper presents the findings of a two-year sampling at three karst springs in Bakar Bay (Croatia), as well as rain gauge stations in their vicinity. Based on the isotopic composition of the collected samples, we concluded that these karst springs are primarily fed by winter precipitation. Temporal changes in groundwater isotopic composition show a seasonal pattern not seen in precipitation. As a consequence, the seasonal oscillation of isotopic composition is interpreted as a function of the karst system itself, i.e. as a dual porosity model consisting of a fissure-porous aquifer (characterized by baseflow during the dry season) and highly developed karstic channels (characterized by rapid infiltration and strong discharge during heavy rainfall). The analysis of auto-correlation functions and time series show that there is a difference in the degree of karstification of individual springs, with a higher degree of karstification indicating a greater sensitivity to potential pollution.

Funding

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GRAIN SIZE, NUTRIENTS AND HEAVY METALS ANALYSIS TO EVALUATE NATURAL *VS* ANTHROPOGENIC SOURCES IN THE SEA ENVIRONMENT (NAPLES BAY, EASTERN TYRRHENIAN SEA)

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Abstract – The study area is located in the Naples Bay offshore the Sarno River plain, this latter is affected by metals contamination as a result of the geogenic nature and the outflow of industrial waste and the high demographic pressure. Grain size distribution coupled with organic matter, nutrients and metals content were analysed through a statistical approach in order to explore how the onshore documented contamination affect the offshore counterpart. The individuation of areas with different contamination pattern has been performed using statistical techniques recognize the potential independent factors governing specific metal trends. Aiming at assessing the natural vs anthropogenic origin of the contaminant a comparison with the published data analysis conducted onshore in the Sarno Plain was carried out. Results showed that the submarine area could be divided in four zones: the first zone offshore Torre Annunziata, with physical and geochemical association mainly linked to the volcanic rocks thus with metal pattern of natural origin; the second and third zones, which contaminant association from the Sarno Plain are anthropogenic in origin, whereas the fourth zone, characterized by low rate of contamination, is mainly influenced by sediment from Sorrento Peninsula. The results show that the river should account as one of the main contribution sources of anthropogenic contaminants.

Introduction

Over the past century, the rapid industrialization has been responsible of the discharge of heavy metals into coastal environments through river input in this way the offshore areas in front of high populated coast have been affected by both natural and anthropogenic inputs.

Grain-size parameters can intensively reflect local sedimentary environments, such as hydrodynamic conditions, sediment transport, subsidence, and redistribution processes. Whereas the natural geogenic contaminants are linked to the outcropping rocks in the onshore and offshore source areas, on the contrary the contaminants from the human activities are generated onshore and transported and deposited in the sea together the clastic sediments. Sediments are multi-phase solids containing silicates, carbonates, hydroxides/oxides, sulfates and organic substances as major components [25] that for their mineralogic features can influence the distribution of metals. The sea floor sediments are the result of the interaction

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between mineral particles and organic matter during the transport of the suspended material/sediment from the catchment area to the bottom-sea, where sediment accumulate [7]. The Sarno river plain is affected by an extreme environmental pollution as a result of the outflow of industrial waste [3 and bibliography therein]. Consequently, the area of the Naples Bay is subjected to the influence by sediment loads derived from the Sarno River. In the in the present study, the distribution of nine metals (Hg, Cd, As, Cr, Ni, Cu, Zn, Pb, Fe and Mn) is investigated coupled with organic matter, nutrient content and granulometry features, aiming to assess metal contamination influence of the Sarno river in the submarine area. A dataset of the sampling campaign referring to 91 sites located in the receiving basin of the Sarno River in the Gulf of Naples, was exploited. The study gets through the following steps *i)* investigation of the current grain size, nutrients (TOC, TN, TP) and heavy metal; *ii)* statistical analysis to extract information on sediment transport path following the TOC and grain-size trend; *iii)* distinguishing pollution sources and recognizing their origin (natural vs anthropogenic) by coupling metals pattern with the spatial grain size and organic matter distribution.

Geological framework

The Southeast Naples Bay is characterized by a relatively wide continental shelf environment with sediment supply from the Vesuvian slope, the Sarno river and Sorrento Peninsula relief (Fig. 1).

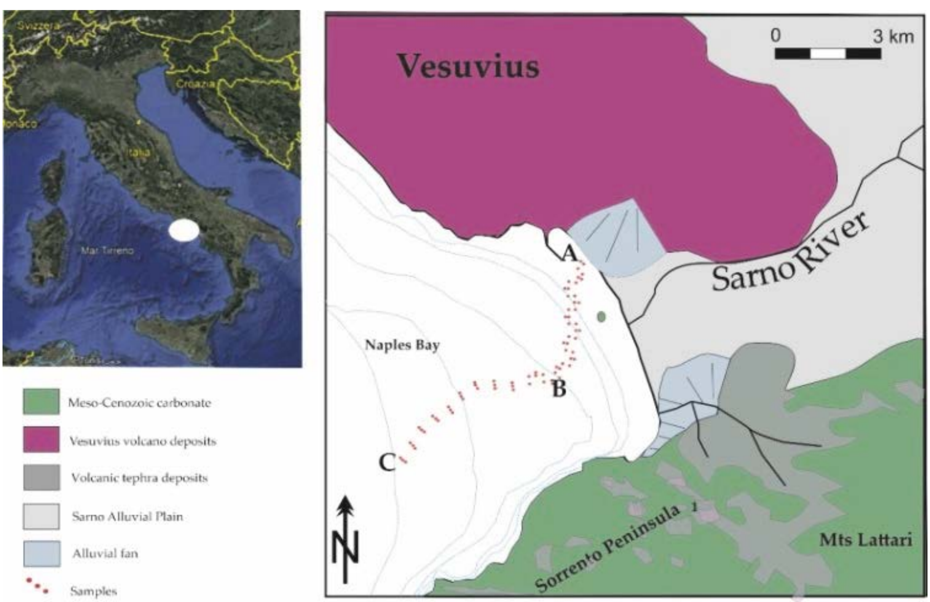

Figure 1 – Location maps of the study area.

The Vesuvius volcano grew up to around 2000 m in height over a time span of ca. 20 ky. The main effusive activity was interrupted around 22 ky BP by the trachytic Pomici di Base Plinian eruption [20], responsible of the formation of the breached crater and the deposition of a large debris avalanche in the submarine counterpart [17, 19]. The deposits of the AD 79 Pompeii Plinian eruption are represented by a widely dispersed pumice fallout and by numerous pyroclastic flow deposits arrived offshore Ercolano [18]. The AD 1631 eruption was followed by the last period of effusive activity (1638–1944). The Sarno river basin is an alluvial plain, that extend for about 440 km^2 (Fig. 1). Much of the coastal zone of the basin and many inland areas are strongly urbanized and industrialized is used for very intensive agriculture, mainly consisting of field horticulture, orchards, vineyards, chestnuts and greenhouse horticulture and floriculture. The upper Sarno valley is largely affected by the presence of numerous leather tanneries, several chemical-pharmaceutical, engineering and manufacturing industries [9]. The Sorrento Peninsula bounding the southern margin of the Naples bay, it is characterized by a thick meso-cenozoic succession of limestone and dolomite covered by clastic sediments. These latter are made up of clastic deposits of Miocenic succession in the western part of the Peninsula and by tephra deposits from Vesuvius and Campi Flegrei that cover the carbonatic relief (Fig.1).

A geochemical prospect was conducted in the Sarno Plain by several authors [e.g. 1, 5, 2, 9, 3]. In particular [3] performed a factor analysis to assess the nature and the extent of contamination sources for the river sediments. The results individuate two main environmental areas: one contaminated mainly by metals of natural origin, corresponding to the hilly and mountain areas; and another moderately to very highly contaminated by metals of anthropogenic sources, corresponding to the economically developed areas in the plain and distinguishing between agricultural, tannery, traffic, and other sources.

Data set and Methodology

A total of 91 sediment samples have been collected by van Veen grab along a transect (long about 9 km) offshore the Sarno Plain coast of (Fig. 1). In particular, surface sediment samples were analyzed for grain size, organic matter, nutrients (TOC, TN, TP) and heavy metals (Hg, Cd, As, Cr, Ni, Cu, Zn, Pb, Fe and Mn). Standardized procedures for sampling, transport and handling sediments were adopted. A first aliquot of sediments sample were stored in clean polyethylene bags and frozen at +4/+6 °C for the physical analyses, whereas a second aliquot was stored in decontaminated HDPE (High-Density Polyethylene) containers at -18°/-25 °C for the chemical analyses.

The granulometric features of sediments were determined with Laser diffraction granulometry (Laser Particle-Size Analyzer). Samples for grain size analysis were treated with H_2O_2 solution, aiming at removing organic constituents and support deflocculating, then washed and dried at 40 °C, and analyzed following the ICRAM Manual Procedure [12]. Trace elements were determined by inductively coupled plasma mass spectrometry (ICP-MS) (EPA Method 6020) after strong acid digestion (HF + HNO3) of sediments in a microwave oven (EPA Method 3052).

TOC and TN were determined according to ICRAM Method [12], whereas TP content was assessed following APAT IRSA-CNR 4110 [4] spectrophotometric method using a Varian Cary 50 spectrometer.

SIMCA 17.01 Program (17, MKS Umetrics AB, Sweden) was used to perform multivariate statistical analyses [10]. The dataset is constituted by 91 sites and 21 variables referring to the absolute values of concentration of As, Cd, Cr_{tot}, Cu, Hg, Ni, Pb, Zn, Fe and Mn, the total organic carbon (TOC), total nitrogen (TN), total phosphorous (TP), including also the percentage of the Wentworth size classes for granulometry. Prior to statistical analysis, log-transformation was performed on variables as well as scaling to unit-variance [24]. On the other hand, STATISTICA 10.0 was used to perform the ANOVA analysis aming to investigate significant differences in metal concentration according to different factors (organic matter and granulometry). The experimental design incorporated independent factor "granulometry" setting up five (5) classes: “silty” class that includes samples with a predominance of the fine fraction (clay+silt) content (more than 55 %); the “sandy” class that includes samples with a predominance of sand fraction (more than 55 %); “mix” class accounting for the remaining cases and other two classes named “silty-coarse” and “sandy-coarse” that include samples in which the “coarse” fraction display content from 2-10 % within the two main classes group ("silty" and "sandy"). As for the independent factor "Organic matter content" expressed in term of TOC, three different range-concentrations were defined: “low TOC”, from 0 to 1 %; “medium TOC”, from 1-3 %; and “high TOC”, more than 3 %.

Finally, regression analyses applying Pearson Correlation were conducted to analyze the correlation between Metal content and the TOC content or granulometry fractions.

Results and Discussion

The study area displays different sediment features in terms of grain size (Fig. 2) with a prevalence of sandy and silty fraction ranging in the intervals of 7÷96 %w and 3÷72 %w respectively.

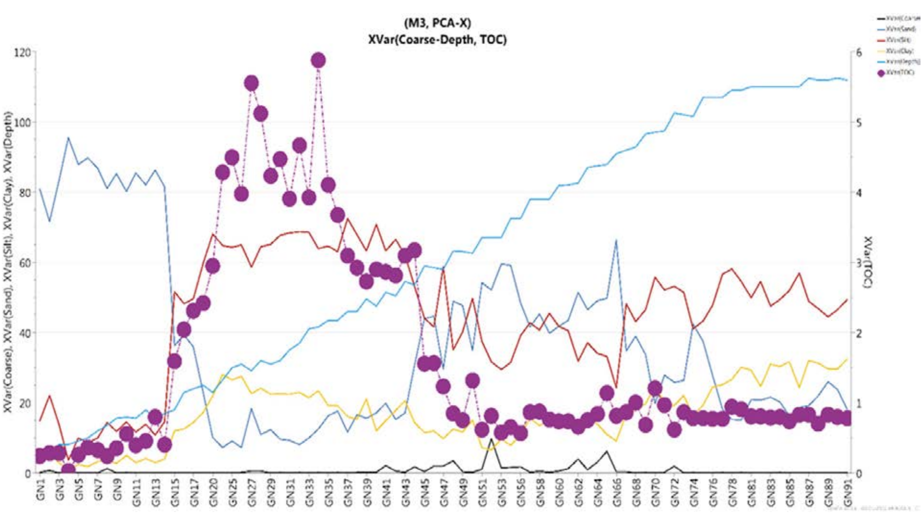

Figure 2 – Comparison between grain size, TOC percentages and water depth in the sediment samples.

On the base of the granulometric distribution, it is possible to recognize four sectors. Sediments, collected between the samples GN1 – GN17 in correspondence of Torre Annunziata (TA) shoreline, are mainly composed of sand (up to 96 W%) and by a minor amount of silty and clay fraction. The second sector, between the samples GN18 - GN42-43, of the track displays a heterogeneous granulometric content with a silty fraction that represents the main component reaching more than 60 %. The third sector, between the samples GN44 – GN71, displays sand and silt that are represented with a similar percentage between 30 % and 60 %, whereas the clay is below the 20%, furthermore, it is important to note the presence of gravel between the 0 and 10 %. Finally, the fourth sector, between the samples GN72-GN91, at a water depth of more than 100 m increase the presence of clay that reach the 30 % and of the silt until the 60 %, whereas decrease the sand around the 20 %.

On the other side, the organic matter (expressed in terms of TOC) spans an unusually large range from 0.01 up to 5.88 %w. The highest concentrations of TOC are displayed offshore the Sarno alluvial plain where TOC reached 5.88 %w. This value is higher respect to that detected in an adjacent area, corresponding offshore Naples, ranging between 0.05 % and 4 % [22]. As can be seen from the plot of TOC content in the plot of the grain size curve (Fig. 2), a "bell" of high TOC area is displayed in the second sector (B). On the other side, the sector A displays low TOC content, whereas the third and fourth sectors (C and D) show a medium TOC content (lower than 3 %).

A positive correlation of the TOC concentration versus the finest grain size fractions (clay and/or silt) is also verified, as can be inferred by the Pearson coefficients TOC *vs* fine grain size (clay and silt) (Table S2). The close association of the two components can be explained by (1) the capacity of the finest particles to hinder the diffusion of the oxygen into the sediments, that induce the preservation of organic matter, and (2) the adsorption of organic particles onto the charged surfaces of the clay minerals [16,11, 8, 15].

The distribution of the heavy metals is represented through the box and whisker plots in Figure 3 reporting a summary of the basic statistics of the concentrations of trace metals analyzed in the study area.

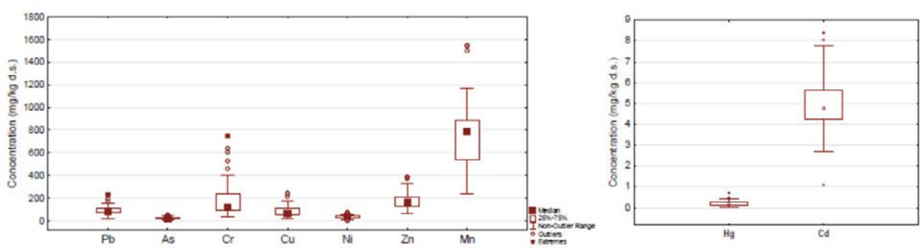

Figure 3 – The box and whisker plot for Pb, As, Cr, Cu, Ni, Zn, Mn and for Hg, Cd.

ANOVA analysis

Aiming at understanding the influence of organic matter content, one-way ANOVA has been performed using as independent factor the TOC content, this approach highlighted the presence of two groups of metals displaying a distinguished trend (Fig. 4): Cr, Cd, Cu, Pb and Zn concentrations increase with increasing of TOC content, while for Fe, Mn, As and Ni a decrease concentration is logged with increasing of TOC content. An irregular trend is displayed by Hg, albeit to a less extent the average concentration of As and Ni within the three classes-groups (low TOC content, high and medium).

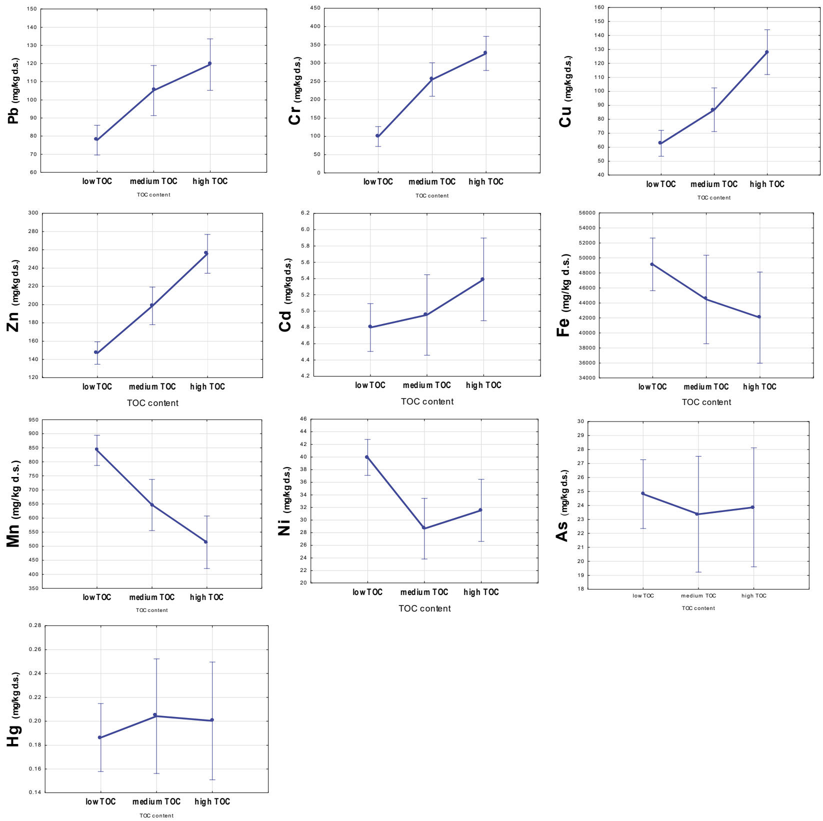

Figure 4 – One-way ANOVA representing variability of the concentration of Pb, Cr, Cu, Zn, Cd, Fe, Mn, Ni, As and Hg within the different TOC content classes defined. The vertical bars denote 0.95 confidence intervals. Wilks lambda=.26442, F(20, 158)=7.4632, p=.00000.

Similarly, the average concentration of metals according to the fixed classes of granulometry were also investigated.

Nevertheless, high variability is detected for same metals when coarser fraction appears. Some studies have indicated that coarser particles show a higher heavy metal concentration than finer ones and the presence of coarser particles are possibly responsible for higher metal content in the coarser size fractions [23, 21]. In our case, this trend is confirmed noticeably for almost all metals (Fig. 5). We can suppose that the heterogeneity of the behaviors of metals with granulometry can be related to the different affinity of these metal for different mineralogical phases (ion-exchangeable, carbonate, organic, iron-oxy-hydroxide, sulphides etc.) of sediments [6, 13, 14].

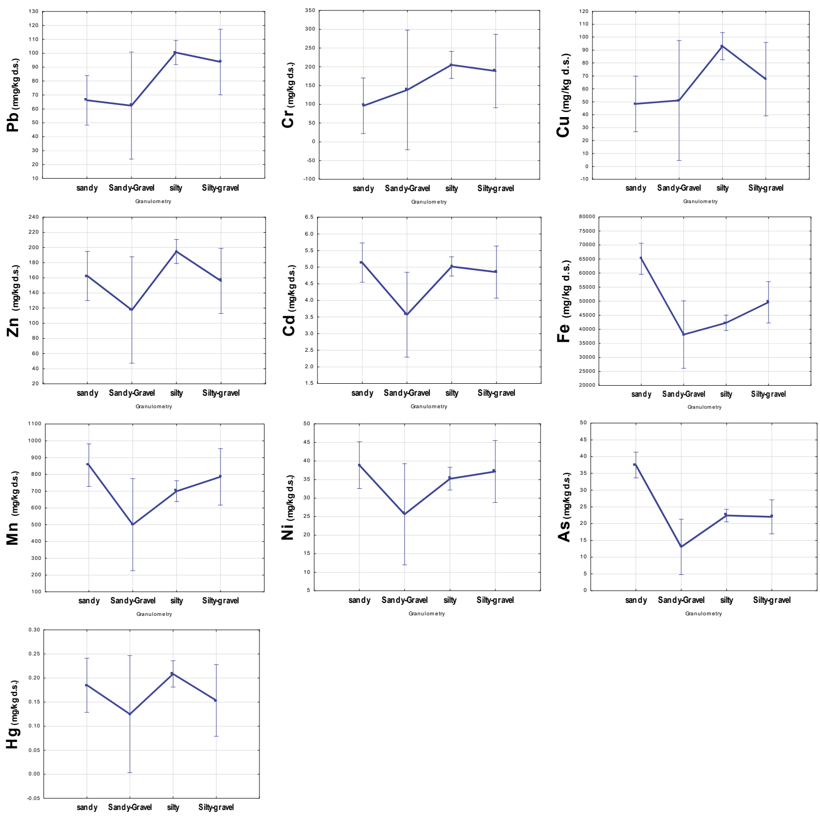

Figure 5 – One-way ANOVA representing variability of the concentration of Pb, Cr, Cu, Zn, Cd, Fe, Mn, Ni, As and Hg within the different Granulometry classes defined. The vertical bars denote 0.95 confidence intervals. Wilks lambda=.24876, F(30, 209.08)=4.2261, p=.00000.

Natural *vs* anthropogenic sources

Tacking in account the heterogeneous lithological substrate of the area that include volcanoclastic sediments reach in heavy metals, to further evaluate whether the metals in this study were influenced by natural or anthropogenic sources the results of this study has been compared with the published data collected onshore. The comparison permitted us to evaluate anthropogenic sources and to bound the area of the influence of the Sarno Plain sediments in the Naples Bay. Among other, the paper of [3] identified metal associations that has been linked to natural or anthropogenic origin. The authors recognize four metals association: F1 (As, La, Al, Mn, U, Fe) associated to the pyroclastics volcanic soils; F2 (Sr, K, P, V, Cu, Co, U) typical of agricultural areas; F3 (Zn, Pb, Cd, Sb, Hg) due to the human activities; and F4 (Ni, Cr, Fe) associated to the tannery district.

Statistical analysis reveals a positive correlation between Fe, As and Mn with the coarse grained sediments and Low TOC percentage. Tacking in account the position of tsamples offshore Vesuvio slope, we can interpret a natural origin for these contaminants mostly controlled by the presence of pyroclastics and volcanic deposits covering hilly and mountain areas surrounding the Naples Bay. Relatively high values of As also characterize sediments collected onshore at the slopes of Vesuvio. Furthermore, this interpretation is in accord with the F1 association of [3]. Some metals as Zn, Cu, Cr and Pb are correlated to the high percentage of silt and high percentage of TOC. These metals are included in the F2, F3 and F4 metal associations of [3] and result linked to the contamination of anthropogenic origin. In addition, the correlation between Zn, Cu, Cr and Pb silt and high percentage of TOC is characteristic of the samples located offshore the Sarno river suggesting that these deposits are the result of the river discharges reflecting the anthropogenic pressure of the receiving Sarno Plain. Between them it is not possible to discriminate from agricultural, human activities and that from tannery district because all are collected in the river and discharged in the sea in correspondence to the Sarno delta. Hg and Cd that are more widely distributed suggesting a mixed origin. Both elements might reflect influence of both human induced discharges (traffic ships, wastewater discharges, etc.) as well as natural phenomena related to the phosphorous (of anthropogenic origin) absorption to the clay fractions that act as carrier for these metals.

The distribution of the contaminant along the tract permit to define a boundary to the major influence of the Sarno delta in the marine environment until the water depth of 60 m.

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DETERMINATION OF NATURAL RADIOACTIVITY LEVELS OF SLUDGES COLLECTED FROM WASTEWATER TREATMENT PLANTS OF ANTALYA/TÜRKİYE

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Abstract – To determine whether the use of wastewater treatment sludge in agricultural areas poses any radiological risk or not, both natural ^{226}Ra, ^{232}Th, ^{40}K and artificial ^{137}Cs radionuclide activity concentration levels of the sludges, collected from wastewater treatment plants located in Alanya, Beldibi, Belek, Çamyuva, Göynük, Hurma, Kemer, Serik, Side and Tekirova districts of Antalya were assessed. Measurement results of the wastewater sludge samples indicate the existence of natural (^{226}Ra, ^{228}Ac, ^{40}K) and artificial radionuclides (^{137}Cs) from the Chernobyl accident and other nuclear activities. The calculated mean ^{226}Ra (10.8 Bq kg^{-1}), ^{232}Th (13.4 Bq kg^{-1}) and ^{40}K (135.7 Bq kg^{-1}) and ^{137}Cs (3.2 Bq kg^{-1}) activity concentrations of the sludges were observed to be below the world average. Findings were found to be consistent with the published results in the literature for Turkey and other countries. The absorbed gamma dose rate (D: 3.1 - 17.5 nGyh^{-1}), radium equivalent activity (Ra_{eq}: 6.4 - 37.7 Bq kg^{-1}), annual equivalent dose (AED: 3.8 – 21.4 µSv h^{-1}), internal ($H_{in}<1.0$) and external ($H_{ex}<1.0$) hazard indices were calculated by using sample activity concentrations. The radiological risk indices (D, Ra_{eq} and AED) are in the permissible limits published by IAEA. As a result, it was observed that the use of wastewater treatment sludge in agricultural areas would not create any risk in radiological terms.

Introduction

Urban wastewater sludge is an end product of urban wastewater treatment and contains many pollutants left over from wastewater treatment. Sewage sludge is a concentrated solids suspension, which consists mostly of organic solids loaded with mineral salts and whose density can vary in slurry or dry form depending on the treatment technique. Today, the agricultural use of sewage sludge is accepted as an economical alternative disposal method compared to other disposal methods. The common finding of the studies carried out to date is that sludge has an economic value in plant cultivation, but pollutants that can mix into the sludge significantly limit their use. Increasing interest and encouragement in the use of sewage sludge, which contains many pathogens and pollutants, is creating increasing social concern over the environmental consequences and potential health hazards of these recycling practices. The production of large quantities of sewage sludge in urban areas, which may contain relatively high levels of salt and heavy metals and other harmful organic pollutants, increases the need for solutions for the safe disposal of

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this material without causing new ecological problems.

In recent years, the use of sewage sludge in agriculture has been made safer with legal regulations regarding the use of sewage sludge in agricultural lands. However, studies on radioactive contamination of sewage sludge are very limited. In this study, sludge from treatment plants in Antalya region will be evaluated in terms of radioactivity pollution.

Materials and Methods

Sludge samples were collected from wastewater treatment plants located around Alanya, Beldibi, Belek, Çamyuva, Göynük, Hurma, Kemer, Serik, Side and Tekirova districts of Antalya province of Türkiye on a monthly basis for one year (Figure 1).

Figure 1 – Study area.

The sludges were numbered and labeled after they were transferred to the sample preparation laboratory of Akdeniz University, Faculty of Science, Department of Physics. Foreign substances and impurities in each sludge sample were removed. Before the measurements, all sludge samples were stored (air-dried) 4–7 d until they reached a constant weight in a ventilated room. All samples were homogenised with the grinding machine and then sieved through a 2-mm mesh in the sample preparation laboratory. The sieved samples were then filled into hermetically sealed (6cm x 5cm) 150 cc polyethylene cylindrical containers, labelled,weighed and stored for 4 weeks in order to reach secular equilibrium between ^{226}Ra and ^{222}Rn prior to counting. Approximately 5 g of sludge from each sample were put in 6-cm diameter cylindrical containers and dried at 80 ˚C for 14 h to determine the moisture rate of the samples.

Radioactivity measurement was conducted by using a p-type, coaxial, electrically cooled, high-purity germanium gamma-ray detector AMATEK-ORTEC with Full Width Half Maximum (FWHM) at 122 keV for ^{57}Co and 1.85-keV FWHM at 1332 keV for ^{60}Co. It is connected to an NIM consisting of ORTEC bias supply, spectroscopy amplifier, analogue-to-digital converter and a computer. The detector was placed into a 10-cm thick lead shield with an inner surface covered by a 2-mm thick copper foil to shield from the x-rays originating in lead. Data acquisition and analysis were carried out with MAESTRO32 software.

All samples were placed to the front face of the detector and counted for 50 000 s. Background intensities were obtained with an empty beaker for 50 000 s under the same conditions before and after measurement of the samples. Then, the average of the background counts was subtracted from the sample spectrums. ^{238}U and ^{232}Th activity concentrations were determined from their daughter products indirectly, while ^{137}Cs and ^{40}K were determined directly by their gamma-ray peaks. To determine the activity concentration of the ^{238}U nuclide, daughter nuclides ^{214}Pb and ^{214}Bi were used, while ^{228}Ac concentration was chosen for the parent ^{232}Th. The gamma transitions of 351.9 keV ^{214}Pb and 609.3 keV ^{214}Bi were used to determine the concentrations of ^{238}U. The gamma transition of 911.2 keV ^{228}Ac was used to determine the concentration of ^{232}Th. 661.6 keV and 1461.0 keV gamma transitions were used to determine the concentration of ^{137}Cs and ^{40}K, respectively. Details of the activity and dose calculations were presented by Ozmen et.al.

Results and Discussion

Measurement results of the wastewater sludge samples indicate the existence of natural (^{226}Ra, ^{228}Ac, ^{40}K) and artificial radionuclides (^{137}Cs) from the Chernobyl accident and other nuclear activities. Activity concentration levels of the sludges were presented in Figure 2.

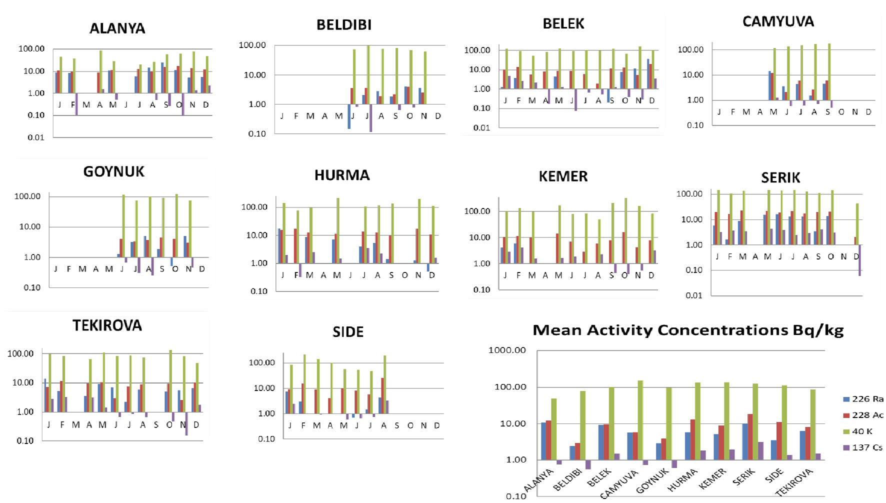

Figure 2 – ^{226}Ra, ^{228}Ac, ^{40}K and ^{137}Cs activity concentrations of Sludges in Bq/kg.

The calculated mean ^{226}Ra (10.8 Bq kg^{-1}), ^{232}Th (13.4 Bq kg^{-1}) and ^{40}K (135.7 Bq kg^{-1}) and ^{137}Cs (3.2 Bq kg^{-1}) activity concentrations of the sludges were observed to be below the world average UNSCEAR (2000). Findings were found to be consistent with the published results in the literature for Türkiye and other countries (Table 1).

Table 1 – Radionuclide activity concentrations of soil samples from Literature (in Bq/kg).

Country	**^{226}Ra**	**^{232}Th**	**^{40}K**	**Reference**
Türkiye	29	22	464	Yaprak & Aslani (2010)
Greece	16	55	305	Ioannides et.al. (1997)
Hong Kong	59	95	530	Wong et.al. (1999)
India	57	87	143	Singh et.al. (2005)
Pakistan	51	59	665	Chauhry et.al. (2002)
Serbia	60	49	379	Dugalic et.al. (2010)
Yugoslavia	39	53	554	Bikit vet.al. (2001)
Bosnia Herzigova	32	32	331	Kasumovic et.al. (2015)
Italy	79	48	640	Guidotti et.al. (2015)
World Mean	35	30	400	UNSCEAR (2000)
Present study	2.4-5.7	3.0-5.8	79-150	

In order to determine the health effects, radiologic risk parameters (D, Raeq,AED, Hex and Hin) of the sludges are calculated and results were presented in Figure 3.

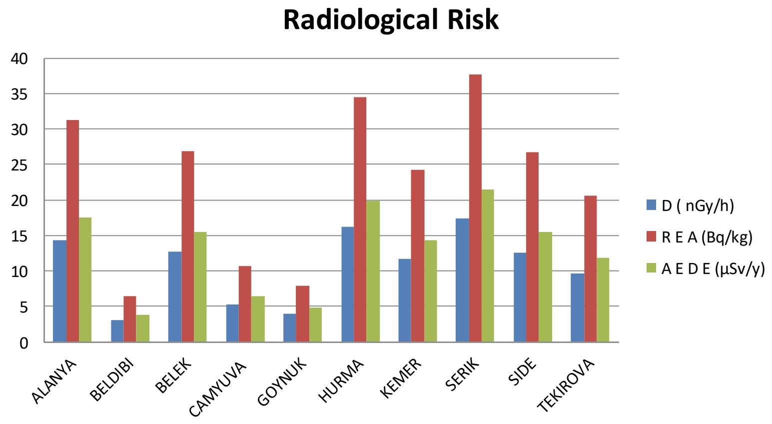

Figure 3 – Mean D, Ra_{eq} and AED values of Sludges.

The absorbed gamma dose rate (D: 3.1 - 17.5 $nGyh^{-1}$), radium equivalent activity (Ra_{eq}: 6.4 - 37.7 Bq kg^{-1}), annual equivalent dose (AED: 3.8 – 21.4 μSv h^{-1}), internal (H_{in}<1.0) and external (H_{ex}<1.0) hazard indices were calculated by using sample activity concentrations. The calculated average values for D, Ra_{eq} and AED are in the permissible limits published by IAEA.

Conclusion

Radionuclide concentrations of waste water sludge samples around Antalya were determined by the present study. Findings were lower or comparable to the literature levels for soil samples around the world. Moreover, annual effective dose exposure due to the radioactivity content of sludges was not very high to pose a serious health risk.

We can conclude that the use of wastewater treatment sludge in agricultural areas would not create any risk in radiological terms. In terms of chemical properties, the Cs element is remarkably similar to the element K, which is a plant nutrient and is consumed significantly by plants. Since sewage sludge contains ^{137}Cs even in low concentrations, it is obvious that care should be taken both in its use in agricultural areas and in discharges to the open sea and similar situations.

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ANALYSIS OF THE LIMITS FOR THE DETECTION OF SMALL GARBAGE ISLAND IMMERSED IN CLUTTER RADAR

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Abstract – The aim of this work is to show the limits of the detection capacity of X-band radars, as the sea state changes, in order to identify, discriminate, characterize and track small floating aggregations of marine litter (Small Garbage Island - SGIs) consisting mainly of plastic. To this end, two distinct radar measurement campaigns were conducted with controlled releases at sea of SGI modules assembled in the laboratory. The measurement campaigns were carried out respectively in conditions of calm sea and almost no wind, in order to test the system in ideal conditions, and in rough sea conditions and presence of wind. The analysis of the data acquired during the experiments confirmed the ability of the X-band radars to detect the aggregations of floating waste on the sea surface, also demonstrating that the state of the sea that characterized the two measurement campaigns identifies the limits within which radars can be used for monitoring plastic marine litters.

Introduction

Although plastic is a very useful material, due to its progressive accumulation in oceans all over the world, it has become one of the great environmental, economic and social problems of our time [1]. Among the different types of waste present in the oceans, plastic is the most abundant material, it is estimated that 75 % of the waste that contaminates ocean habitats is made up of plastic [2–4]. Furthermore, plastic is omnipresent, due to its widespread use in every corner of the planet, and durable over time, since its degradation is extremely slow. Moreover, due to its great mobility, it can travel very far from its point of entry into the environment, since the degradation times of the plastic are much longer than its transport scales [4-7]. The impact of plastic on marine habitats and organisms is very worrying, so much so that it represents a serious threat to the biodiversity of the oceans [8].

To respond to the various problems associated with the dispersion and accumulation of plastic in the sea, the world scientific community is producing an important research effort aimed both at studying the impact of plastic on marine organisms and ecosystems, and at monitoring the movements and accumulations of plastic waste in the oceans. For a review of the different types of marine litter and plastic monitoring, readers are referred to [9-17].

This manuscript presents the results of a research activity for the study of the evolution of plastics floating on the sea surface based on the use of X-band radars. Marine litter monitoring techniques based on remote sensing are still in their infancy and are mainly based on technologies not developed specifically for marine plastics, X-band radar is one of them.

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Remote sensing techniques make it possible to provide uniform observation coverage of large areas of the ocean and coasts. However, due to the great variability of the specific characteristics of marine litter (e.g. size, shape, chemical composition, type and buoyancy), no remote sensing technique is capable of returning information with a sufficient level of accuracy. Therefore, to respond to particular observation needs, it is necessary to integrate different technologies.

Under favorable conditions (e.g. no cloud cover), photographic images can provide very detailed information on marine litter. The technologies available today make it possible to work at different resolutions, from a few cm of the cameras installed on board the aircraft, up to 30-50 cm of commercial satellite images at higher resolution.

Spectroscopy is based on the acquisition of the unique spectral signatures of the polymers that make up marine plastic waste. However, for a correct identification of plastics, it is necessary to create a database of the characteristic spectra of the different types of waste based on laboratory and local experiments.

Synthetic Aperture Radars (SAR), currently used in the oceanographic field to detect high-resolution information on the ocean surface (e.g. topography, roughness, surface waves, winds and currents), are among the most promising technologies for detecting marine litter as they allow observations to be made both day and night and in all weather conditions.

Raman spectroscopy is a relatively new technology which, unlike other detection methods, has the potential to detect particles suspended below the sea surface as well. This technology is still under development and its actual monitoring capabilities require fine-tuning both in the field and in the laboratory. For a review of remote sensing techniques for marine litter monitoring, readers are referred to [18-21].

X-band radars were born mainly as navigation support tools, however, thanks to their ability to detect targets at sea, they have also assumed a very important role in the oceanographic field, where they are used for remote monitoring of the physical state of the sea and reconstruction of the field of surface currents and bathymetry [22-25].

The study of the intensity of the backscattered radar signal from plastic targets floating on the sea surface [26] has shown that in calm sea conditions and almost no wind, X-band radars are able to discriminate and characterize these kinds of objects. The purpose of this report is to identify the limits of the detection capability of X-band radars, as the state of the sea increases.

Material and methods

The radar used for the measurement campaign was a Consilium/Selesmar SRT Xband, 25 kW with a 9” feet antenna length and was purchased by the National Research Council (CNR) of Italy with funds of RITMARE project and installed on the roof of the “Scoglio della Regina” building in Livorno at coordinates Lat: 43_32021.1000N and Lon: 10_17058.9000E. The measurement campaigns were conducted in the stretch of sea in front of the IBE–CNR headquarters, located at the southern entrance of the port of Livorno.

The sea area on which the survey was conducted has a radius of about 0,98 nautical miles and is characterized by intense maritime traffic and by the presence of various signals (buoys, lighthouses, lights, etc.) which testify to the existence of navigation hazards. Figure 1 shows the study area on google map and the corresponding radar image.

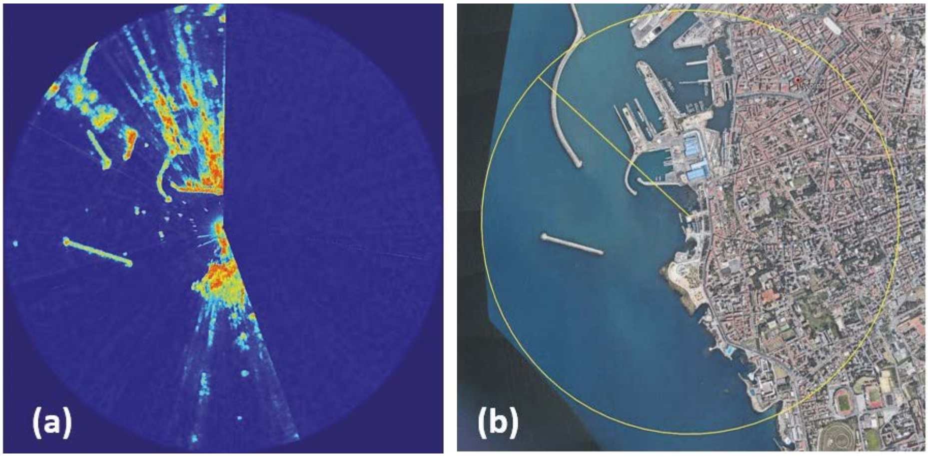

Figure 1 – Aerial image of the survey area (Google, images ©2019 CNES).

To verify the ability of an X-band radar to identify and track small aggregations of floating waste in the sea and to have repeatable and standardizable measurements, it was first of all necessary to manufacture in the laboratory 4 SGI modules with the following characteristics: a module/target T0, of the size 1 m x 1 m, consisting of mixed waste, which approximates the small aggregates of floating garbage; a module/target T1, measuring 1 m x 1 m, consisting mainly of plastic; a module/target T2 consisting of the union of three plastic bottles held together by a plastic band; a module/target T3 consisting of a single plastic bottle. For a detailed analysis on the construction methods of the modules used for the experiments, readers are referred to [26].

Two distinct measurement campaigns were conducted: the first in calm sea conditions, in order to verify the sensitivity of the radar in an ideal scenario; the second campaign in rough sea conditions (hs = 1,77 m) and presence of wind, in order to verify the upper limit of the target detection capability.

To evaluate the radar detection capabilities and understand the distance limits within which the radar is able to detect the presence of targets, in each of the measurement campaigns, three distinct target releases were made at three distances from the antenna: first release 0,12 nautical miles; second release 0,24 nautical miles, third release 0,39 nautical miles.

To define the radar's ability to detect SGIs, an analysis of the intensity of the radar signal received and reflected by the modules released into the sea was carried out. The radar worked for the entire duration of the measurement campaigns, recording the raw data which were subsequently analyzed in the laboratory. The step-by-step sequence of the radar data analysis procedure used to identify the targets in the first measurement campaign is given below:

1. Identification of the targets on the radar image using photographic images. This phase is essential to have spatial and temporal references to ensure the exact identification of the targets;

2. Extraction of mobile sub-areas containing the targets under investigation for each of the targets T0, T1, T2 and T3. Due to the presence of surface currents and wind, targets are subject to drift/leeway; therefore, it would be necessary to define mobile subareas that are able to "follow" the targets taking into account their speed;
3. Measurement of the maximum intensity value detected for each sub-area containing the targets T0, T1, T2 and T3 at each instant of time.

In the second measurement campaign, the intensity of the backscattered signal from the SGI is scarcely distinguishable from the average clutter of the sea (thus making it difficult to identify and recognize the modules), in this case the investigation was therefore focused only on the analysis of the sea average clurrer, in order to identify the upper limit of detection of targets using X-band radar technology.

Figure 2 contains the radar and photographic images relating to the first release of the first measurement campaign, and clearly shows that all the SGI modules (T0, T1, T2, T3), are clearly visible and distinguishable from the other targets in the area (e.g. signaling beacons: Buoy 1, Buoy 2, Buoy 3; boat and port infrastructures).

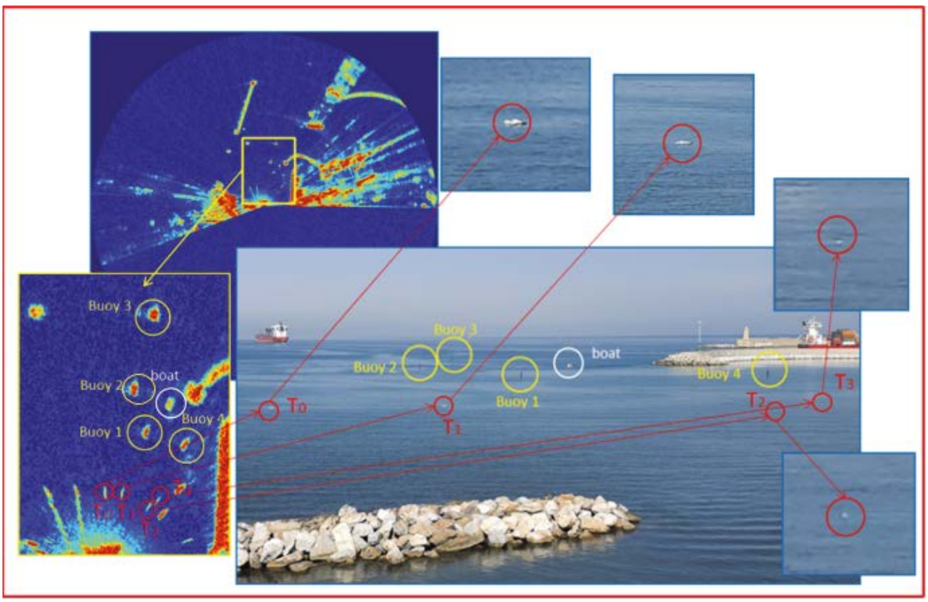

Figure 2 – Radar and photographic representations of the first release of the targets in calm sea conditions and no wind.

For an in-depth analysis of the radar signal received and reflected by the targets, readers are referred to [26].

Results

Figure 3 (a) shows the trend over time of the radar intensities of targets T0, T1, T2 and T3 normalized with respect to the maximum radar intensity recorded during the second release of the first measurement campaign. Figure 3 (b) shows the trend of the radar intensities of the targets related to the third release (unlike the previous two releases, only targets T0, T1 and T2 are visible, while target T3 was not detectable by the radar). The black line at the bottom of Figures 3 (a) and 3 (b) represents the average value of a sub-area containing only the clutter extracted in the vicinity of the area where the targets were released. The high intensity values highlighted by the arrows in Figure 3 (a) and 3 (b) for the target curves T1 (red line), T2 (green line) and T3 (yellow line) are due to the entry into the sub-area of the inflatable dinghy used for the releases; it follows that these extremely high intensity values are associated with the radar signal of the boat and not with that coming from the targets. Given the high radar reflectivity of the inflatable dinghy, this occurrence was recorded by the radar as a sudden rise (spike) in the radar intensity of the areola containing the targets until the inflatable dinghy left the sub-area.

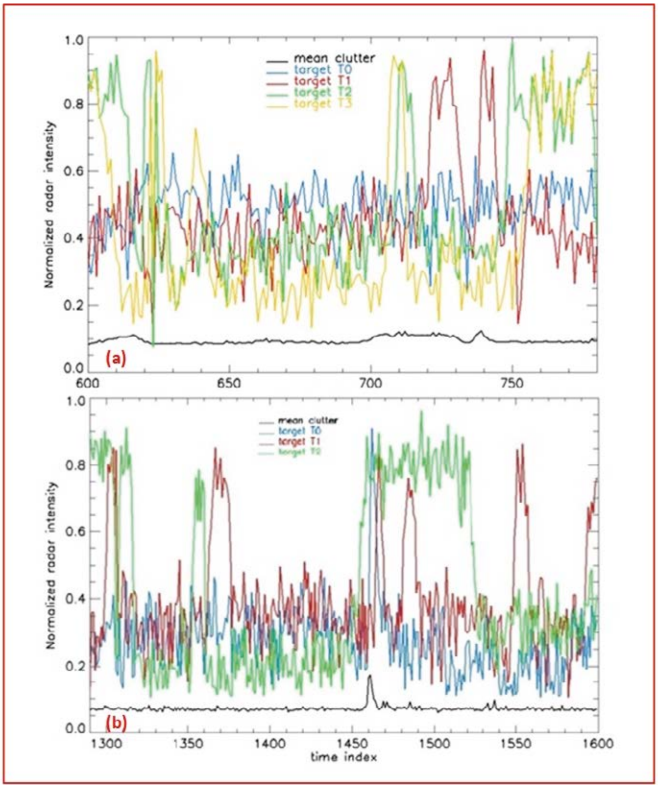

Figure 3 – Radar intensities of the targets related: to the second release (a) and the third release (b) of the first session of measures.

As already anticipated in “materials and methods”, due to the poor distinction of the backscattered signal from the targets compared to the average sea clutter, during the second measurement campaign the investigation was limited exclusively to the analysis of the marine clurrer, in order to identify the upper detection threshold of the targets through the X-band radar. In particular, Figure 4 compares the average clutter of the sea for the first measurement campaign (black line) and the average clutter for the second measurement campaign (red line). The image clearly shows that the average clutter of the sea relating to the second measurement campaign, conducted in rough sea conditions, has increased until it assumes values comparable to the intensity of the radar signal backscattered by the SGI modules during the second and third release of the first measurement campaign (respectively: 0,24 and 0,39 nautical miles). In the case of targets closer to the radar (0,12 nautical miles), the intensity of the backscattered signal from the SGI is barely distinguishable from the average clutter of the sea, also making it difficult to identify and recognize the modules in this case.

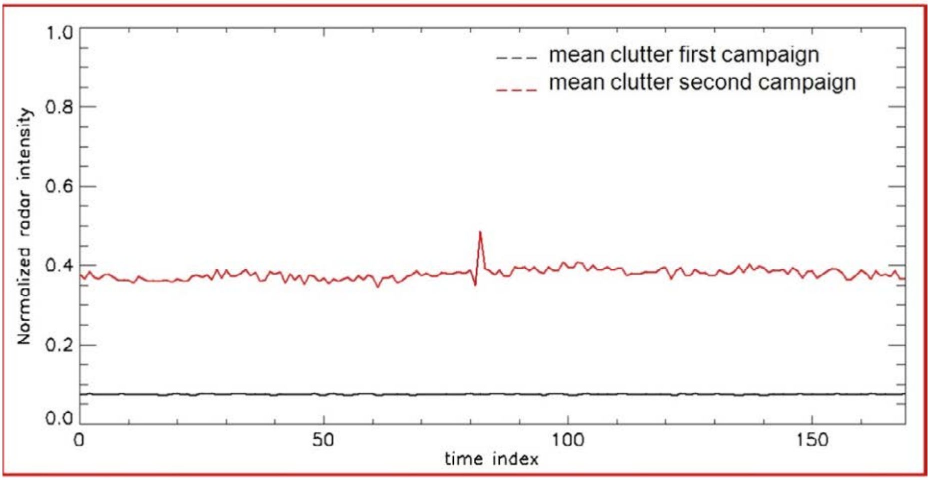

Figure 4 – Comparison between the average clutter of the sea during the first measurement campaign (black line) and that of the second measurement campaign (red line).

Discussion

As regards the identification and recognition of SGI modules, the following can be stated. During the first measurement campaign, characterized by calm sea and almost no wind: all targets, T0, T1, T2 and T3 (Figure 3), are clearly visible from the radar and can be clearly distinguished with respect to the average sea clutter.

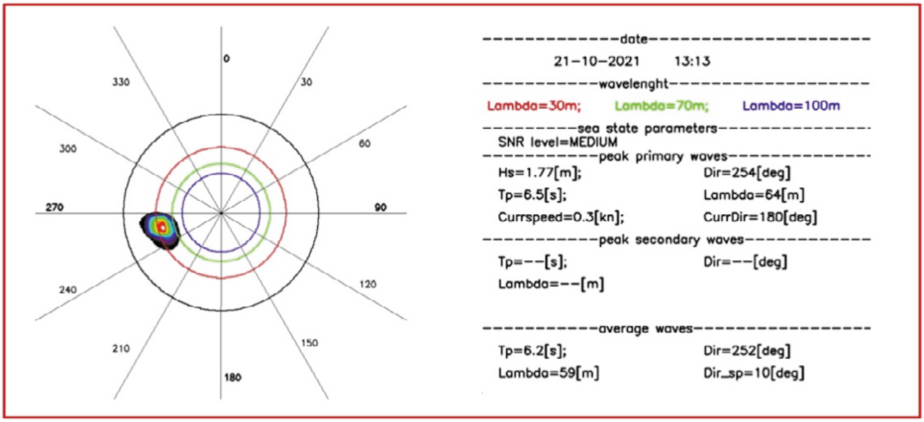

Figure 5 – Energy spectrum and sea state relating to the second measurement campaign.

In the conditions of the second measurement campaign, characterized instead by a sea state with hs = 1.7 m (as shown in Figure 5), the average sea clutter assumes values comparable to the intensity of the radar signal backscattered by the targets and detected during the first measurement campaign, it follows that the conditions of the second measurement campaign identify the sea state limit threshold beyond which the intensity of the backscattered signal from the targets mixes with the average clutter of the sea, making it difficult or ineffective to use radar for SGI monitoring purposes.

Conclusions

The purpose of the radar measurement campaigns illustrated in this work is: verifying the ability of an X-band radar to detect the presence of floating targets on the sea surface, mainly or exclusively made of plastic; define the limits of its use in terms of distance from the antenna, evaluating the performance of the radar system as the sea conditions increases; identify the sea state limit threshold beyond which the intensity of the backscattered signal from the targets is comparable with the average clutter of the sea, making the use of radar ineffective for SGI monitoring.

The results of the experiments showed that in calm sea conditions, the characteristics of the signal reflected by the SGIs are different, and therefore discriminable, from those reflected by other targets. In fact, in calm sea conditions and with almost no wind, the empirical data showed that the X-band radar distinguishes the targets of the experiment within the maximum distance of 0.39 nautical miles from the receiving antenna. Beyond this distance, the intensity of the signal received by the radar is very attenuated and no longer recognizable. In the sea state conditions that characterized the second measurement campaign, the average sea clutter is comparable with the signal backscattered by the targets; it follows therefore that these conditions can be identified as the limit threshold beyond which the monitoring of marine litter with an X-band radar is ineffective.

The conditions under which the two measurement campaigns were conducted therefore identify the limit thresholds within which it is possible to use the X-band radar for monitoring marine litter.

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EXTRACTION AND CHARACTERIZATION METHODS FOR MICROPLASTICS FROM ESTUARINE AND COASTAL SAMPLINGS – EXAMPLE OF THE 2019 TARA EXPEDITION

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Abstract – The Tara Microplastics 2019 mission aimed to investigate plastic pollution in rivers across different scientific fields of study: plastic chemistry, physical oceanography and marine biology. From May to November 2019, the Tara schooner collected samples from 9 of the main European rivers: Thames, Elbe, Rhine, Seine, Ebro, Rhone, Tiber, Garonne, Loire. The objectives of the present study are: i) to quantify the microplastic (MP) contamination and ii) to identify the chemical nature of microplastics. Long and tedious protocols are often necessary to extract and analyze microplastics from environmental samples. Thus, extraction methods and automated computer processing for polymer characterization were developed. Preliminary results for microplastics in the range of 500 µm – 10000 µm in Feret length from the river Tiber are presented. Most of the particles were between 800 µm and 1600 µm. The three main polymers found were polyethylene (PE), polypropylene (PP) and polystyrene (PS). These results must be compared to the results from other river to draw a consistent pattern. Their interpretation can be complex as they depend on seasons, run-offs, sampling date, and hydrodynamic features. Nevertheless, this investigation presents the advantage to apply a consistent methodological framework to very different sampling sites.

Introduction

Plastic materials are a combination of synthetic or natural polymers with additives. Thanks to their functional properties, lightness and low cost, their use is increasing worldwide since the 1950's. Because of poor waste management, a significant portion of them enters and persists in marine ecosystems.

The sources of marine plastics are diverse: they can originate from river and atmospheric transports, beach littering, and human activities at sea such as aquaculture, shipping and fishing [1]. As land-based sources are considered as the dominant input of plastics into oceans [1], [2] through rivers and run-off, studies on microplastics has recently shifted focus toward freshwater ecosystems.

Few studies have reported levels of plastic contamination of freshwater worldwide [3]. Sampling and characterization methods, studied size and reported units (for instance pieces or grams for the amount of plastics, m^2 or m^3 for the filtered water volume) vary significantly between different investigations [4]. It has been suggested that population density, levels of urbanization or industrialization, rainfall and artificial barriers play a major role in measured river-based microplastic concentrations [5].

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Concerning the identified polymers, polyethylene, polypropylene and polystyrene are predominant on surface waters due to their buoyancy and their widespread use in various industries [6].

To investigate plastic pollution in European rivers, the Tara schooner collected samples from 9 rivers: Thames, Elbe, Rhine, Seine, Ebro, Rhone, Tiber, Garonne, Loire (cf. Figure 1). Among the 19 partner laboratories, the Research Institute Dupuy de Lôme (Lorient, Fr) objectives are to quantify the microplastic contamination and to identify the chemical nature of microplastics. The study of microplastics in rivers can be more arduous than that of marine MP. Indeed, the large amount of organic and inorganic matters is a major obstacle to overcome for further analyses. Non-anthropogenic particles and biofouling could make polymer spectra identification more difficult. Although drawing a consistent pattern from the obtained results is complex - as they depend on the seasons, the run-offs on the sampling date, and the hydrodynamic features of the sampling station-, they will provide valuable data on European rivers. These data have the great advantage of having been acquired by the same methods, allowing a relevant comparison between samplings. For the specific case of the Mediterranean Sea, where plastic litter inputs are poorly understood [7], results from the Tiber river are presented. This work follows a previous investigation on plastic pollution of the Mediterranean Sea surface, and proposes some improvements to the original methodology.

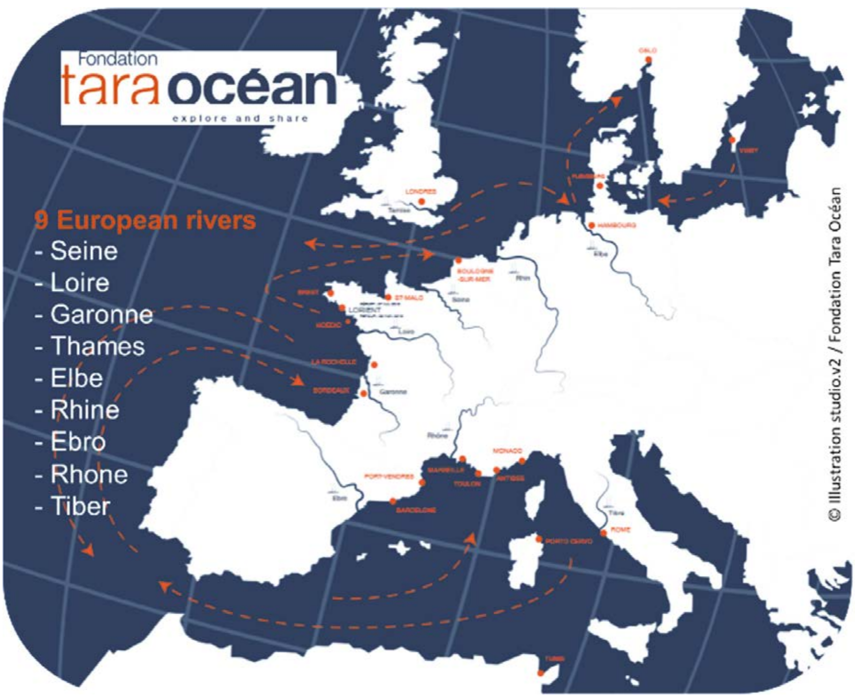

Figure 1 – Routes of the Tara Microplastics campaign in 2019.

Materials and Methods

Samplings were carried out in five sampling sites for each river (cf. Figure 2): i) at sea in front of the river mouth, ii) at the mouth with two salinity gradients, iii) downstream of the first city encountered (Roma for the Tiber), iv) upstream of this city. At each of these sites, numerous samplings were done to study plastic debris and the associated biota. To collect microplastics, a 300 µm-mesh size manta trawl was used to filter tens to hundreds of cubic meters of water (cf. Figure 2). Largest pieces of organic matter were removed (branches, leaves, algae, fishes…). Then, samples were stored in a freezer at -20 °C.

Figure 2 – Sampling sites along the Tiber River.

After defrosting in the lab, the remaining organic matter was digested with a combination of different chemical digestion processes, using acidic or alkaline solutions: a potassium hydroxide (10 % KOH) solution, a hydrogen peroxide (30 % H_2O_2) solution, the Fenton's reagent (H_2O_2 with an iron catalyst) [8]. Depending on the amount of organic matter, the process was adapted to every sample. Then, using a saturated sodium iodide (NaI) solution (density = 1.8 g/cm^3), high density inorganic matter was also removed. Filtrations through a 500 µm-mesh stainless-steel sieve were performed after each step. Afterwards, microplastics were rinsed, disposed in Petri dishes and dried at 50 °C (cf. Figure 4). For technical reasons, only microplastics superior to 500 µm to 5 mm were considered in the present study.

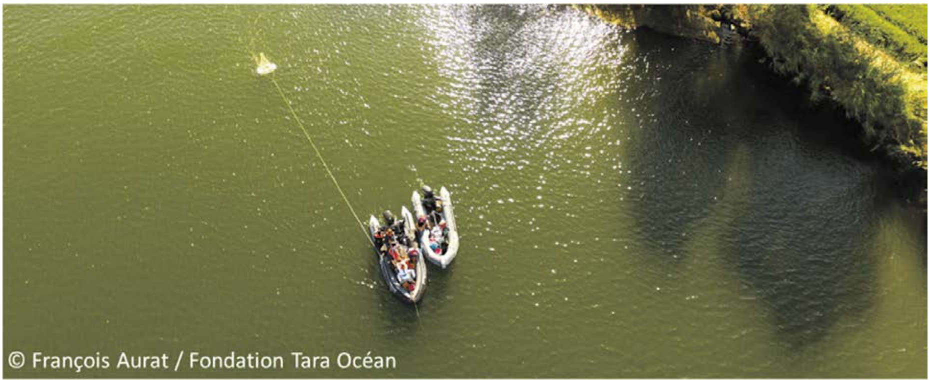

Figure 3 – In-use manta trawl during a sampling on the Tiber.

The Petri dishes were then photographed in high resolution images (Nikon D850 with an AF-S VR Micro-Nikkor 105 mm f/2.8G IF-ED lens). Particles were counted and measured using the Fiji image processing software (cf. Figure 4) [9]. Although particles below 500 µm were removed by sieving, some smaller ones could remain. They were excluded with the Fiji analysis (particles with area inferior to 500 µm-diameter circle area were not considered). Using a statistical approach, a particle random drawing enabled to limit the amount of work needed to analyze the extracted microplastics by infrared spectroscopy (ATR-FTIR). This method, developed in a previous study, allows to analyze only a statistically representative proportion of the total population of microplastics collected [10]. MP spectra were acquired using an Attenuated Total Reflection Fourier Transform Infrared spectrometer (ATR-FTIR Vertex70v, Bruker). All spectra were recorded in absorbance mode in the 4000–600 cm^{-1} region with a resolution of 4 cm^{-1} and 16 scans. All the spectra were then identified using the POSEIDON (Plastic pOllutionS ExtractIon, DetectiOn and aNalysis) software which was developed with R i386 3.1.2 [11].

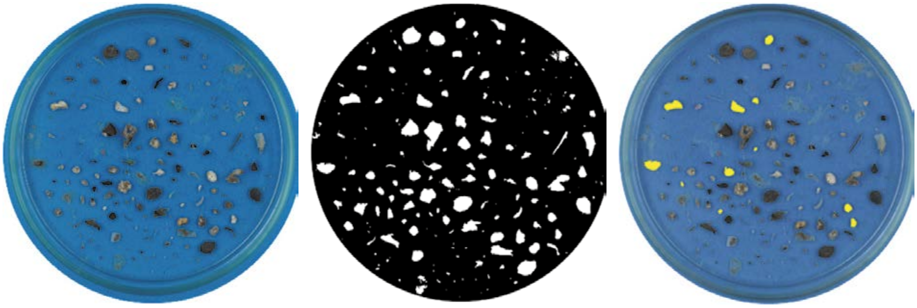
Figure 4 – From left to right: high definition photograph of a Petri dish containing the extracted microplastics; binary mask generated by Fiji after thresholding; randomly drawn particles colored in yellow.

Results and discussion

For the sampling site downstream of Roma, 1500 particles were detected. Most of them were in the size range of 800 µm to 1600 µm and showed a median value of 1066 µm in Feret length. Among them, 92 particles were randomly drawn to be analyzed by infrared spectroscopy. Their size distribution showed a shift to higher values and a significantly higher median value at 1698 µm. This gap suggests that the quantity of drawn particles was not sufficient to be representative of the whole particle population in this specific study. Further analyses are necessary to verify if this gap applies to every sample. However, the random draw process applied to the Petri dish photographs is crucial. Indeed, it allows to pick microplastics in the whole size range, and not only those that easily catch the human eye.

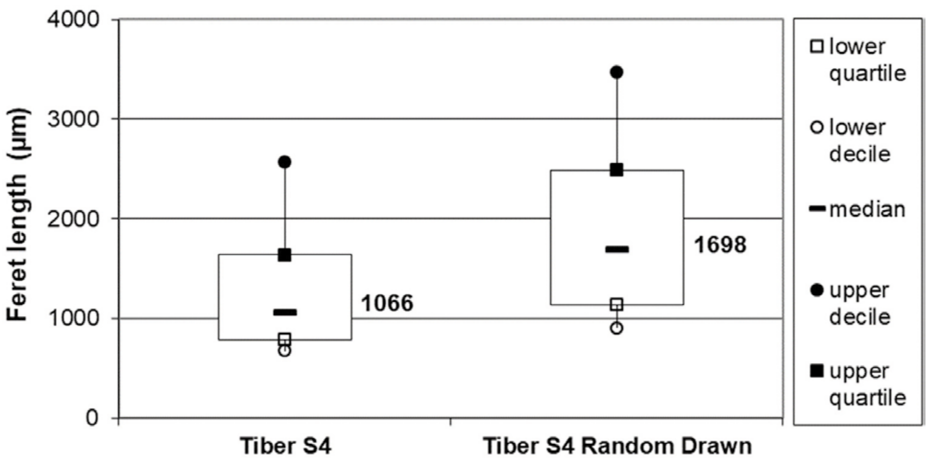

Figure 5 – Feret length of all detected particles and random drawn particles from Tiber S4 (downstream of Roma).

The preliminary results showed that polyethylene, polypropylene and polystyrene were predominant within the randomly drawn microplastics (cf. Figure 6).This is in congruence with polymers found in previous studies [3]. Indeed, their prevalence in numerous packaging products and various plastic parts is well known. Nevertheless, the unknown category is quite significant (10 %) and consists in unidentifiable particles and remaining organic matter. Thus, these results also suggest that more particles must be drawn and more efforts are necessary to increase the accuracy of the particle identification, compared to previous studies concerning the sea surface [6]. River samplings contain a high amount of organic matter and the extraction process is not sufficient to remove all organic matter.

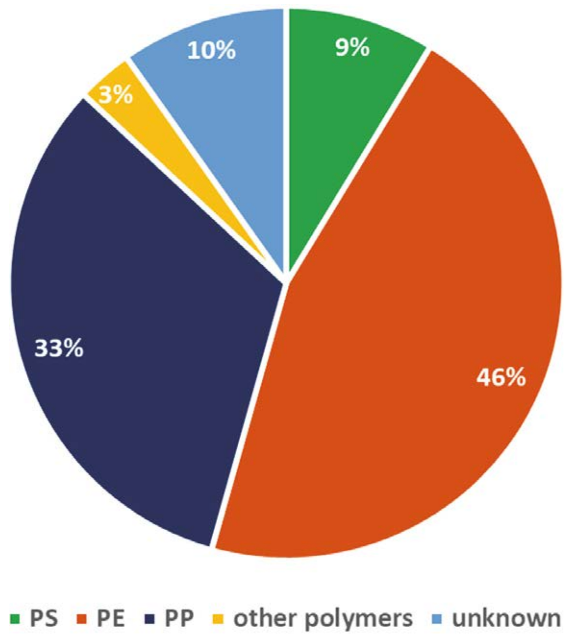

Figure 6 – Proportions of polymer types for randomly drawn microplastics from Tiber S4. PS: Polystyrene; PE: Polyethylene; PP: Polypropylene.

Conclusion

Manta trawl samplings, microplastic extraction and infrared polymer identification were carried out using similar protocols in 9 European rivers. Thus, this investigation presents the advantage to apply a consistent methodological framework to very different sampling sites.

Preliminary results showed that the extraction and characterization of plastic particles collected from rivers were significantly more arduous than marine plastics. Indeed, high amounts of organic and inorganic matter were found, making the extraction steps necessary to isolate the microplastics. Besides, these steps are often long and tedious and are potential sources of human mistakes, contamination or loss of microplastics. Regarding MP characterization, automated and statistical approaches were developed successfully but need more optimization efforts. Despite these experimental issues, these new data are precious to quantify the microplastic input from European rivers. The Tiber was investigated for the first time with these methods. Obtained results will help to understand microplastic concentration and chemical nature in the Mediterranean sea, especially in the Tyrrhenian sea [6]. For a complete understanding of the obtained results, the influence of the seasons and the hydrodynamic conditions must be understood. Moreover, temporal monitoring campaigns are crucial.

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NEW ARTIFICIAL REEF IN COASTAL PROTECTION RECONVERSION AND ELECTRIC POWER PRODUCTION

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Abstract – Sea energy is characterized by the conversion of offshore pulsing vertical wave energy into inshore horizontal current energy in the seabed transition of shallow coastal waters. These currents cause excessive erosion compared to natural summer-winter erosion, which, as is widely known, is greatly increased by anthropogenic activities. The issue therefore, is to contain the kinetic energy in excess of the sea currents. An "innovative aspect" is illustrated analyzing a standard vertical section of "sea approaching the coast" as (fig. 1). Coming from the offshore deep sea we found that the wind energy produces vertical pulsating waves only until the seabed reaches 10 or 12 m depth. At this point a great number of water particles start moving horizontally to the coast, triggering a very strong horizontal current, just below the sea surface, which causes flooding and erosion, accentuated on the seabed by return currents. This stream is so regular that it produces a very calm zone until the seabed reaches about 5 or 6 meters, where the "heavy zone" starts. In the calm zone we propose to install series of "impeller wheels" in order to: 1) generate *electric power,* 2) diminish water velocity leaving sand in suspension with the result of *no more erosion but nourishment.* The proposal is to dampen the currents by means of artificial reefs positioned in the "calm belt zone". This is certainly brought about by the abovementioned energy conversion, which mimics the location of coral reefs. This makes it possible to overcome the delicate problem of maintenance of the new reef, which is situated far from the storm area. In contrast, the annual costs of upkeep of artificial nourishment and of breakwater barriers are very high and add to public spending. Coastal and seabed monitoring, particularly by satellite, has highlighted for many years the fact that breakwaters, rather than reducing erosion, have exacerbated it, to the extent that in America breakwaters have recently been banned. The proposal is therefore to reconvert existing coastal protection works by substituting breakwaters with an artificial reef, specially *integrated with new sea energy* productions. The impeller is between the floats and the blades are semi-submerged, close to an indifferent buoyancy, in order to favor the number of revolutions even at minimum currents. Moreover, they allow seagrass (posidonia nurseries) to grow in the protected area of the seabed, thus favoring the repopulation of fish stocks. The banking of the beaches also counteracts flooding, caused by the rising of the sea level, with further benefits deriving from every square meter of beach reclaimed for use by beach resorts. It should be emphasized that in eolic and fotovoltaic electricity production there are fewer hours of energy production, without the *beach recovery benefits*. The cost of a barrier is competitive with those of eolic offshore energy, especially floaters, and with the breakwaters and artificial nourishment. As regards the *regulatory context*, it is worth noting that the NTC2018 standard allows for the employment of the observational method where *initial experimental worksite criteria* must be respected.

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Pierfranco Ventura, Manlio Palmarocchi, Claudio Domeniconi, *New artificial reef in coastal protection reconversion and electric power production,* pp. 568-580 10.36253/979-12-215-0030-1.53

1 State of the art and innovative aspects

With regard to the production of energy from the sea (Bianchi 2012, ENEA 2022) a dozen types of solutions have been created with over 5700 patents in various countries, especially the WEC Wave Energy Converter: from Emec's vertical offshore pistons, to Flotec horizontal floats in Scotland, up to waves against cliffs by Oyster in Scotland or Oscillating floaters by Eco Wave Power in Gibraltar and Mallorca.

Currently in Italy are tested: sea kite type turbine with propeller of aeronautical type or under a raft (Coiro - Venice or Kobold - Strait of Messina), articulated pulsator (40South Energy, ENEL Green Power - Castiglioncello), columns of air resonating in the docks through the waves (Boccotti – Civitavecchia WEC SAX; Lipari), gyroscopic raft (ISWEC-Politecnico Torino, ENI, MORE - Ravenna, 2020), PEWEC pendulum (ENEA), oscillating floaters (Coastenergy Italy-Croatia).

Similar productions are obtained from multi-propellers in river currents (Watercity - Rovereto) or in the Gironde in Bordeaux, mini-hydroelectric (Lazzarini&Lucchini - Gottolengo MN) or in 13 weirs on the Arno (Iniziative Bresciane).

Our idea starts with the observation that when the bathymetry is deep, wind energy produces only *vertical pulsing offshore waves*. These can be enormous even in a stationary regime as they cannot move horizontally in the water, having to respect the balance of radial symmetry around any vertical axis (Boussinesq 1987). As they approach the coast, where the seabed is, for example, around 5 ÷ 10 m, the waves (fig. 1) are converted to *horizontal inshore currents*. These are directed towards the coastline, which they model to respect the balance of the wedge of water which flows along the sloping seabed, tending to laminate in the surface direction of the stranding and in the opposite direction on the eroding seabed.

This transformation of marine energy forms a calm band that enables the formation of coral reefs. Within this offshore / inshore calm belt, at about 300 ÷ 500 meters on average from the shore, there is the formation of horizontal currents. In this particular zone a new artificial barrier can be positioned as a soft defence (fig. 1 and 3), imitating a coral reef, positioned far from storm surges to avoid damage to the turbines, which is a first important innovative aspect. (patent N. 0001411057).

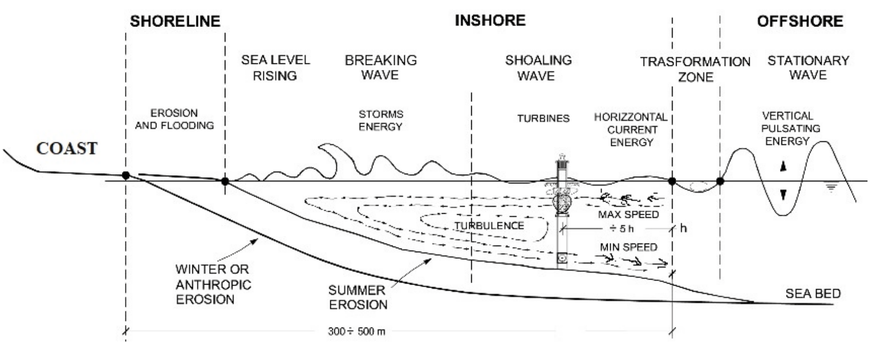

Figure 1 – Location of turbine barriers, resembling the soft protection of coral reefs, where the vertical pulsating energy of the waves (offshore) converts into horizontal sea currents (inshore) in the 2 opposing directions: superficial, and on the seabed.

Figure 2 – Impeller close to indifferent equilibrium or in meso-float, similar to jellyfish, so that it can turn even at the slightest sea currents, and the project logo.

When the currents then proceed to lower depths of 4 ÷ 5 meters, they convert into storm surges, causing damage precisely where the energy should naturally begin to fade. However, this is where the traditional breakwaters are positioned, which instead have the effect of magnifying the energy, with upheavals of the seabed, which are clearly documented by satellite surveys (ISMAR, ESA).

The second innovative aspect is to couple the impellers to floats, in conditions close to the indifferent Archimedean buoyancy (fig. 2) or meso-float and allow the blades to turn even with the minimum speed of the currents. Thus, the surface currents, which are the strongest, are exploited; in fact, the speed of the stranding currents is rapidly reduced with depth.

The vast range of the spectrum of variation of the sea energy, with variation in wind speed, generates waves of the order L = 2 m in length with H = 1m in height with greater frequency. Consequently, more efficient and lasting production of electricity is brought about by the above-described transformation of these waves into currents.

It should be noted that the marine energy that must be dampened by the turbines is intensified by excessive erosion resulting from the modification of coastal areas, by the reduction of solid transport of rivers caused by dams and by the indiscriminate removal of sand from riverbeds, alongside urbanization, which has destroyed the dunes and the sloping Mediterranean scrub that protected the beaches from the wind, raising it above the shoreline.

Therefore, the limiting of irreparable changes in the area is a priority when choosing to use the turbine barriers, as well as for proposing naturalistic defences (green gratings, etc.).

On the other hand, the summer-winter erosion, characterized by shoals and mobile sand banks on the seabed, is a powerful natural damper of marine energy which defends the coasts.

This natural defence is in fact aided by the turbine barrier, which has a comb-filtering effect and serves above all to avoid excess anthropogenic erosion, in order to leave natural erosion. In this regard, coastal monitoring and research on the impact of storms along the coasts are very important (Ciavola P. et al. 2011, Maiolo M. 2022, Unical), in particular by inshore / offshore current meters such as: compound floats with GPS, or chalks oriented at wind rose, with differentiated consumption, or triaxial acoustic current meters or gravels running on the seabed equipped with GPS. The bathymetric survey of the mobile sandbank further identifies the strip of sea where the turbine barrier is to be located, in order to integrate the above-mentioned monitoring of the currents (fig. 1) which are to be exploited to the best.

2 New reef description

The first artificial barrier proposed to protect the coasts were based on floating finned cylinders anchored to ballast on the seabed, which did not produce electricity. Models in 1: 4 scale were tested at the CNR-INM (former INSEAN) naval tank in Rome with encouraging results regarding the damping of the wave height as the test frequencies increased (Ventura 1992).

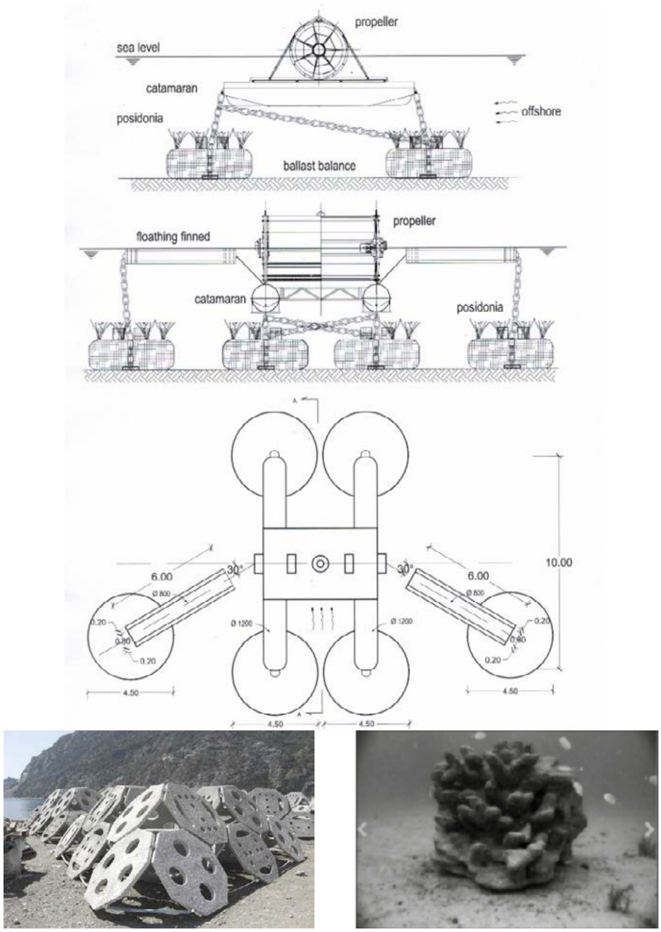

Figure 3 – Turbine with horizontal axis meso-float impeller with 7 semi-submerged blades in surface currents and counter-current air, covered with a shockproof hood, and with 2 generators of 30 kW. These are flanked by finned damper floats and anchored with chains, which can be doubled for damage resistance, to ballasts, such as submerged breakwaters of boulders, which are ecological (photo Tecnoreef or petrified sand for artificial coral, D-Sharp, Dini), and reusable in order to dampen the eroding currents on the other seabeds.

Analisi dinamica Turbina HTP001													
Alternatore Alxion 400 STK 6M	Unità												
Potenza elettrica massima dichiarata sec. grafico Alxion: Potenza/Rpm [1)]	W	2.320	5.175	8.555	11.970	15.175	17.800	20.100	22.400	24.470	26.501	28.549	30.588
Velocità corrispondente dell'alternatore	Rpm	50	100	150	200	250	300	350	400	450	500	550	600
Numero delle paia di coppie polari	N°	12	12	12	12	12	12	12	12	12	12	12	12
Rendimento della turbina	%	90	90	90	90	90	90	90	90	90	90	90	90
Distanza dell'asse turbina sul livello del mare	m	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30
Raggio giratorio del baricentro della paletta	m	0,822	0,822	0,822	0,822	0,822	0,822	0,822	0,822	0,822	0,822	0,822	0,822
Semilarghezza media della paletta della turbina	m	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Rapporto di trasmissione del moltiplicatore dei giri	N°	8	8	8	8	8	8	8	8	8	8	8	8
Densità del fluido	kg/m³	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020
Coefficiente d'efflusso all'imbocco della turbina	-	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Frequenza elettrica generata	Hz	10	20	30	40	50	60	70	80	90	100	110	120
Rendimento dell'alternatore [2)]	%	82,87	83,79	84,71	85,63	86,55	87,47	88,39	89,32	90,24	91,16	92,08	93,00
Semisuperficie della paletta	m²	2,5056	2,5056	2,5056	2,5056	2,5056	2,5056	2,5056	2,5056	2,5056	2,5056	2,5056	2,5056
Velocità della corrente idraulica a valle e della stessa turbina [3)]	m/s	0,538	1,076	1,614	2,152	2,690	3,228	3,766	4,304	4,842	5,380	5,918	6,456
Portata massica della vena idraulica	kg/s	1.100	2.200	3.300	4.400	5.500	6.600	7.700	8.800	9.900	11.000	12.100	13.200
Potenza della corrente idraulica a valle della turbina	W	159	1.274	4.298	10.188	19.899	34.385	54.602	81.505	116.049	159.189	211.881	275.079
Potenza trasmessa all'alternatore	W	2.800	6.176	10.099	13.978	17.533	20.349	22.739	25.080	27.118	29.072	31.005	30.698
Potenza trasmessa alla turbina	W	3.111	6.862	11.221	15.532	19.481	22.610	25.265	27.866	30.131	32.302	34.450	34.109
Potenza della corrente idraulica a monte della turbina	W	3.270	8.136	15.519	25.720	39.379	56.995	79.867	109.371	146.179	191.491	246.331	309.187
Velocità della corrente idraulica a monte della turbina	m/s	2,438	2,720	3,067	3,419	3,784	4,156	4,555	4,986	5,434	5,901	6,381	6,845
Altezza dell'onda	m	0,303	0,377	0,480	0,596	0,730	0,881	1,058	1,267	1,506	1,775	2,076	2,389
Sfruttamento dell'energia disponibile della corrente idraulica a monte	%	70,95	63,61	55,12	46,54	38,54	31,23	25,17	20,48	16,74	13,84	11,59	9,23
Velocità dell'alternatore a vuoto	Rpm												
Tensione elettrica dell'alternatore a vuoto	V												

Note

1) Con fattore di potenza = 1.

2) Linearizzato fra 220 e 600 Rpm come da dati del cosruttore.

3) Al raggio giratorio del baricentro della paletta.

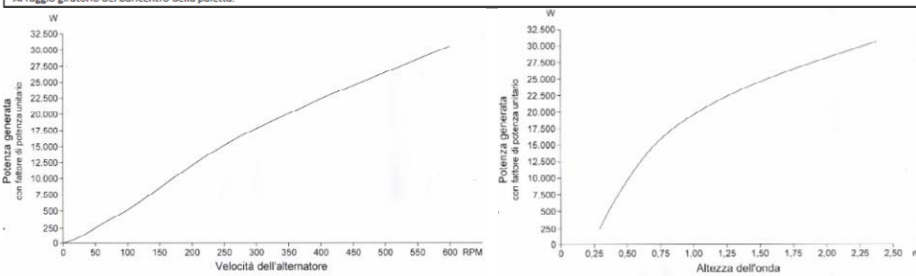

Figure 3 bis – Dynamic analysis to calibrate the turbine power on the marine kinetic energy. The production marine energy with 200 impellers/km becomes 12 MW and 30 GWh/yr/km. This analysis must be supported by specific experimental research in true magnitude. *The article is proposed to develop the Italian research on renewable marine energy.*

This proposal, which differs from many other patents, subsequently integrated these anti-erosion floats with indifferent floatation turbines by means of a catamaran supporting horizontal axis turbines (fig. 3) to increase the production of electricity, through a barrier of staggered turbines (CNRSOLAR 9861TR2914).

The above-mentioned innovative criteria, which are necessarily based on the scientific roots of the past, have converged in the most efficient choice of horizontal axis impellers with large extensions.

The prototype, patented with the Energy Reef logo, (fig. 2) was elaborated in the project report, drawings tables, reconversion of the traditional breakwaters and the bill of quantities.

The 2 generators and the impeller are supported in conditions close to the indifferent balance of the masses by means of a catamaran (fig. 3), consisting of 2 ϕ 1200 floats anchored by chains to the 4 ballasts.

The chains are under slight tension in conditions of hydrostatic calm, and in tension in hydrodynamic operating conditions. This allows the impeller to rotate even with minimum speeds of surface sea currents and makes it possible to limit the size of the chains and ballasts. There are also 2 ϕ 800 floats, with 4 radial fins of 20 cm, (fig. 3), similar to models tested in the naval tank mentioned above, as an obstacle to sea currents, which are moored in a longitudinal barrier on the sides of the catamaran, while the ends of the floats are ballasted by chains similarly to the turbine-carrying catamaran. These floats are anchored with crossed chains in order to minimize the roll-pitch-yaw. The bracing chains also serve to ensure against any breakage of the vertical chains and are equipped with strain gauges to guarantee the prompt repairing of any problem areas. Scheduled maintenance should, however, guard against the need for such repairs. The finned floats are also inclined planimetrically at 30 °, creating a funnel-shaped effect, which directs the sea currents to the blades. This process is also favoured by meso buoyancy, as mentioned above.

Each catamaran has 2 turbines and has a width in the order of 10 m of the floats transversal to the impeller; the longitudinal length of the module is in the order of 20 m, therefore with a maximum of 1 turbine / 10 m, or a barrier of 100 turbines / km.

The modules are independent so they can be arranged diagonally in staggered comb formation in the barrier and are therefore adaptable to the various prevailing wind angles of the site to be protected. Initially, a minimum distance between the modules is proposed, so that they can be positioned in a continuous formation (fig. 4) to obtain maximum protection against erosion of the beaches.

In the light of the experimentation and the weather-maritime characteristics, it will be possible to thin out the floats and offset them appropriately to counteract the sea currents.

The choice of materials is particularly important, namely the epoxy powders of large wind turbines which are usable for 3D printers. Given the much smaller size of offshore wind turbines, turbines can also be made with aluminium alloys for the impellers and steel for the shoulders, which must be adequately protected from corrosion. The use of lighter and new economical fiber-reinforced materials or recyclable natural resins and polymers is therefore proposed; thus, the floats are expected to be made of recycled tires, which will reduce illegal landfills. The use of glebanite, a new material derived from the recycling of reinforced fiberglass with lamellar tearing anti-abrasion and non-toxic *anti-fouling,* to minimize maintenance of the descaling ballast, is also envisaged.

Furthermore, by slightly pressurizing the coated rubber floats, the elements of the module are made more resilient to impact. Fatigue resistance is also concentrated in the anchoring shackles of the suspension chains, with periodic maintenance programmed. It should be noted that the turbine blades are only half immersed (fig. 2), with the other half in the air above sea level, rather than counter current. The impellers are therefore completely immersed during the active phase and emerge in the next phase, emulating the efficiency of traditional water mills, albeit with a different ratio between the dimensions of the blades and the diameter of the wheel. The 7-blade impeller (fig. 3) is covered by an emerging shockproof hood and wave guard, with vents to eliminate the air conveyed by the upper half-blades. The number of blades to be tested is 7, each with dimensions of 4 m^2 in the prototype. These will be adapted to the site that is to be protected, to exploit the sea currents to the maximum and in a compromise between performance and costs. The impeller, supported at the ends by widely sized roller bearings, drives 2 three-phase current generators, each of 30 kWp (cosφ = 1) of nominal or peak power subsidized by a planetary multiplier with a transmission ratio of 8/1. This transmission ratio together with the high number of poles, equal to 12 couples, of the generators makes it possible to enhance the efficiency of the generators and to achieve electrical frequencies, in conditions of maximum power, up to 12 x 10 Hz (50 Hz ≈ 12 x 8 x ½ Hz of the impeller with the longest lasting power at 15 kW) (fig. 3 bis).

The construction uses a signalling lantern powered autonomously by a photovoltaic cell and cutting-edge construction solutions in terms of materials, corrosion protection, lubrication, static and dynamic seals, generator temperature monitoring, and their electrical connection through umbilicals for the transport of energy to the ground and maintenance. It will be possible to separate the turbine from the float, which will remain anchored to the seabed. The floats are anchored to ballasts (fig. 3) consisting of mattresses with nets containing perforated discs such as Tecnoreef or Oceanus (Budoni) or sand traps (Teti) or boxed (geocontainers) Reef Ball or artificial coral to favor habitats for fish. An ecological new barrier is created that can be visited and which constitutes a deterrent to combat illegal fishing. These ballasts can have a circular or oblong plan for 2 crossed chains, upwind type, which will withstand the various angles of prevailing wind, especially from longitudinal coastal currents. The ballasts can be integrated with soil to act as a nursery for posidonia (fig. 3 and 4), in order to also imitate coral reefs and minimize the environmental impact of the new submerged protection without altering the landscape. It should be noted that the set of *ballasts* constitutes a sort of submerged reef that dampens the currents which erode the seabed, while at the same time letting sand pass for natural nourishment. Simultaneously, (fig. 1) the kinetic energy of the surface currents is damped both by the energy-producing *impellers* and by the dispersions caused by the obstacle of the *finned floats*.

It should be noted that satellite analysis of the seabed affected by breakwaters made of boulders and artificial nourishment have indicated significant increases in erosion, despite the mounting costs of these protections.

The use of traditional breakwaters and groynes has therefore recently been banned in the USA, so it is necessary to study new coastal protection systems. The proposal to start modifying coastal protections by eliminating at least 3 breakwaters (fig. 4) is therefore very important, in order to enhance the maximum erosion between them.

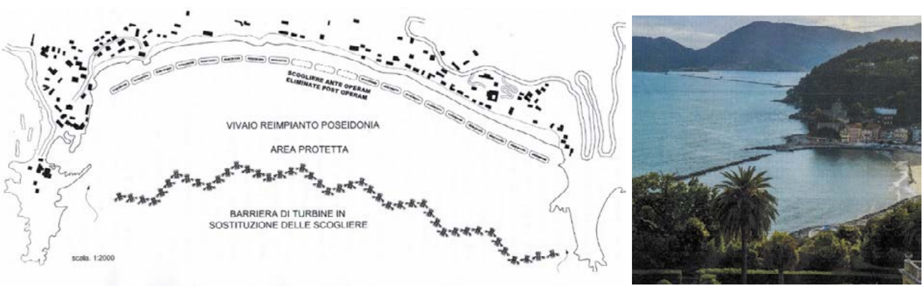

Figure 4 – Experimentation of the anti-erosion effectiveness of the artificial barrier, compared to traditional breakwater of boulders in the simplest case of a bay. The row of anti-erosion modules also allows a posidonia nursery to take root in a protected area.

The coast in front of the removed breakwater must therefore be protected, with a proposed barrier of suitable length, in order to test its effectiveness in worst-case erosion conditions. The proof of the barrier's anti-erosion effectiveness is simplified if it is carried out to protect a bay between two promontories, where the littoral currents do not influence the reduction of the beaches (fig. 4) and where, as previously highlighted, there are no significant variations in the surroundings.

On the other hand, in the case of open sea, i.e., where there is not a bay between promontories, lateral protections are provided at the ends of the barrier, such as in figure 3, to counteract the coastal currents even in shallow waters.

To speed up the experimentation times, the new barrier can be coupled with a contained artificial nourishment strip, without however modifying the sandy seabed in front of the beach for bathers. Monitoring of the beach where the breakwaters have been removed, as well as of the artificial nourishment that simulates the natural mobile sandbank, will increase the anti-erosion efficiency of the barrier.

The planimetric distribution of the turbines, which restores the sandbank or bar of moving sand, must be adapted to each coast (Ricci Lucchi 1992) based on the geomorphology of the seabed and maritime meteorological data (*marine energy spectrum, swell, fetch…*).

These data characterize the energy of the waves, ranging from over 10 kW / m in Sardinia to less than 5 kW / m on the Tyrrhenian coast (Sannino 2012).

The executive sizing of the barriers must naturally be carried out according to average wave energy at the chosen site, assisted by the current and pressure measurements mentioned above. The drawings are based on the hypothesis of a sandy seabed at a depth of 8 m, with wave energy of 5kW / m, and on drastic pseudostatic analysis, which are the first point of reference for the reliability of the calculations (§ 10.2 NTC2018).

Appropriate computer simulations (CFD) and full-scale fluid dynamics tests conducted on the offshore prototype will be able to define precisely the characteristics of the generator and its proportions; in particular, these will evaluate the speed increases of the blades due to the reduced buoyancy, which is close to indifferent.

Dynamic analysis of the kinetic energy usable by 2 generators was carried out on the prototype, driven by prototype blades of 4 m^2 which makes it possible, as the speed of sea currents systematically increase, to exploit a nominal design power of up to 30 kW.

3 Cost/Benefit analysis

The limitation of coastal erosion and the increase in the level of sand on the beaches, to stem the rise in sea level, represent a significant economic advantage. The other important benefit is produced by the numerous, small, low-impact marine electricity units.

It should be noted that the *maintenance costs* of the barriers are much lower than those of the breakwaters and artificial nourishment. The protection of the coasts is "soft" with minimal side effects, unlike traditional defences.

The location of the turbines is far from storm surges, like that of mussel farms, meaning the modules do not require continuous repairs. The energy of the sea acting on almost indifferent floating turbines makes them turn even with minimal currents, making them competitive with onshore wind. Electricity is also produced with higher nocturnal production hours than photovoltaics, especially in winter.

The *functioning* of the new defence makes it possible to eliminate the breakwaters, allowing contracts which are calibrated with the observational method.

The patent moreover allows *the contract to be exclusive.*

The redevelopment of the original landscape is carried out with the *removal* of the breakwater; the boulders from this can be crushed, transforming them into gravel and sand, allowing granulometrically suitable nourishment or the production of ballast.

The need for inland quarries for the extraction of boulders would be *eliminated* as would the removal of sediments, which are often unsuitable for nourishment, obtained with the extraction of sand at sea or on land, thus reducing other significant environmental damage.

The new *defence* also leads to the raising of the level of the beaches through natural nourishment, which will realistically defend against the rise in the level of the Mediterranean Sea (currently 3 mm / year) caused by climate change.

In Italy, erosion affects over 1200 km of coastline, which is the equivalent of 1/3 of sandy beaches, with over 25 m of average erosion, or more than 2.5 ha / km.

The barriers provide further advantages as they allow posidonia (Marsella 1986) to take root. This is a typical marine vegetation that prevents erosion and favours fish repopulation and marine depollution.

The twenty-year-plus life of the barriers favours the growth of sea grasslands, and even submerged dunes or matte posidonia, which constitute precious natural defences against erosion. The mobile barriers can then be transferred to new sites in need of defending.

The barriers allow for the creation of protected areas and indicate the coastal limits for fishing (no fishing zone); the safety of bathers is increased by delimiting recreational boating and favouring panoramic navigation along the coast parallel to the barriers. This protection can also lead to the development of underwater tourism to visit the turbines, even setting up sections of the barrier for water-sub sports and for fish-watching. Generating electricity, especially for coastal lighting, increases night-time safety.

Energy storage can be achieved with classic accumulation in direct current, which is then transformed into alternating current at 50 Hz. Alternatively, it can be stored with hydraulic accumulation, by means of reverse turbines that pump water to a higher altitude, if close to the coast, as is typical in the Apennines. It can also be stored with the use of accumulators.

Marine energy can also be used to pump desalinated water from osmotic membranes lying on the seabed, as has been done in Perth in Australia, and especially in areas undergoing desertification, where there is a lack of aqueducts, such as on many islands.

It is also possible to equip the barrier with a series of marine aspirators (*seabins*), whose function is to free the sea from plastic and other floating waste; at the same time, underwater robotic systems can be used for the collection of waste on the seabed, which is often much more consistent than that which is found floating. This collection will be particularly useful if the barriers are positioned at the mouths of rivers; in order to collect the waste thrown indiscriminately along the riverbeds. Sensors for permanent weather and chemical monitoring could also be incorporated, to document the quality of the water and increase the number of "*blue flags*" displayed on the beaches.

In addition, the protective hood on the turbines shields the motion of the blades and protects swimmers; the blades favour the oxygenation of the water, thereby improving the flora and fauna of any nearby mussel farm.

The turbines, protected with screen cleaners, can also be used in rivers, especially in the deltas and during the ascent of the sea in the mouths of rivers (mascaret).

It is possible to temporarily moor pleasure boats along the turbines, such as dolphin, also for battery recharging. This frees up ports, which become especially choked in summer. Berth owners could also purchase turbines (Prosumer) to power the boats via charging stations on the docks.

The supply of electric power to ships in ports is another particularly promising benefit, as it removes the pollution caused by diesel engines which are otherwise permanently turned on. This has been installed in Norway and has been proposed for the port of Livorno.

The barriers, marked by red buoys and illuminated by red LEDs at night, limit recreational navigation to a safe distance from the shore; naturally, there are gates for the passage of boats from the land.

The barriers, with their recycled rubber floats, could also make a significant contribution to the reduction of car tire dumps by recycling tires into composite materials.

They could also help to reduce the crisis in the automotive and nautical industries by converting them into *marine turbine factories*.

It is worth noting that the proposed conversion could defend many kilometres of beaches, gradually replacing the 1291 kms of breakwaters, with a significant contribution to the production of renewable electricity, thus favoring the development of the *Ecological Transition (Laudato si').*

New training courses and jobs would be activated: from design to maintenance, from planned evaluation (*auditing*) to environmental protection. The very topical theme of apprenticeships through training schemes and retraining would get a good contribution from the sector of coastal protection with the production of marine energy.

The risk of corrosion and incrustation can be prevented by standard marine protections and by the fact that the alternator-blade monoblocks can be removed for periodic cleaning and maintenance and for lubrication. Maintenance work can also be carried out annually by divers; the low depth of the interventions, immediately below the water level, mean immersion times would be short.

Turbines, especially those made of light materials, have an equivalent mass similar to water and bearings with negligible friction, or zero relative mass, so they also have a zero-oscillation period that is not affected by resonance, because the proper period is $T \div 0 < T_{Tirreno} \div 3s$, similar to the harmonious frequency of the surf. They are therefore anti-seismic and will function in an earthquake. They also self-submerge and mitigate tsunamis when the anomalous waves are not enhanced by shallow waters, as happened instead in Livorno (1742.) Furthermore, the submarine cables, which are not susceptible to damage caused by storms and snowfalls, like those on land, are much shorter than offshore ones.

For the 62 eolic offshore floaters proposed by Falk Blue Float in Sardinia the the length of the underwater cables is 40 ÷80 km. The harmful collateral effects on pitch-roll-yaw vibrations and the environment, evident in all other electricity production, including hydroelectricity, are also negligible with the proposed barrier. We can hope for a *comparison between Blue float, Iswec-Eni, Pewec-Enea, other renewables* and *Energy reef.*

The project also includes a detailed time schedule for the construction of the prototypes, from current measurements to the certification of the beach's anti-erosion efficiency. The cost of the prototype barrier can be amortized according to its length, and can be reduced as mass production increases and the kW / m of the chosen site increases.

It is also worth noting that as the depth of the seabed increases, the ballasting chains can be lengthened with little expense; this is very different from the costs of breakwaters which instead have rapidly increasing trapezoidal sections.

By conservatively assuming an average production of 50 % of the maximum power of the turbine barrier, we obtain 15 x 100 = 1.5 MW / km or, for about 4000 hours or 50 % per year, an order of at least 6 GWh / y, which can be increased to 12 GWh / y with 10 kW / m waves instead of the assumed 5 kW / m.

In addition to the income from electricity, for every m/km of beach, further income can be derived in the space of a few years from the recovery of the beach. This occurs as tourist activity in the bathing establishments increases, considering that the life of the barrier is in the order of 25 years.

The current costs of the breakwaters and nourishment, in the absence of quality aggregates and the closure of the quarries, are comparable with those of the new proposed barrier. The costs of seasonal maintenance, such as the replacing of boulders in breakwaters or new artificial nourishment after the undermining caused by storm surges each winter (Cipriani 2021) are certainly greater than those of the proposed barrier. Moreover, the new "winter sand traps" (Teti), tested along the coast of Torre Guaceto (Bari), are less expensive, but without the electricity production and seabed protection of this project.

In contrast, the costs of 1 kilometer of barrier are very competitive when compared with those of floating offshore mega-wind turbines, proposed to Budoni or to Civitavecchia, or with the mini-hydroelectric turbines positioned in rivers (Arno).

The kinetic energy of transformation of the waves into marine currents is furthermore greater than that of the wind currents in eolic production.

The comparison with the costs of photovoltaics is competitive, as 3 MWp photovoltaic production requires 2 hectares of panels, with daytime supply only and low production < 1 MWp in winter. Moreover, night-time supply requires accumulators to be changed after 10 000 cycles / 10 years and it is also not very productive in winter. By contrast, the barriers are also productive at night when energy is most needed and in winter when the sea currents are greater. It is essential that renewables should be increased to more than 20 % of Italian electricity consumption (280 000 GWh/y). The lifespan of the turbine barriers also makes the cost of nurseries for the gradual regrowth of sea grasslands and the restoration of the ecosystem economically viable. This is currently not feasible with traditional defences, as evidenced by the lack of successful root-taking, especially facing the breakwaters.

It is interesting that *Energy-Tourist Communities*, with cooperation of the prosumer; and outcome funds, are developing for use the various benefits mentioned above.

It is worth repeating that ecological conversion with the proposed production of marine energy, which is clean, very useful locally and competitive thanks to the recovery of the beaches, has significant economic advantages compared to other renewable sources.

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SESSION

FLORA AND FAUNA OF THE LITTORAL SYSTEM: DYNAMICS AND PROTECTION

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FLORA AND FAUNA OF THE LITTORAL SYSTEM: DYNAMICS AND PROTECTION

Coastal ecosystems are important for biodiversity conservation of animal and plant species. These environments are highly dynamic, extremely vulnerable, and subjected to several disturbances due to cyclic phenomena, climate change, and human pressure.

Monitoring coastal ecosystems involves collecting a variety of data that are needed to improve our knowledge on coastal processes and understand where the risks, opportunities and consequences are in coastal management.

A total of 22 papers coming from six different countries (France, Israel, Italy, Malta, Spain and Tunisia) have been published in the Proceeding of the Session *Flora and Fauna of the littoral system: dynamics and protection* of the *IX Symposium Monitoring of Mediterranean coastal areas: problems and measurement techniques*.

The thematic areas covered by these papers refer to different issues, such as the assessment of the quality status of waters in coastal ecosystems, invasive alien species, and actions carried out to improve management, conservation, monitoring, and control of coastal habitats. Here follows a short introduction to the contents of the papers.

The structure, composition and dynamics of planktonic communities may be highly impacted by variations of climatic and hydrological conditions or concentrations in contaminants. Drouet et al. studied the mercury contamination of the planktonic compartment in the Bay of Toulon (France).

The effects of petroleum hydrocarbons on *Salicornia perennans* Willd. growth at different saline concentrations were investigated by Lazzeri et al. using data collected at Calambrone on the coastal area of Tuscany (Italy).

Sahbani et al. assessed the trophic level of Ichkeul Lake (Tunisia) and predicted the effect of climate change and anthropogenic pressures on European eels using the Random forest model.

The presence of high concern substances (per- and poly fluoroalkylsubstances) in striped dolphins stranded along the Tuscany coast (Italy) was investigated by Mazzetti et al.

Due to anthropogenic activities the harbour's sediments are affected by pollutants and are subjected to remediation treatments. Florio Furno et al. carried out a preliminary screening on fungi isolated in the sediments of a polluted port area in order to identify fungal strains endowed with oxidative abilities and to

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evaluate the producers of metabolites or enzymes of interest for applications in future environmental bioremediation.

Invasive alien species represent a threat to native plants and animals in coastal ecosystems.

The presence and abundance of invasive alien macroalgae on the rhodolith bed of the Capo Carbonara Marine Protected Area (Italy) was investigated by Caronni er al.

Cecchi G. et al. report new areas of settlement of the species *Callinectes sapidus* (Rathbun, 1896) present both in the Tyrrhenian Sea and in the Ionian Sea along the coast of Calabria (Italy).

Seagrasses colonise coastal areas worldwide and a considerable proportion becomes detritus that can be used as food, physical habitat and occasional or permanent shelter by several benthic macroinvertebrates. Costa et al. tested if colonisation of the seagrass detritus was related to substrate availability rather than food and whether the colonising assemblages were similar according to the structural complexity of the meadow.

The spatial dynamic of *Posidonia oceanica* (L.) Delile transplanted during a large-scale seagrass restoration in a previously disturbed area of the Tyrrhenian Sea (Italy) was investigated over a two-year period by Mancini et al. using high-spatial resolution underwater photomosaics.

Lolli report the complex network of rules that the Italian legal system sets up for the protection of *P. oceanica* in the sea and for the management of the beach-cast leaves ashore.

The National Monitoring Program of Israel's Mediterranean waters was presented by Herut and the team of Scientists of *Israel Oceanographic and Limnological Research*.

The *Medsen* index was used by Turicchia et al. to assess the ecological status of the subtidal coastal rocky habitats, including the coralligenous reefs, in the Tuscan Archipelago National Park (Italy).

Cecchi E. et al. assessed the distribution and extension of the coralligenous cliffs in Tuscany (Italy) and described the structure and the patterns of spatial variability.

Castro-Fernández et al. tested a video-based methodology for monitoring fish assemblages at various temporal and spatial scales and compared it with other non-invasive techniques.

De Gioia et al. used low-impact monitoring methods (standard photographic sampling method and visual census) to study the benthic communities and the fish assemblages and compared the results with data from a Remote Operative Vehicle.

Lapinski et al. report the presence of *Epinephelus caninus* (Valenciennes, 1843) in North-western Mediterranean coastal habitats (France) where an experimental ecological restoration project was carried out to restore altered ecological functions of the rocky coastline.

The first data of stomachs contents of *Tursiops truncatus* (Cetacea: Odontoceti) stranded in Tuscany coasts (north-western Mediterranean) between 1990 and 2021 was reported by Neri et al.

Fungal disease associated with eggs of the endangered sea turtle *Caretta caretta* L. in the Tuscan archipelago (Italy) were studied by Risoli et al.

The species composition of nearshore plant communities represents a continuous biological response to environmental gradients perpendicular to a marine shoreline. Cutajar and Lanfranco evaluated possible changes to nearshore plant communities in response to a change in shoreline in three coastal areas in Malta.

Coastal pine forests offer valued recreational uses and provide habitats for plant and animal species of conservation interest.

Ferraro et al. described silvicultural interventions carried out in coastal pine stands in southern Italy for re-naturalization purposes.

Stand structure and natural regeneration in a coastal stone pine (*Pinus pinea* L.) forest in the Regional Park of San Rossore (Central Italy) was studied by Travaglini et al.

Habitat changes in the Mediterranean wetland system of "Zone Umide della Capitanata e Paludi presso il Golfo di Manfredonia" (Italy) were monitored by Tomaselli et al. using vegetation maps.

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ARE *CAULERPA* SPECIES ABLE TO SETTLE AND DEVELOP ON RHODOLITH BEDS? THE CASE STUDY OF MARINE PROTECTED AREA "CAPO CARBONARA"

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Abstract – The two green algae *Caulerpa taxifolia* (M.Vahl) C. Agardh and *Caulerpa cylindracea* Sonder, (Chlorophyta; Bryopsidales) are currently considered among the most invasive alien macroalgae in the Mediterranean Sea, where they have spread very quickly in the last three decades, with severe effects on biodiversity conservation (Streftaris and Zenetos, 2006). Currently both *C. taxifolia* and *C. cylindracea* as well as their congeneric *Caulerpa prolifera* (Forsskäl) J.V. Lamouroux, that is considered as native in the Mediterranean Sea, appear to be particularly abundant all over the basin. Nevertheless, little is still known about the competitive relationships that are established among them and with other organisms, such as rhodoliths. The aim of this study is to investigate the presence and abundance of *C. prolifera*, *C. taxifolia* and *C. cylindracaea* on the relatively deep rhodolith bed of the Capo Carbonara Marine Protected Area (MPA), along the Southern Sardinian Coasts (Italy).
The percent cover of the substratum by the three species was estimated by image analysis on frames extracted from videos in three different sites of the MPA (Is Piscadeddus, Santa Caterina and Serpentara, three transects of 200 m in each). The obtained results were analysed by means of univariate statistical analysis techniques (ANOVA and SNK test), considering as factors both the site and the transect.
Significant differences in the percent cover of the substratum by the three species were highlighted among sampling sites and species. *C. cylindracea* seems the most abundant species, especially in Santa Caterina, where it reached the 24 %. Significantly lower percent covers were instead recorded for the other two species in all sites. Anyway, the presence of the three species in the study area proved that they are all able to settle also in deep and particular habitats such as rhodolith beds, representing a possible threat for their conservation. However, only *C. cylindracea* seems to find there the right conditions to diffuse significantly and, thus, must be monitored with particular attention, due to its high invasive potential.

Introduction

Rhodoliths are unattached nodules, mostly consisting of Crustose Coralline Algae (CCA) [1], slow-growing and long-lived organisms that act as ecosystem engineers secreting high-Mg carbonate, forming both mobile (i.e., rhodoliths) and stable substrates (i.e., algal reefs).

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Sarah Caronni, Fabrizio Atzori, Sandra Citterio, Valentina Bracchi, Nicoletta Cadoni, Rodolfo Gentili, Lara Quaglini, Daniela Basso, *Are* Caulerpa *species able to settle and develop on rhodolith beds? The case study of Marine Protected Area "Capo Carbonara",* pp. 587-595 © 2022 Author(s), CC BY-NC-SA 4.0, 10.36253/979-12-215-0030-1.54

Usually, rhodoliths are in the form of a single or multiple coralline algal species, frequently overgrowing one over the other, and with a wide variety of growth forms, from foliose to fruticose to lumpy [2]. Rhodolith beds are formed by aggregation of free-living (>10 %) rhodoliths [3,4] and they are considered as an important biogenic marine habitat between mobile and stable substrates. Their 3D structure serves as a habitat for a diverse associated community and as a local hotspot of biodiversity, providing a suite of ecosystem goods and services [5].

They are distributed worldwide, and they generally develop on float or gently sloping seabed [4] from the intertidal down to 270 m depth [6]. In the Mediterranean Sea, they occur typically within 30 and 75 m depth [7] and they are considered of high conservation interest and they are protected within the framework of the United Nations Program's Mediterranean Action Plan. Moreover, they are included in the monitoring program in the Marine Strategy Framework Directive 2008/56/EC of the European Community.

According to [8], rhodoliths survival depends on the possibility to continue to overturn, avoiding in particular overgrowing by other organisms and smothering by burial [8,9]. With regard to overgrowing, flashy algae such as some invasive *Caulerpaceae*, able to form dense carpets on the substratum of different environments can represent a significant stressor for rhodoliths, as described by [10], analysing the interactions between rhodoliths and *Caulerpa sertularioides* Gmelin Howe. No data are instead available on the presence and abundance of other *Caulerpa* species, potentially invasive in such habitats. In particular, the two green algae *Caulerpa taxifolia* (M.Vahl) C. Agardh and *Caulerpa cylindracea* Sonder, (Chlorophyta; Bryopsidales) are currently considered among the most invasive alien macroalgae in the Mediterranean Sea, where they have spread very quickly in the last three decades, with severe effects on biodiversity conservation and could represent a threat also for rhodoliths conservation [11].

C. cylindracea was initially considered as a Lessepsian migrant in the basin but, recently, its south-western Australian origin has been proved [12]. *C. taxifolia*, instead, is native to the Caribbean Sea and was accidentally released from the Oceanographic Museum of Monaco into the Mediterranean Sea [13]. Both the species are able to colonize any type of substratum at depths ranging from the intertidal zone down to almost 90 m in particular conditions and to actively compete with the endemic seagrass *Posidonia oceanica* (L.) Delile [14]. Besides *C. taxifolia* and *C. cylindracea*, also their congeneric *Caulerpa prolifera* (Forsskäl) J.V. Lamouroux, that is currently considered as native in the Mediterranean Sea, appears to be particularly abundant all over the basin. Although numerous studies have been conducted in the last decades on the three species, little is still known about the competitive relationships that are established between them and on their presence in relatively deep environments.

In the framework of an agreement between the Marine Protected Area (MPA) “Capo Carbonara” and the University of Milano-Bicocca for the realization of the monitoring project for the Italian Marine Strategy Framework Program, we firstly described a wide heterogeneous and relatively deep rhodolith bed (41.08 km^2, 40-60 m water depth [15]). In the same sites, now we study the presence and abundance of *C. prolifera*, *C. taxifolia* and *C. cylindracaea*, which occurrence was firstly signalled but never deeply investigated, by using a quantitative approach, define which species are present and their local distribution and abundance.

Materials and Methods

Study area

The study was conducted in the MPA "Capo Carbonara", along the Southern Sardinian Coasts (Italy) in the summer of 2017 (Fig. 1). The MPA was established by the Ministry of 'Environment and of Land and Sea (currently Ministry of Ecological Transition), by Ministerial Decree of 15 September 1998, modified in 1999 and totally replaced by Ministerial Decree of 7 February 2012 (GU No. 113 of 16 May 2012).

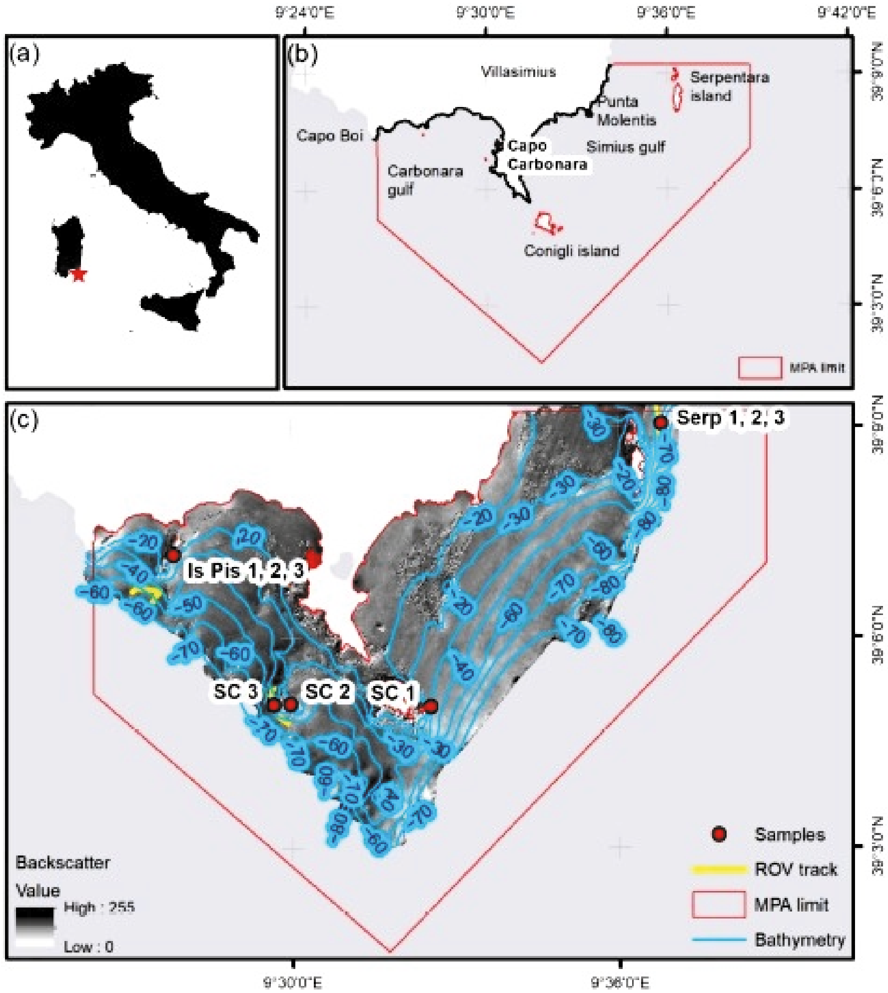

Figure 1 – Backscatter photomosaic of the area (property of the MPA) with the indication of the ROV tracks and sampling location. Is Pis is for Is Piscadeddus, SC is for Santa Caterina, and Serp is for Serpentara.

The territory of the MPA extends from Capo Boi (W) to the area in front of Serpentara Island (E) on the whole continental shelf, down to an average of 125 m water depth (Fig. 1). Rhodoliths are indicated to be particularly abundant in the area [16].

In the area, 3 different sites were identified at a distance of >200 m (Fig. 1): the Is Piscadeddus shoal (from here on Is Piscadeddus) towards W, the Santa Caterina slope (from here on Santa Caterina) in the middle, and the Serpentara Island (from here on Serpentara) towards E (Fig. 1).

Image collection and analysis

Each site was investigated by a remotely operated vehicle (Steelhead Seamore, property of the University of Milano-Bicocca, Milan, Italy), equipped with two video-cameras. In each site, three transects of 200 m were considered (Fig. 1).

To evaluate the abundance of the three seaweeds on the substratum, their percent cover was estimated by image analysis (sub-squared method) on photo-frames extracted from the videos obtained by the ROV at 40-50 m of depth (with a the shooting angle of the ROV camera of about 45°). In particular, from each video, 20 frames (6 m^2 of substratum for each) were obtained. Onto each image, a grid of twenty-five sub-quadrats (1 m^2 of area) was superimposed on a computer screen, and each sub-quadrat scored from 0 to 4 %. The total % cover value was obtained by adding up the 25 resulting values [17] (Fig. 2).

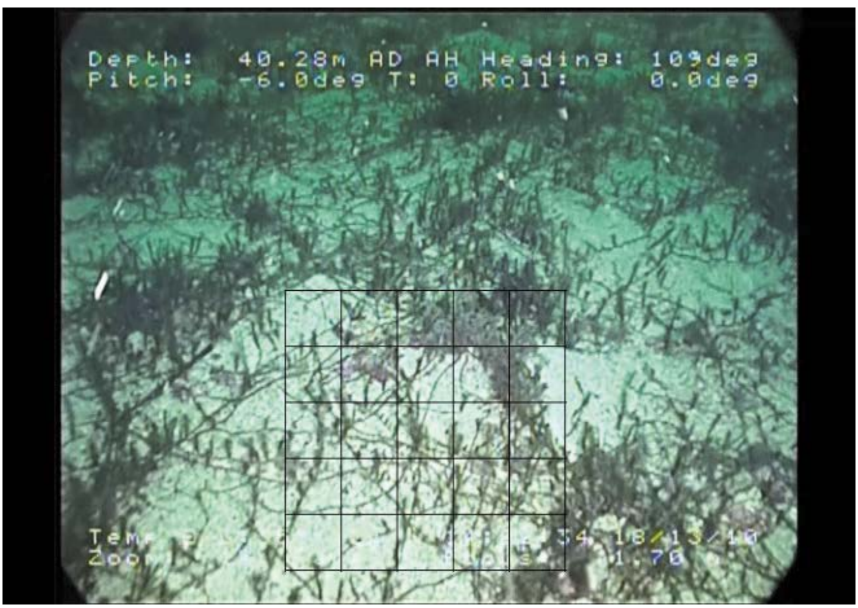

Figure 2 – Example of the analysed frames.

Statistical analysis

Data regarding the percent cover of the substratum by each *Caulerpa* species were analysed by means of univariate statistical analysis techniques (ANOVA and SNK test) [18]. In particular, a two-way ANOVA was run when the three species were found on the substratum, considering Species (3 levels: *C. taxifolia* vs *C. cylindracea* vs *C. prolifera*) and Transect (3 levels, t1 *vs* t2 *vs* t3) as fixed factors.

Results

Some significant differences in the distribution (percent cover) by the three species were highlighted among sampling sites. While their presence was significant at Santa Caterina, where their total cover was more than 25 %, they appeared negligible at both Serpentara and Is Piscadeddus (<1 % of mean cover) (Fig. 3).

Considering only Santa Caterina site, some quite interesting differences of cover were observed among the three considered species (Fig. 3; Tab. 1).

C. cylindracea is the most abundant species in all the transects with a mean percent cover of the substratum that reached 25 %. Significantly lower percent covers were instead recorded for both *C. prolifera* and *C. taxifolia* (<1 %) but, anyway some differences were highlighted also in their abundance in relation to the considered transect of the same site (Tab. 1).

While in transects 1 and 2 the mean cover by these two species appeared to be very similar (<0.1 %), a different situation occurred in transect 3, where *C. prolifera* was significantly more abundant (~ 5 %) than *C. taxifolia* (<0.1 %). The latter, in particular, was scarcely present in all the transects with a mean cover of 0.08 % (Fig. 3; Tab. 1). Finally, some significant differences among transects were highlighted also for *C. cylindracea*, for which a significantly higher percent cover of the substratum was observed in transect 2 (Tab. 1).

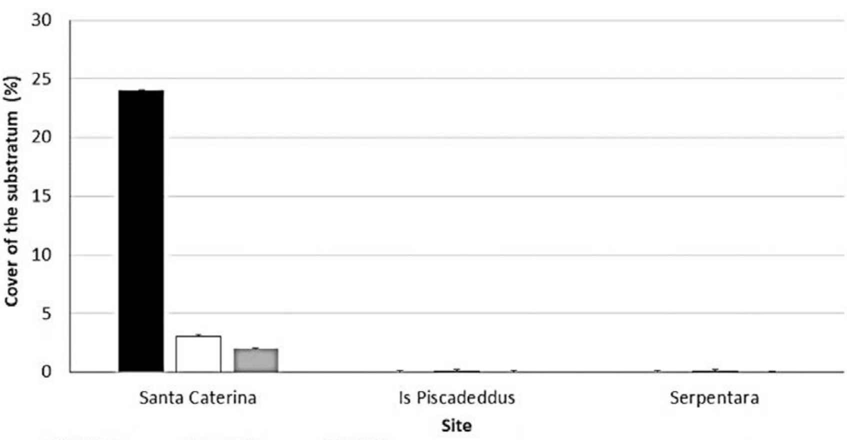

Figure 3 – Mean (SE) percent cover of the substratum of the three species in the three considered sampling sites.

Table 1 – Results of ANOVA and SNK to test for significant differences in the percent cover of the substratum between species and transects for Santa Caterina site. Significant ($P < 0.05$) results are in bold. The SNK test for the interaction Species*x*Transect is also presented.

ANOVA				
Source	**df**	**MS**	**F**	**P**
Species	2	9903.1722	19.54	**0.0086**
Transect	2	336.0056	6.49	**0.0019**
SpeciesxTransect	4	506.8056	9.79	**0.0000**
Residual	171	51.7485		
Total	179			
Cochran's test = 0.5539				
SNK test (Species x transect)				
Species	**Transect**	**Transect**	**Species**	
C. prolifera (CP)	t1=t2=t3	t1	CT=CP<CC	
C. taxifolia (CT)	t1=t2=t3	t2	CT=CP<CC	
C. cylindracea (CC)	t1=t2<t3	t3	CT<CP<CC	
S.E. =1.6085				

Discussion

These preliminary results appear particularly interesting from both an ecological and a management point of view. They furnish some interesting insights on the ability of the *Caulerpa* species to settle and develop in quite peculiar habitats, such as rhodoliths beds, focusing also on their competitive interactions.

First of all, these results represent one the first report of *Caulerpa* species in the rhodolith bed of the MPA "Capo Carbonara", and in particular the two alien species *C. cylindracea* and *C. taxifolia* as well as of the native one *C. prolifera.* Until today, indeed, some species of the *Caulerpa* genus had been reported in oceanic rhodolith beds (*e. g.* [19,3], which, however, are significantly more superficial (20 m depth) than the ones considered during this study (45 m depth) and in which, therefore, green algae as *Caulerpaceae* are expected to find quite suitable conditions to settle and develop. In particular, while *C. cylindracea* has already been observed at similar depths [20], even if not in rhodoliths beds, both *C. taxifolia* and especially *C. prolifera* are reported to be typical of more superficial waters [21,22] even if other researchers observed the former also at about 50 m of depth [23]. Therefore, the presence of the two latter Caulerpace*e* in the study area provides the first evidence of their ability to survive also in deep environments, where the environmental conditions, and in particular light, are not usually favourable for green algae colonisation. In such environments, indeed, light that is considered the key variable for seaweed distribution appears to be spectrally limited. According to Ramus et al. [24], sunlight becomes blue-green after passing through several meters of seawater. For this reason, seaweeds living deep beneath the sea receive little light of wavelengths which are effectively absorbed by chlorophyll (violet and red light). Indeed, green seaweeds, having chlorophyll as the main photosynthetic pigment, are normally presumed to be scarce in deep waters, where only few species successfully adapted to tolerate such extreme light conditions can be found [24].

Analysing data regarding the mean percent cover of the substratum by three species, some quite interesting information can be obtained. Indeed, significantly different covers were recorded. In particular, *C, cylindracea* appeared to be more abundant than the other two species, thus suggesting that this species find in rhodolith beds more favourable right conditions to diffuse significantly if compared with the other two species. The above described differences can be partially explained taking into account the very high invasive potential of this macroalga, that is currently considered as one of the most threatening invaders in the Mediterranean Sea [25,14]. Beside its ability to tolerate the quite peculiar environmental conditions typical of high depths habitats, also the type of substratum seems to play a key role in determining *C. cylindracea* presence in the study area. Detritic bottoms with coarse texture, indeed, seem to facilitate the spread of the alga more than fine sand [26] and this pattern becomes particularly relevant in rhodolith beds, because these bottoms provide a complex three-dimensional substrate for stolon attachment [27]. Moreover, due to its high invasive potential, *C. cylindracea* seems to be able to win the competition with the other two species, that also suffer because they are less adapted to the peculiar conditions of the area, as already proved by [28].

Finally, also the significant differences in the percent cover of the substratum by all the considered species among sampling sites and also transects prove that the peculiar geomorphological features of the considered area can play a key role for the successful establishment and expansion of these species. Regarding the sites, in particular, some important cover differences were observed, as the three species were found only in Santa Caterina slope. Indeed, such site, due to its position and substratum morphology, is characterized by clear waters that favour the penetration of light and is interested by currents that avoid the presence of muddy sediments typical of deep environments, that usually don't promote *Caulerpa* species development, as highlighted at the end of other studies on the ability of the above-mentioned species to develop on different types of [29].

Conclusion

The obtained results suggest that *C. cylindracea* is currently the only *Caulerpa* species representing a potential threat for rhodolith beds conservation and, thus, its presence, abundance and expansion trend should be monitored with particular attention in such kind of habitats.

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USING DIVER-OPERATED STEREO-VIDEO TO MONITOR JUVENILE FISH ASSEMBLAGES IN MEDITERRANEAN COASTAL HABITATS FORMED BY MACROPHYTES

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Abstract – Temperate coastal ecosystems dominated by macrophytes are diverse, ranging from macroalgal forests to seagrass meadows. They provide numerous ecosystem services and are highly valuable as nursery areas for fish. However, these habitats are under increasing pressure due to anthropogenic actions.

In the last decades, the use of Diver Operated Stereo-Video (stereo-DOV) systems has become popular for making accurate, precise, and repeatable measurements of fish lengths. The objective of our study is to develop an efficient video-based methodology for studying the patterns of recruitment of temperate littoral fishes at various temporal and spatial scales. We aim to evaluate our methodology compared to other non-invasive techniques used for the study of juvenile fish assemblages.

In this paper, we propose a combination of habitat mapping and stereo-DOV transect methodologies and test them in two case studies to investigate the link between juvenile fish and macrophytes, considering various scales of heterogeneity of littoral habitats. Data on species composition, abundance, and mean total length of the juvenile assemblages and canopy height from each habitat can be obtained and geo-referenced in the sampling sites, mapping their distribution in space and time to understand recruitment patterns.

Some benefits of using stereo-DOV transects and habitat mapping for monitoring fish assemblages in comparison with traditional non-invasive methods used for fish counts, are a) videos are permanent, they can be reanalyzed; b) divers do not have to be experts in fish and macrophyte identification; c) inter-observer variability can be controlled through quality checks; d) high accuracy and precision in fish count and length measurements; and e) image data can be used for developments of artificial intelligence (AI). However, there are also some disadvantages: a) cameras have a limited field of view; b) video processing is time-consuming; and c) experts are needed for fish identification during image processing.

In conclusion, the combination of stereo-DOV and habitat mapping is an effective methodology for monitoring fish recruitment patterns and habitats at different scales. It can be also advantageous for evaluating temporal changes in the habitat structure, and therefore, in the ecosystem functions provided for the fish community.

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Introduction

Mediterranean shallow coastal ecosystems are diverse, ranging from rocky to sedimentary substrates, usually dominated by the presence of structurally complex marine macrophytes such as macroalgae (e.g., *Cystoseira* sp., *Halopteris* sp., or *Dictyopteris* sp.,) or seagrass (e.g., *Posidonia oceanica*). Macroalgal forests and seagrass meadows provide numerous ecosystem services and have been proved to be key nursery habitats, essential for the life cycle maintenance of many coastal fishes in the Mediterranean Sea [3] [13]. Several studies suggest a positive relationship between macrophyte three-dimensional structural complexity and its key role in fish recruitment, by providing increased potential prey and shelter from predators [4] [10] [14] [18].

However, these habitats have suffered a severe regression in the last decades due to an increasing pressure created by anthropogenic factors such as eutrophication, mechanical disturbances, climate change, or the introduction of invasive species, among others [4] [5]. Habitat transformation may have consequences on the recruitment of coastal fish assemblages [2]. Detailed data on the factors affecting the abundance of juvenile fish and their spatio-temporal patterns (e.g., habitat complexity, temperature, or depth) is needed for understanding the dynamics of these communities.

In the last decades, the use of Diver Operated stereo-Video (stereo-DOV) systems has become popular for making accurate, precise, and repeatable measurements of fish abundance and lengths [9] [15]. This method gives permanent information on species and related habitats than can be reanalyzed as many times as necessary. It also allows making precise measures of fish density and biomass. These properties are key to understanding the long-term evolution of population dynamics in an environment subjected to multiple stressors such as the infralittoral strip. While different sampling methodologies of stereo-video have been used to study adult fish communities [17], this method has been rarely used for evaluating the spatio-temporal dynamics of fish recruitment in shallow habitats of different complexity in temperate seas.

The objective of our study is to develop an efficient video-based methodology for studying the patterns of recruitment of temperate littoral fishes at various temporal and spatial scales. In this paper, we describe and evaluate our sampling methodology and explore some of the preliminary data collected in two case studies: a restored *P. oceanica* meadow and rocky reefs covered by macroalgae.

Materials and Methods

Stereo-DOV censuses and habitat mapping

Samplings for juvenile fish and associated habitats were performed 50 cm above the seabed by SCUBA divers operating a low-cost calibrated, un-baited, stereo-DOV system (Fig. 1). Associated GPS track data was taken from the surface by a snorkeling diver, shadowing the stereo-DOV position to attain a more precise geo-location measure of each fish or macrophyte measured. The system consisted of two GoPro HERO7 Black cameras (GoPro, Colorado USA) in waterproof housings, set to record on the wide field of view mode at 30 frames per second with a 1440-pixel resolution to optimize video quality and battery consumption. Previous trials with differing inter-camera distances and angles were carried out to determine the field of vision that would provide an accurate estimate of juvenile fish and macrophyte sizes. As a result of them, cameras were mounted separated from each other by 34 cm and with a 6º inward inclination angle which gives a wide field of view of 1.5 m. The stereo-DOV systems were calibrated in a pool before the sampling, and the processing of the calibrating videos was performed with CAL SeaGIS software (www.seagis.com.au).

Figure 1 – SCUBA diver operating the stereo-DOV system.

We considered juveniles all individuals of each species recorded smaller than one-third of the adult maximum total length (TL) [1] [6] [16]. Data on every fish that was observed on each transect was obtained from the continuous analysis of the stereo-pairs of videos with SeaGIS EventMeasure software Version 3.22 (specific software to count and identify fish) (Fig. 2). Species composition, abundances, and mean TL of the juvenile fish assemblages, as well as habitat structural parameters, were also obtained from the videos. To ensure accuracy and precision, fish total lengths were only measured when individuals had their bodies straight and were located within the field of view of both cameras. Only fish situated less than 7 m away from the camera were considered for the analysis. Fish individuals that did not follow those rules were discarded and were just identified and counted but not measured. Each fish observed and identified (at species level when possible) was geo-referenced in the sampling site with QGIS software Version 3.18.2 (QGIS Association. http://www.qgis.org), mapping the fish distribution in space and time to understand the habitat use of juvenile fish in a defined area.

Two case studies (CS) were carried out for testing the versatility of this methodology: CS-A) recovery of the nursery function in a shallow restored *P. oceanica* meadow and comparison with the adjacent meadows (Pollença Bay; NE Mallorca); and CS-B) seasonal variation of juvenile fish assemblages from three shallow rocky reefs, dominated by the presence of macroalgal forests (SW Mallorca) (Fig. 3). Habitat types from both CS sites were identified and mapped before the beginning of the sampling period to obtain a context of the seascape characteristics (e.g., habitat heterogeneity, boulder sizes and distribution, vegetation cover) on a broader spatial scale.

Figure 2 – SEAGIS EventMeasure screen capture of: a) TL measurement of *Symphodus tinca* and *Chromis chromis* individuals in a *Posidonia oceanica* patch located in a rocky reef; b) height measurement of various *Caulerpa prolifera* blades to calculate mean canopy height.

Figure 3 – Sites and habitats sampled (Mallorca, Balearic Islands, Spain).

Maps of the area of CS-A were created using QGIS, applying the Voronoi algorithm to the habitat information obtained from the videos taken using a Towed Stereo Video (TSV) system operated 50 cm above the seabed along 20 transects of 400 m separated by 25 m during the years 2018, 2019 and 2020. This algorithm is based on shortest distance constraints and generates a polygon layer containing the inputs points [19]. Then, a simplification of the layer was performed to smooth the geometries of the generated polygons. Due to the impossibility to use TSV because of the abrupt relief of the landscape of the CS-B, maps of the reefs were created by using sequential time-lapse underwater images of the seafloor, taken from the surface in the summer of 2021 with a GoPro HERO7 Black camera, along 10 transects of 270 m in "Cala Egos", 7 transects of 310 m in "Cala Llamp" and 7 transects of 200 m in "Es Total". Images were taken early in the morning to avoid the shade of the boat which hindered the process of analyzing the images for habitat mapping. Mosaics from the images were created with Microsoft Image Composite Editor software. With the habitat information obtained from the mosaics, a polygon layer was created with QGIS.

Case study A

We sampled a sedimentary bottom, between 4 to 8 m in depth, covered by *P. oceanica* at different vegetative development stages and structural complexities, quantified as shoot density and size, and canopy height. Between March 2018 and March 2020, 12 800 *P. oceanica* fragments were replanted in a 2-ha area over a dead matte substratum, about 200 m North from an extensive living meadow. The sampling sites included an undisturbed meadow (inner and edge sections, structurally complex), the restored meadow (with transplanted rhizome fragments, structurally simple), and a dead matte meadow now colonized by the seagrass *Cymodocea nodosa* and the macroalgae *Caulerpa prolifera* (structurally simple) (Pollença Bay; NE Mallorca) (Fig. 3). These meadows are being sampled eventually during the summer season, starting from August 2021. On each sampling date, 7 transects of 7 minutes were performed in the three study habitats. Preliminary trials and analysis demonstrated that the number and duration of transects were sufficient to obtain a representative sample of the fish community of the study area with at least 90 % of the species present in each transect area. Transects were orientated in parallel to each other, separated by 10-20 m. Due to the habitat characteristics, depth among transects was constant in each area (4-5 m in the restored area; 6-8 m in the dead matte and the undisturbed meadow). Transects were not necessarily parallel to the coastline. Seawater temperature data were recorded on every sampling location and date.

Case study B

We sampled three rocky reefs of variable structural complexities, quantified as morphotype diversity [14] and canopy height: "Es Total" and "Cala Egos" as structurally simple habitats (1 km between sites), and "Cala Llamp" as structurally complex habitat (3-4 km to the other sites) (SW Mallorca) (Fig. 3tab). These reefs were sampled monthly, starting from July 2021. The same protocol as in the CS-A was followed (7 transects of 7 minutes by zone). However, in this case, the transects were performed in parallel to the coast following the depth profile of the rocky reef. The lower limit of the rocky reef, where sedimentary habitats commenced, was found at 7 meters at all three sites, therefore the depth of transects ranged from 7 m to 0 m. Transect dives were carried out at one-meter-depth intervals starting from the 7-6 m isobaths towards the shallowest transect at 1-0 m depth. Seawater temperature data were also recorded on every sampling location and date.

Results

Stereo-DOV censuses and habitat mapping

For creating the map of the CS-A sampling site, the 20 transects carried out using TSV information (seagrass meadows) covered an area of 191000 m^2 (Fig. 4). In the CS-B, the area covered with time-lapse images (rocky reefs) was 14000 m^2 on "C. Egos" (10 transects), 6150 m^2 on "Es Total" (7 transects) and 9900 m^2 on "C. Llamp" (7 transects) (Fig. 4). The mapping fieldwork took approximately 15 minutes per transect in both CS-A (TSV technique) and CS-B (time-lapse technique). The time required for posterior image processing was lower for TSV information (1 h/transect) than for the time-lapse images (3 h/transect). The optimal conditions to take the TSV and time-lapse images and create the maps require good weather (low wind velocity and absence of waves) and good underwater visibility (>15 m).

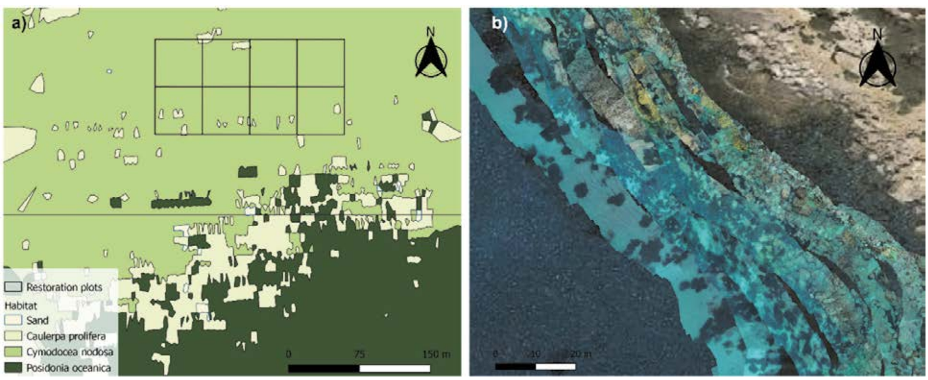

Figure 4 – Maps obtained for: a) CS-A study area; b) CS-B "C. Egos" area.

The stereo-DOV sampling covered an area of 139.5 m^2 ± 11.2 m^2 per 7-minute transect in CS-A zone and 158.4 m^2 ± 21.7 m^2 in CS-B zone. The total study area covered per sampling site in 1 hour of diving was approximately 976.5 m^2 in CS-A and 1108.6 m^2 in CS-B. A team of 4 divers was able to sample 3 sites per day, covering an area of 2929.5 m^2 in 3 h of effective diving in CS-A and 3325.8 m^2 in CS-B. Posterior video processing with SeaGIS EventMeasure took approximately 2 h per transect, including fish and macrophytes identification and measurement after training. The optimal conditions for the sampling require luminosity, good underwater visibility, and the absence of waves.

The stereo-DOV system was able to deliver high precision measurements for the juvenile fish density (in this case number of individuals by area) and fish total lengths, as well as habitat structural parameters such as macrophyte canopy heights or boulder sizes, among others.

To date, videos from August 2021 have been analyzed for the three habitats included in CS-A study, and videos from July and August 2021 have been analyzed for the three areas of study of CS-B. In this preliminary analysis, the stereo-DOV system was able to detect juveniles with a minimum TL of 1.1 cm belonging to 18 species of 6 families (Table 1).

Table 1 – Range of TL (mm) of the juvenile fish found during the sampling.

Family	Species	Rocky reefs			Seagrass meadows		
		Cala Llamp	Es Total	Cala Egos	Undis-turbed	Re-stored	Dead matte
Atherinidae	*Atherina* sp.		35-39	37-39			
Labridae	*Coris julis*	21-66	24-70	18-67	50-67		
	Symphodus mediterraneus		67.9				
	S. ocellatus		31-65	25-59			
	S. roissali	34-66	22-65	28-70			
	S. rostratus		64-67		67		
	S. tinca	30-70	17-69	19-67	42-69	22-58	
	Thalassoma pavo	51.2	46-60	47-59			
Mullidae	*Mullus surmuletus*	71-76	40-82	36-93	51	47	
Pomacentridae	*Chromis chromis*	18-36	12-39	11-36			
Serranidae	*Serranus scriba*	85		80-99			
Sparidae	*Diplodus annularis*		67-79	39-75	12-79		
	D. puntazzo			48.2			
	D. sargus sargus	62.7	58-98	82-99			97
	D. vulgaris	57-96	51-98	44-99	44-99		
	Oblada melanura	33-75	15-99	21-92			89-99
	Sarpa salpa	78-97	47-99	39-65			
	Spondyliosoma cantharus				44-69		

Case study A

In the videos analyzed from the seagrass meadows (August 2021), a total of 9 species were observed (2 in the restored zone, 2 in the dead matte, and 7 in the undisturbed meadow) (Table 1). The abundance of juvenile fish in the restored meadow and the dead matte area was very low. Higher abundances were found in the natural *P. oceanica* meadow, indicating the relevance of mature and undisturbed meadows for fish recruitment.

Case study B

In the videos analyzed from the macroalgal forests (July and August 2021), 17 species were observed (11 in "C. Llamp", 15 in "Es Total", and 15 in "C. Egos") (Table 1). The abundance of juveniles was similar between the three areas in both months analyzed. Differences in the depth preference for recruitment are yet to be analyzed.

Discussion

According to the preliminary results of our study, we can consider that the video-based methodology proposed here is appropriate to identify and count recently settled juveniles (TL>1.1 cm) of a great number of species that recruit in temperate shallow areas [8]. It also provides valuable information about the composition, cover, and height of the macrophytes present in the study area. However, it presents some limitations such as the restricted area recorded by the cameras. Habitat mapping allowed us to obtain the spatial information that is lacking in the videos.

Shallow macroalgal forests and seagrass meadows are both important nursery areas for many littoral fishes, including commercial species, as previously reported by other studies [2] [7]. Although some studies have already determined the microhabitat use and seasonality of littoral juvenile fishes in the north-western Mediterranean [8] [11], with this new approach we will be able to provide updated, integrated, and precise data on the settlement patterns at various spatial scales, including a broader seascape context. Moreover, with this methodology, we will be able to provide precise information on temporal patterns for most littoral species inhabiting NW Mediterranean waters depending on environmental factors such as depth, temperature, or habitat structural complexity (e.g. changes in macroalgal or seagrass canopy height through the year).

The versatility of stereo-DOV allows using it in a wide variety of temperate littoral nursery habitats in comparison with other stereo-video techniques. Some other video-based techniques used for studying adult fish communities, such as TSV or Remotely Operated Vehicles (ROV), present a similar adult fish detectability potential as stereo-DOV [15], but may not be appropriate for studying juveniles, as they need to be operated higher above the substrate, which may result in a poor capacity to observe small fish. Moreover, remote underwater stereo-video (RUV) is also not appropriate for the study of juvenile fish due to their low density and patchy recruitment patterns [8], which would require a great number of replicates. Transects of stereo-DOV covering bigger areas are more adequate for identifying juvenile initial recruitment patterns (TL 1-2cm) and subsequent dispersion and habitat changes with growth. Also, stereo-DOV can orientate towards fish within the transect providing higher quality images for better identification and size determination.

Moreover, the combination of stereo-DOV (and SeaGIS EventMeasure) and habitat mapping presents several benefits compared to traditional methodologies used for the study of juvenile fish communities (e.g. UVC). Some of the benefits are: a) videos are permanent, so they can be reanalyzed as many times as necessary; b) divers do not have to be experts in fish and macrophyte identification, as pictures can be consulted with experts if verification is needed; c) inter-observer variability can be controlled through quality checks; d) accurate and precise counts and measurements of fish and macrophytes lengths can be made independently of the diver experience; e) the observation of fish can be geo-localized on an individual level in the particular habitats they are, while with other methods fish are usually integrated over the whole transect despite the different micro-habitats present along the transects; f) a context on the seascape is obtained from the maps, allowing to estimate spatial variables that may be essential for recruitment; g) habitat complexity and heterogeneity can be measured in an easy way directly from the maps and the video images, decreasing fieldwork efforts (e.g. macrophyte % cover or canopy height); h) videos can be revaluated and the attained image data can serve as a data source for artificial intelligence (AI) applications that aim to automate the image analysis (identification of species and quantification); and i) stereo-videos allow to make precise measures of fish density and biomass, not possible to obtain with other video-based methods such as non-stereo or baited cameras.

However, there are also some disadvantages compared to other methodologies: a) cameras have a limited field of view; b) cryptic species are difficult to observe with this methodology; c) video processing is time-consuming; and d) experts are needed for fish identification during image processing. Further efforts are needed to reduce the time cost of processing the video imagery through the automation of identification and measurement of fish [17].

Conclusion

Using a combination of the stereo-DOV and habitat mapping is an effective methodology for monitoring the spatio-temporal patterns of recruitment and habitats of preference for juvenile fish of temperate coastal areas at different scales. The methodology can be also advantageous for obtaining long data series and evaluating possible temporal changes in the habitat structure, and therefore, in the ecosystem functions provided for the fish community.

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CORALLIGENOUS CLIFFS IN TUSCANY: DISTRIBUTION, EXTENSION OF THE HABITAT AND STRUCTURE OF ASSEMBLAGES

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Abstract – Coralligenous reefs are the main biogenic constructions of the Mediterranean Sea. The two main coralligenous morphologies are the coralligenous cliffs and platforms, the former developing in shallow waters (about 20-50 m) on vertical/subvertical rocky substrate and the latter built over horizontal substrates below 50 m depth also on detritic bottoms. The present study aims at assessing the distribution and extension of the coralligenous cliffs in Tuscany and describing the structure and the patterns of spatial variability. The mapping of seabed was obtained through Multibeam echosounder data coupled with video images recorded by using a Remote Operating Vehicle equipped with a high-resolution camera. Coralligenous cliffs were sampled by SCUBA divers in 11 sites (sectors of rocky costs) following the STAR procedure. Coralligenous cliffs were present in all study sites, with a total length of about 62.5 km and a total surface of 0.47 km^2. The linear extension of the habitat may be estimated about the 20 % of Tuscany rocky coast. The assemblages of continental coasts segregated from those of islands and were mostly characterized by algal turf, encrusting sponges and *Corallium rubrum*. The southern islands (Giglio, Montecristo and Formiche) were separated from the others and mostly characterized by terete and flattened Rhodophyta, *Eunicella* spp., *Paramuricea clavata* and erect bryozoans. The other Island had high abundance of *Flabellia petiolata*, *Halimeda tuna* and massive sponges. Gorgona was separated from all other sites and showed a high abundance of *Peyssonnelia* spp.

Introduction

Coralligenous reefs are the main biogenic constructions of the Mediterranean Sea which are considered indicators of the ecological quality of coastal systems and of "seafloor integrity" by the Marine Strategy Framework Directive [4]. The two main coralligenous morphologies are the coralligenous cliffs and platforms, the former developing in shallow waters (about 20-50 m) on vertical/subvertical rocky substrate, and the latter built over horizontal substrates below 50 m depth also on detritic bottoms [4]. Both habitats are widely investigated; coralligenous cliffs are sampled mostly by SCUBA divers, while ROVs (Remotely Operated Vehicles) are usually utilised for coralligenous platforms [5, and references therein]. In most cases, mapping programs do not distinguish the two coralligenous habitats and cliffs, due to their development on vertical bottoms, are normally not considered or under-estimated. Consequently, information about the relative importance of the two habitats within the same geographic area lacking. The present study aims at

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assessing the distribution and extension of the coralligenous cliffs in Tuscany and describing the structure and the patterns of spatial variability.

Material and Methods

The mapping of seabed was obtained through Multibeam echosounder data coupled with video images recorded by using a Remote Operating Vehicle equipped with a high-resolution camera during different surveys between 2014 and 2020. The spatial extension of coralligenous cliffs and platforms was obtained from digital images of bottoms considering as coralligenous cliff the hard bottom included in a depth of 30-40 m and a slope of 60°-90°, and as coralligenous platform the hard bottom included in a depth 45-100 m and a slope of 10°-50°. Coralligenous cliffs were sampled by SCUBA divers in 11 sites (sectors of rocky costs, Fig. 1) following the STAR procedure [3]. In each site, two areas several kms apart were chosen. At each area, three plots of about 4 m^2 where randomly selected on a vertical rocky substrate at 35 m depth. In each plot, ten photographs of 0.2 m^2 areas were collected by a framed camera. The percentage cover of the main taxa/groups was assessed in each photo by manual contour technique using the ImageJ software [3]. Spatial differences in the structure of assemblages (presence and abundance of taxa/groups) were analyzed by permutational analysis of variance (Primer6 + PERMANOVA, [1]) on fourth root transformed Bray-Curtis resemblance matrix. A multi-factorial model was used with the factors Site (*Livorno, Argentario, Gorgona, Capraia, Elba nord, Elba est, Pianosa, Montecristo, Giglio, Giannutri* and *Formiche di Grosseto*) as fixed, Area (2 levels) as random and nested in Site, and Plot (3 levels) as random and nested in Area. An MDS (Multi Dimensional scaling) ordination was used to highlight the variability among sites and the taxa/groups mostly responsible of the spatial pattern.

Figure 1 – Study sites and distribution of coralligenos cliffs.

Results

PERMANOVA detected a significant variability at all examined spatial scales (Table 1). The assemblages of continental coasts segregated from those of islands and were mostly characterized by algal turf, erect sponges and *Corallium rubrum*. The southern islands (Giglio, Montecristo and Formiche) were separated from the others and mostly characterized by, *Eunicella* spp., *Paramuricea clavata* and erect bryozoans. The other Island had high abundance of *Halimeda tuna*. Gorgona was separated from all other sites and showed a high abundance of *Peyssonnelia* spp. and terete Rhodophyta (Fig. 2).

Coralligenous cliffs were present in all study sites, with a total length of about 62.5 km and a total surface of 0.47 km^2. The linear extension of the habitat may be estimated about the 20 % of Tuscany rocky coast (Fig. 3).

Table 1 – PERMANOVA on coralligenous cliff assemblages of Tuscany.

Source	df	MS	Pseudo-F	P(perm)
Site = S	12	46483	3.688	**0.001**
Area(S)	13	12602	18.539	**0.001**
Residual	754	679		
Pair-wise test: LIVO≠PIOM≠ARGE≠VADA=MELO≠PIAN= MONT =GIGL=FORM=EL-ES=EL-NW≠CAPR≠GIAN≠GORG				

df= degree of freedom; MS=mean sum of squares; Pseudo-F= F value by permutation; P(perm)=p-value based on permutation

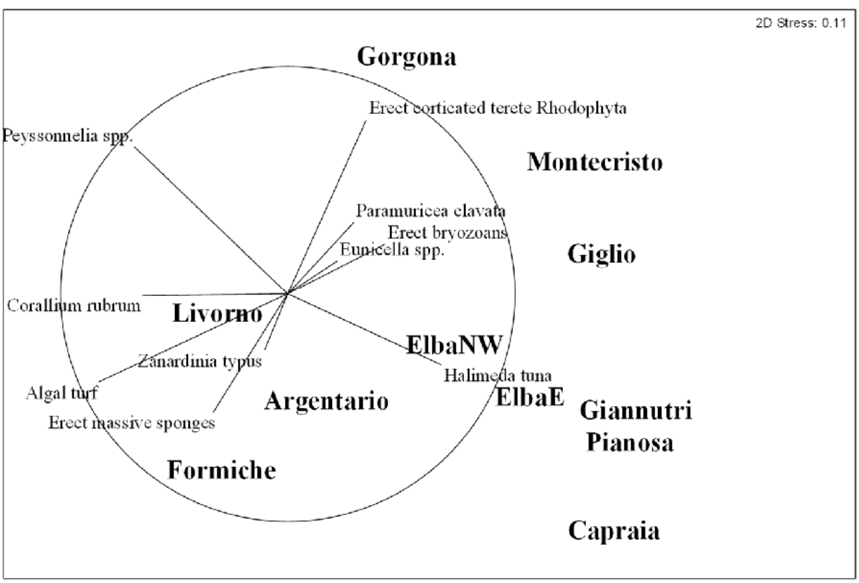

Figure 2 – MDS ordination on coralligenous cliff assemblages of Tuscany.

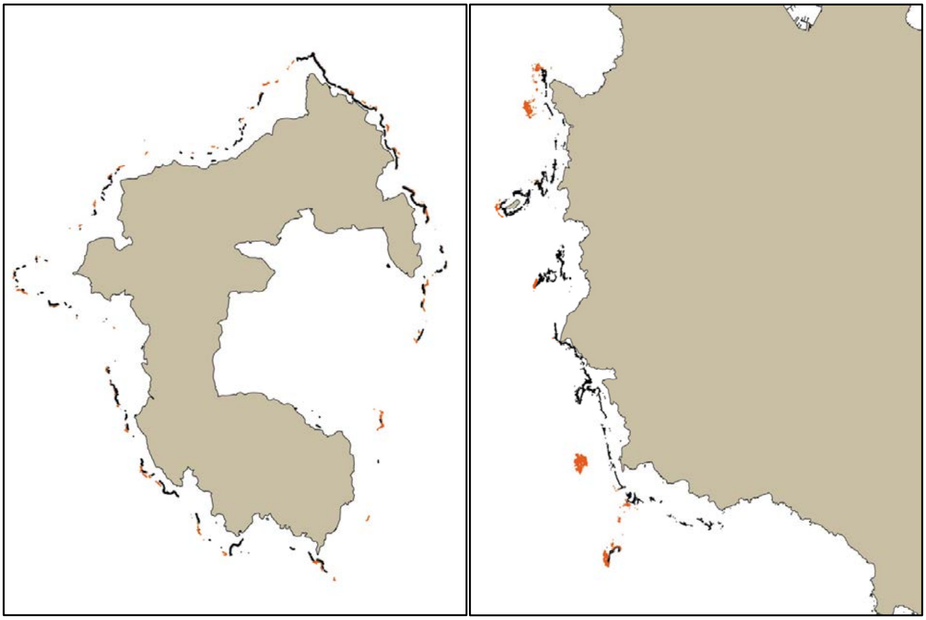

Figure 3 – Distribution of coralligenous cliffs (black) and platform (orange) at Giannutri (left) and Argentario (right).

Discussion

This study compares, for the first time, the surface of coralligenous cliffs and platforms highlighting the great importance, in term of extension and biodiversity, of coralligenous cliffs within the wide geographic area considered (Tuscany). Overall, the surface of coralligenous cliffs was about the 12 % of that of the Tuscany coralligenous reefs but values were highly variable. In fact, most coralligenous platforms are distributed around Meloria Shoals (more than 70 % of the whole habitat). In most of the other sites the spatial extension of coralligenous cliffs and platforms is similar and in some of them, such as Livorno, Capraia, Elba, Argentario and Giannutri, coralligenous cliffs are largest than coralligenous platforms. Thus, the approach used in the study highlighted that coralligenous cliffs represent a considerable part of circalittoral biogenic habitat, suggesting that its relevance could be higher than that normally emerges from seabed mapping.

Moreover, results confirmed the high level of biodiversity and spatial heterogeneity of coralligenous cliff assemblages already described in other Mediterranean areas. The assemblages mostly varied at large (among sites) and small (among samples) spatial scales, confirming a pattern already highlighted in previous studies [2]. The variability at small scale may be attributed to the patch distribution of assemblages mostly due to the high heterogeneity of biogenic substrate [2].

Conclusions

Coastal and continental shelf coralligenous reefs provide different ecosystem services and are subjected to different human related threats. These features combine to separate coastal coralligenous cliffs from other coralligenous habitats, such as platforms, banks and outcrops distributing on continental shelves. In this context, the assessment of their extension, structure and variability patterns plays a fundamental role from a conservation point of view. Thus, following the approach used in the present paper, coralligenous cliffs should be considered separately in monitoring programs, impact assessment studies and management plans

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NEW REPORTS ON THE PRESENCE OF *CALLINECTES SAPIDUS* (RATHBUN, 1896) ALONG THE CALABRIAN COAST

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Abstract – This work, carried out in collaboration with professional fishing operators, aims to indicate new areas of settlement of the species *Callinectes sapidus* (Rathbun, 1896) present both in the Tyrrhenian Sea and in the Ionian Sea along the coast of Calabria. Part of the individuals of *C. sapidus* sampled were taken at the mouths of the rivers and part in the salt lakes. For each individual caught, biometrics, weight, specific areas and distribution periods, as well as fertility or the presence of eggs (if female) were recorded. The captured individuals have been housed in aquariums to monitor and study their social behavior, predation techniques and food preferences for about six months. The sampled individuals of the species *C. sapidus* were found for the most part in the Ionian Sea and, more precisely, in the surroundings of the mouth of the river Corace in the direction of Catanzaro Lido (CZ), in the area of Steccato di Cutro where the river Tacina flows into the Gulf of Squillace and within the lakes of Sibari (artificial lakes), in whose area are currently also used as a food resource. Other specimens have been found in the Tyrrhenian Sea in the lakes La Vota of Gizzeria (CZ).

Introduction

Callinectes sapidus is a decapod crustacean of the Portunidae family, native to the western Atlantic Ocean and Mexican gulf. Its introduction into the Mediterranean Sea occurred through ballast water present in ships coming from the Atlantic calling at the ports of our coasts [6]. *C.sapidus* is found to be one of the most prevalent alien species in European waters [4].

C. sapidus is considered an invasive alien species because, by establishing itself outside its native range, it has overcome biotic and abiotic obstacles that have favored its establishment. This species has generated a negative impact both at the ecological level and at the quantitative level of the number of native species present [1].

C. sapidus tolerates large variations in temperature and salinity, euryhaline and eurytherm, tolerating values below 0.08 mg/l of dissolved oxygen. It is assumed that fertilized females head to the open sea for the release of eggs [5].

C. sapidus usually lives at depths of 35-90 meters and prefers sandy and muddy bottoms. It has been also reported in estuaries and mouths of rivers [10]. It is moderately omnivorous and feeds on fresh algae, small echinoderms, actinias, fish, molluscs, and organic debris of all kinds, with a marked preference for fish [7].

The first reported capture of this species in the Mediterranean occurred in 1949 in Grado (upper Adriatic Sea), and it was an adult female specimen.

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In 1950 a male specimen was caught in the Venice Lagoon. Also found in the Gulf of Genoa [5], Calabria and Sicily [9].

C. sapidus has also been found in Sardinia in marine, freshwater and transitional sites in the period between 2017 – 2018 [2].

Another 5 individuals have been found in the Channel Sicily off the port of Mazara del Vallo [3], the species is continuing its expansion.

The small number of *C. sapidus* specimens on which the study has been conducted, only 8, delivered by fishermen in the areas concerned, is not an indication of a low presence of the species, but represents a small portion of the quantities currently caught and exploited for food. Capture of mature females and males reveals possible establishment of the species in the reference area although no juvenile or postlarval stages have been observed. The objective of this work is to report the presence of C. sapidus in the new areas colonized by it in the Ionian and Tyrrhenian Seas of Calabria. The rapid expansion of this species underscores the importance and priority of conducting invasive species monitoring. In addition to documenting the presence and speed of expansion of the species themselves, monitoring also serves to understand whether their distribution in Calabria is due to a natural spread of crabs into areas increasingly suitable for their survival or has been induced by fishermen as a new commercially exploitable resource.

Materials and Methods

C.sapidus specimens were generally acquired by delivery from fishing companies with whom cooperation agreements were made through the intermediation of the 4 Calabrian FLAGs (Fisheries Local Action Groups).

These organizations are concerned with pursuing balanced development of the fisheries sector while respecting marine and environmental resources by making investments on the ground from EMFF (European Maritime and Fisheries Fund) resources.

When one of the boats owned by the agreement companies caught the specimens, the project contact person was notified.

If the latter was in a position to go to the landing site when the fishing vessel arrived, the animal was delivered in its live state; otherwise, the specimen was frozen and delivered later. For each specimen, of course, the boatmaster indicated the coordinates of the point of capture and reported them to the project contact person.

For each delivery, the specimen acquired was not chosen from all those available according to predetermined criteria, but one was acquired at random.

Since this is a very desirable species, currently used for food purposes in Calabria and increasingly in demand by the restaurant industry, the number of crabs delivered by fishermen for study purposes is by no means representative of the total quantities found in a given area, but should be considered only an index of its presence in the new territory.

Eight specimens of *C. sapidus* were caught during fishing operations. The sampled individuals of the *C. sapidus* species have mostly been found in the Ionian Sea and, more precisely, in the surroundings the mouth of the Corace River in the direction of Catanzaro Lido (Cz), in the area of Steccato di Cutro (Kr) where the Tacina River flows into the Gulf of Squillace, and inside the Lakes of Sibari (artificial lakes), in whose area they are also currently used as a food resource.

Other specimens have been found in the Tyrrhenian Sea in the La Vota Lakes of Gizzeria (Cz). One ovigerous female specimen (Figures 2-3) was caught at a depth of about 20 meters in front of one of the rivers in which its presence was confirmed. Biometries, weight, specific areas and periods of distribution, and fertility or presence of eggs (if female) were recorded for each individual caught.

The captured individuals (Figure 1 specimen A - B) were housed in aquariums to monitor and study their social behavior, predation techniques and food preferences for about six months.

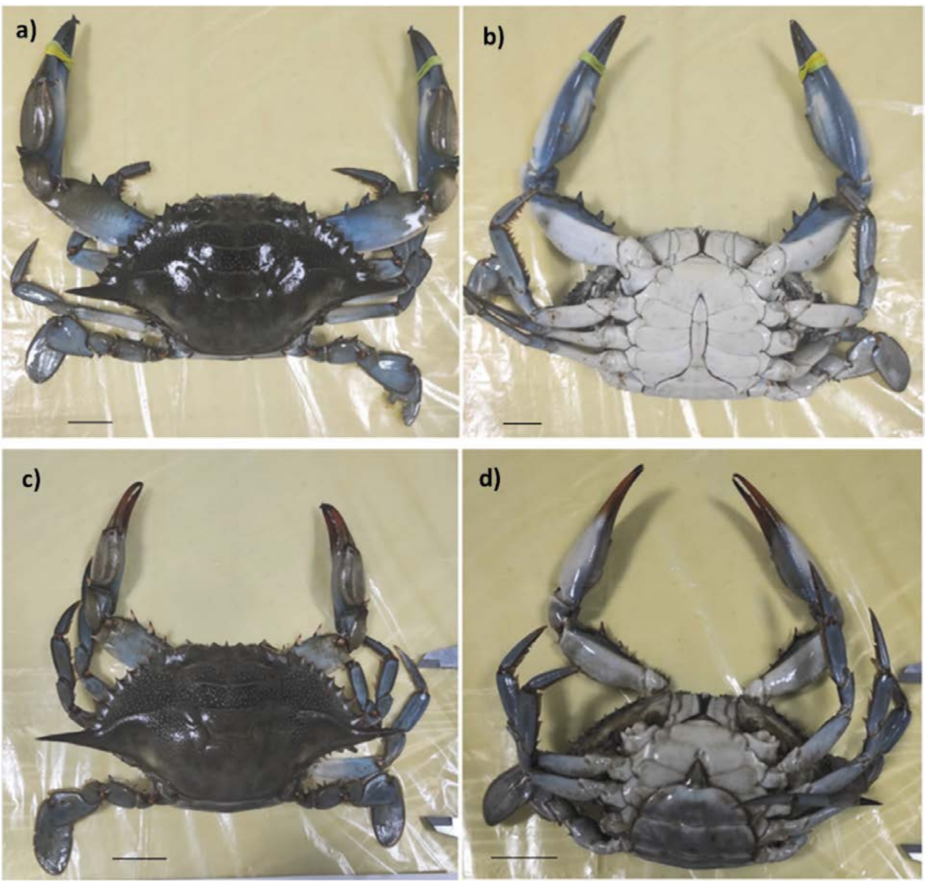

Figure 1 – a-b) Specimen (A) *C. sapidus* male found in Catanzaro Lido. c-d) Specimen (D) *C. sapidus* female belly and abdomen found in Falerna Marina. (Scale bars =2 cm).

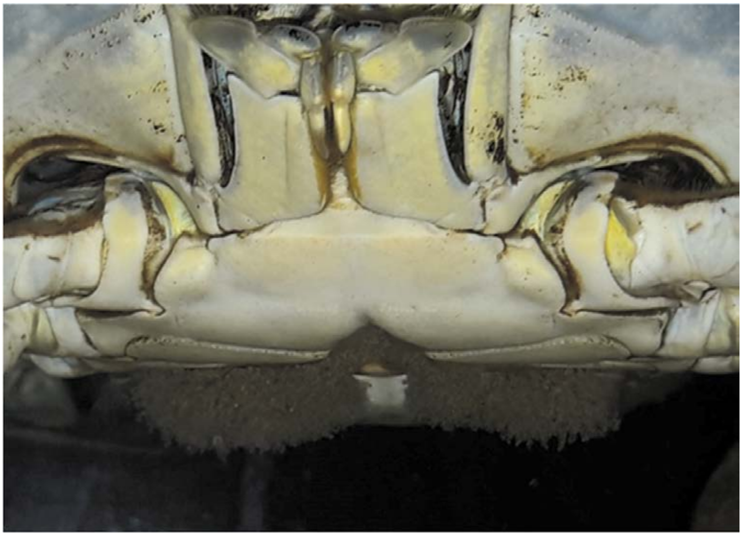

Figure 2 – Female of *C. sapidus* with presence of eggs (from MUPEM).

Figure 3 – Abdominal area enlargement (From MUPEM, photo taken on 10/05/2020)

Results

The first specimen (A) of *C.sapidus*, male (Figure 1- a-b), weighed 227 g, was from Catanzaro at the mouth of the Corace River captured alive on 03/05/2019 and died on

06/12/2019 in the aquarium, where it was possible to study its behavior. The carapace length of (A) (CL, mm - the distance between the center of the anterior interorbital margin and the center of the posterior margin) was 66 mm and the carapace width (CW, mm - the maximum distance between the posterior anterolateral spines) was 146 mm.

The second specimen (B), male, who died on 8/11/2019 in the aquarium e captured alive on 16/06/2019 and came from Crotone in the municipality of Cutro at the mouth of the Tacina River, weighed 252 g, with CL 74 mm and CW 163 mm.

The specimen (C), female from Catanzaro and municipality of Falerna in the locality of Lake La Vota captured dead on 13/ 11/ 2019, weighed 158 g, with CL 72 mm and CW 165 mm.

The specimen (D), female, captured dead on 13/11/2019 (Figure 1- c-d), from Falerna, weighed 171 g, with CL 68 mm and CW 151 mm.

The specimen (E), male, from Falerna, in the locality of La Vota Lake captured alive on 20/06/2019 and died on 2/12/2019, weighed 144 g, with CL 64 mm and CW 125 mm, had many epiphytes on the carapace and blackish cover.

The specimen (F), female, from Falerna captured dead on 13/11/2019, weighed 233 g, with CL 75 mm and CW 170 mm, with the presence of black spots on the limbs.

The specimen (G), an ovigerous female (Figures 2-3), from Laghi di Sibari in the municipality of Corigliano Calabro in the province of Cosenza and captured alive on 05/11/2019 and died on 01/07/2020, weighed 122 g, with CL 58 mm and CW 123 mm.

The last specimen (H), male, from Laghi di Sibari in the municipality of Corigliano Calabro in province of Cosenza and captured live on 05/06/2020, weighed 147 g, with CL 60 mm and CW 125 mm and dead on 05/10/2020.

The results (table 1) obtained showed a rapid expansion of their distribution area, but also a corresponding greater attention of the fish system operators towards the species, as well as towards other potentially impacting but with great potential for exploitation for food purposes.

Table 1 – Information related to the specimens of *C. sapidus* examined.

Specimen name	Finding location	Province	Municipality	Sex	Weight (g)	CL (mm)	CW (mm)	UTM_X	UTM_Y	Date of catch	Date of death	Sea
A	Foce fiume Corace	Catanzaro	Catanzaro	M	227	66	146	640468	4297419	03/05/2019	06/12/2019	Ionian
B	Foce del fiume Tacina	Crotone	Cutro	M	252	74	163	664065	4309619	16/06/2019	08/11/2019	Ionian
C	Lago La Vota	Catanzaro	Falerna	F	158	72	165	602458	4311405	13/11/2019	13/11/2019	Tyrrhenian
D	Lago la Vota	Catanzaro	Falerna	F	171	68	151	602458	4311405	13/11/2019	13/11/2019	Tyrrhenian
E	Lago la Vota	Catanzaro	Falerna	M	144	64	125	602458	4311405	20/06/2019	02/12/2019	Tyrrhenian
F	Lago la Vota	Catanzaro	Falerna	F	233	75	170	602458	4311405	13/11/2019	13/11/2019	Tyrrhenian
G	Laghi di Sibari	Cosenza	Corigliano Calabro	F Ovigerous	122	58	123	630666	4392203	05/11/2019	01/07/2020	Ionian
H	Laghi di Sibari	Cosenza	Corigliano Calabro	M	147	60	125	630666	4392203	05/06/2020	05/10/2020	Ionian

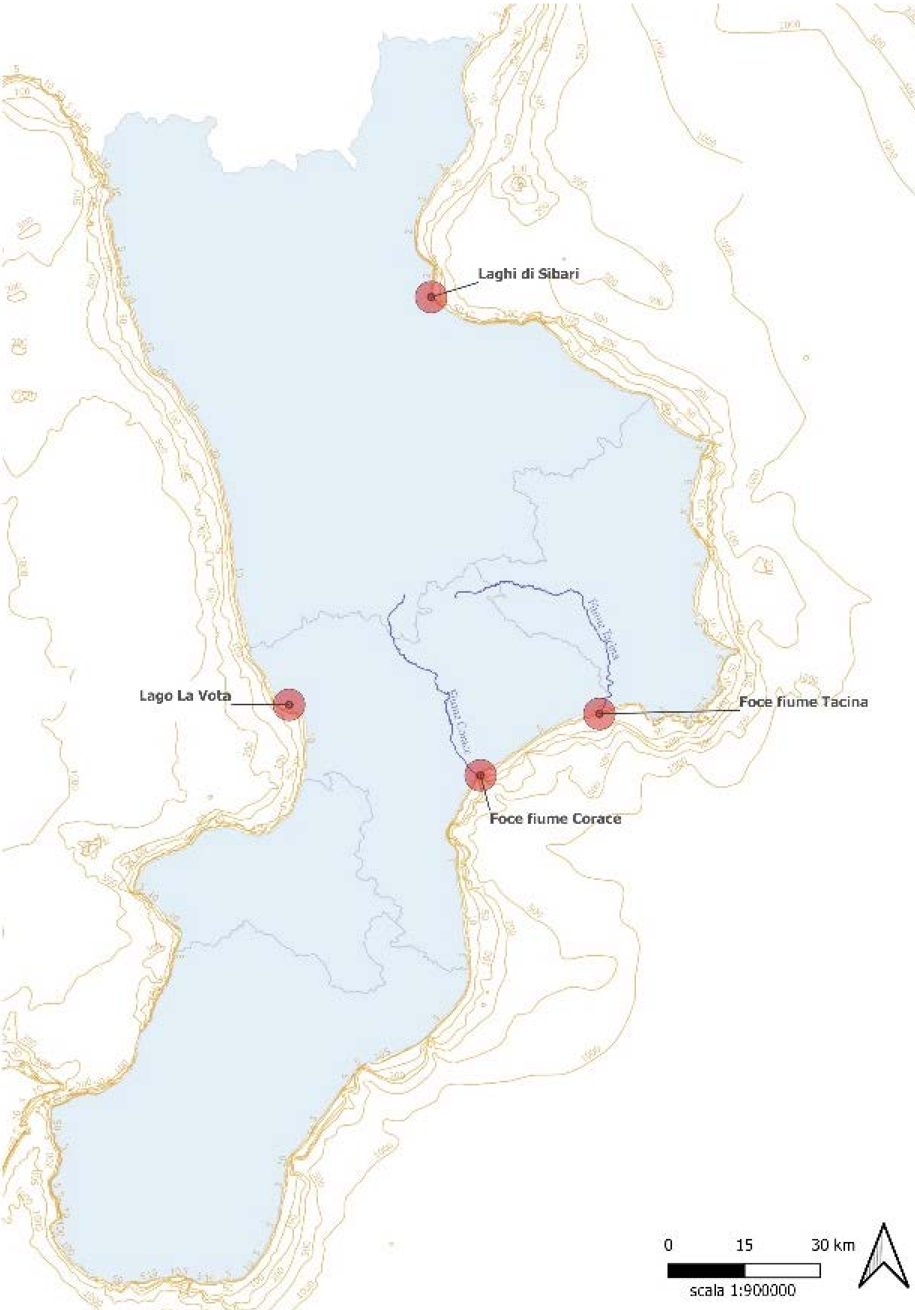

Figure 4 – Geolocation map of *C. sapidus* finding sites.

Discussion

In our opinion, the capture of mature females and males reveals a possible settlement of the species *C. sapidus* for the most part in the Ionian Sea in the following areas: mouth of the Corace River in the direction of Catanzaro Lido (Cz), Steccato di Cutro area at the point where the Tacina River flows into the Gulf of Squillace, Sibari Lakes (artificial lakes), although no juvenile or postlarval stages have been observed. Other specimens in smaller numbers have been found in the Tyrrhenian Sea in the La Vota lakes of Gizzeria (Cz).

Individuals of *C. sapidus* were monitored in a controlled environment for about 6 months and showed considerable aggression among individuals of the same species and both sexes, with females being more aggressive than males. The individuals studied and monitored in aquarium were very violent in the competition to grab food and win space. When a new specimen was placed in the aquarium, the attack took place in few seconds, and only one of the two specimens survived. It should be noted, however, that no phenomena of cannibalism were found among the specimens observed in the aquarium. The ovigerous female present in the aquarium was monitored and hatched on May 16, 2020. Unfortunately, the larvae did not survive.

Conclusions

These results confirm the continued expansion of *C. sapidus* in the Tyrrhenian and Ionian Seas areas. The monitoring of this species is of paramount importance to try to mitigate the impact it is generating on the ecosystem and biodiversity of native species and to look for future models of containment and utilization.

In conclusion, given the new numerous reports of the presence of *C. sapidus* specimens along the Tyrrhenian coasts, one wonders if the individuals sampled in the Tyrrhenian Sea come from the Ionian Sea and, if so, if this is the result of a spontaneous migration or due to deliberate anthropogenic activity. A first answer could be provided by an environmental DNA analysis, which, through molecular methodologies, is able to reveal information about the presence of a given species in a target area, on the vastness of the invasion and on its relative abundance [6].

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SEAGRASS DETRITUS AS MARINE MACROINVERTEBRATES ATTRACTOR

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Abstract – Seagrasses colonise coastal areas worldwide. Despite their high primary production, a considerable proportion becomes detritus that can be used as food, physical habitat and occasional or permanent shelter by several benthic macroinvertebrates. In turn, macroinvertebrates can contribute to regulating seagrass decomposition, and represent an important trophic link between primary producers and higher consumers. Nonetheless, several factors could modify colonizer responses to this habitat.

In this study, we tested if colonisation of the seagrass detritus of *Zostera noltei* Hornemann, 1832 was related to substrate availability rather than food and whether the colonising assemblages were similar according to the structural complexity of the meadow. We used artificial seagrass detritus to mimic the physical structure of the natural detritus while disentangling the effect of food attractiveness *vs.* physical habitat availability. Litterbags were filled with natural or artificial detritus and deployed within a seagrass meadow in Thau lagoon (Étang de thau, France) in areas of different structural complexity. During two field experiments, detritus decomposition and litterbag colonisation were analysed.

A total of 11270 individuals belonging to 26 taxa were identified (including polychaetes, crustaceans, molluscs, and chironomids larvae). Habitat structural complexity shows no effects on the colonisation of the detritus, but there were clear differences between empty and filled litterbags, which had a higher number of species and individuals, but without a general preference for the natural or artificial detritus substrate.

In conclusion, colonisation appeared to be driven by the presence of debris material, and not by its type. The natural and artificial detritus acts as an attractor for macroinvertebrates, which use opportunistically one or the other type, with no differences according to the seagrass habitat complexity, probably indicating a supply of individuals from further distances.

These findings show that the detritus, acting as a faunal magnet, can be colonised by a rich and diverse benthic community, highlighting its important role in maintaining the biodiversity within the seagrass meadows.

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Valentina Costa, Renato Chemello, Davide Iaciofano, Sabrina Lo Brutto, Francesca Rossi, *Seagrass detritus as marine macroinvertebrates attractor,* pp. 619-626 10.36253/979-12-215-0030-1.58

Introduction

Seagrasses form underwater meadows colonising coastal areas worldwide [1]. Seagrass ecosystems contribute to fundamentals ecosystems services, including carbon sequestration in marine sediments and coastal protection [2, 3]. Despite their crucial role, a worldwide decline of these species is well-documented as a response to numerous threats (e.g. eutrophication, invasive species, urbanization, etc) [4]. Seagrass biomass production is comparable to the aboveground production of mangroves and terrestrial forests [5], but a considerable proportion of seagrass production does not enter the green food web pathway [6]. The grazing pathway by some herbivorous fish and some invertebrates (e.g. *Sarpa salpa*), is highly variable [7]. The amount of primary production not directly used becomes detritus (defined also as litter) and can accumulate within the meadows, or can be exported to deeper water or to the shoreline where is often referred as wrack or beachcast [6].

Seagrass detritus can be used as food, physical habitat and occasional or permanent shelter by several benthic invertebrates [8]. Small crustaceans and molluscs are often the main colonizers of the detritus [9, 10]. They can feed on the detritus itself, as reported for some detritivorous crustaceans (i.e. *Gammarella fucicola* and *Gammarus aequicauda*), or on the microbial community that colonizes the detritus during the decomposition process [9, 11]. Biotic and abiotic variables regulate seagrass decomposition, such as litter quality and hydrodynamics conditions [12, 13]. Additionally, benthic invertebrates, as direct detritus shredders and enhancers of microorganisms' activity, can contribute to regulating seagrass decomposition [14] and represent an important trophic link between primary producers and higher consumers. Nonetheless, several factors could modify invertebrate responses to this habitat.

In this study, we tested if the colonisation of the seagrass detritus of *Zostera noltei* Hornemann, 1832 by macroinvertebrates was related to the substrate availability rather than food and whether the colonising assemblages were similar according to the structural complexity of the meadow. In particular, we used artificial seagrass detritus to mimic the physical structure of the natural detritus while disentangling the effect of food attractiveness *vs.* physical habitat availability.

Materials and Methods

The data presented in this paper form part of a project presented in Costa *et al.*, (2021) with further remarks [15]. The study was conducted in Thau lagoon (Étang de Thau, France) (Figure 1). The lagoon, located on the French Mediterranean coast, has a surface area of 75 km^2 and an average depth of 3.8-4.5 m [16]. Two seagrass species, *Zostera marina* and *Z. noltei*, form monospecific or mixed meadows representing about 22 % of the macrophyte biomass of the lagoon [17]. Seagrass detritus accumulates within the meadows, in adjacent bare sediment and on the lagoon shores.

Seagrass detritus Litterbags (15 x 10 cm) were filled with natural (NSD) or artificial seagrass detritus (ASD) or left empty (EMPTY). Seagrass detritus was collected in the lagoon, epiphytes were removed, and leaves were cut in fragments of 10 cm, as well as for the green plastic strips used for the ASD. The litterbags were deployed within a seagrass *Z. noltei* meadow in 3 areas of different structural complexity: Low Complexity (LC), Medium

Complexity (MC) and High Complexity (HC) (Figure 1). The structural complexity, based on shoot density and canopy height, was estimated on five plots per area.

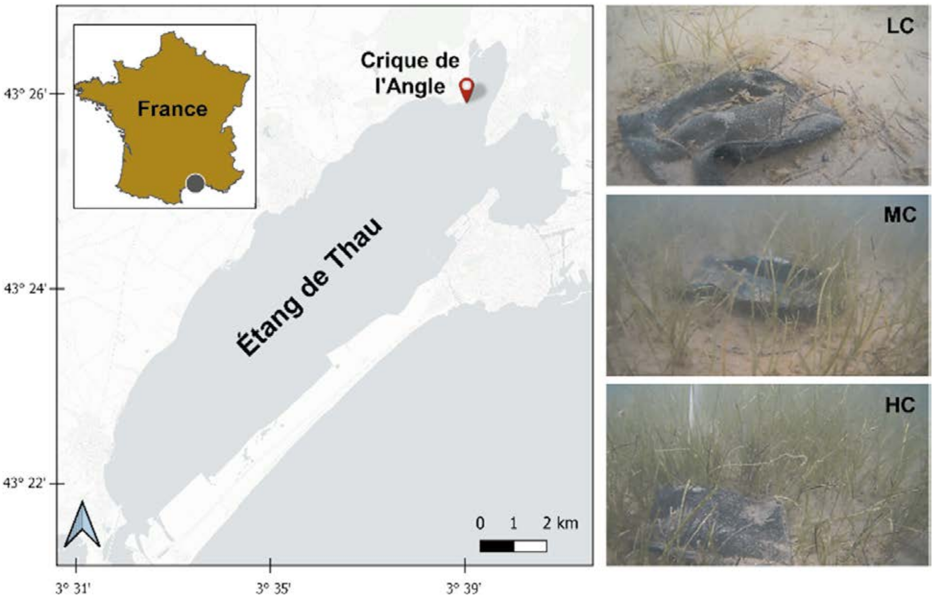

Figure 1 – Left side: map of the study area Crique de l'Angle, Thau Lagoon (Etang de Thau, France). Right side: litterbags in the three Habitat Complexity levels, Low Complexity (LC), Medium Complexity (MC) and High Complexity (HC).

During two field experiments, carried out in April and May 2018 (22 and 19 days, respectively), the detritus decomposition and the colonisation by invertebrates of 5 litterbags per substrate per area were analysed.

At the end of each experiment, each litterbag was singularly collected, put in plastic bags, and transported chilled to the laboratory. Each litterbag was gently rinsed with water and leaves and invertebrates were carefully separated. The seagrass detritus was rinsed, dried at 60 °C for 24 and weighed, while the colonizers were identified at the lowest possible taxonomic level and counted.

Diversity of the epifaunal assemblages, in terms of Number of Individuals (N), Number of Species (S) and Shannon-Wiener index of diversity (H'), was estimated. The R environment (version 4.2.0) in RStudio (2022.02.3 Build 492) was used for data analysis and visualization using the packages *tidyverse* [18] and *vegan* [19].

Results

Habitat complexity, in terms of shoot density and canopy height, was higher in HC, followed by MC and LC (Figure 2). Seagrass detritus decomposition was not significantly affected by the Habitat Complexity (0.0218±0.0103 day^{-1}).

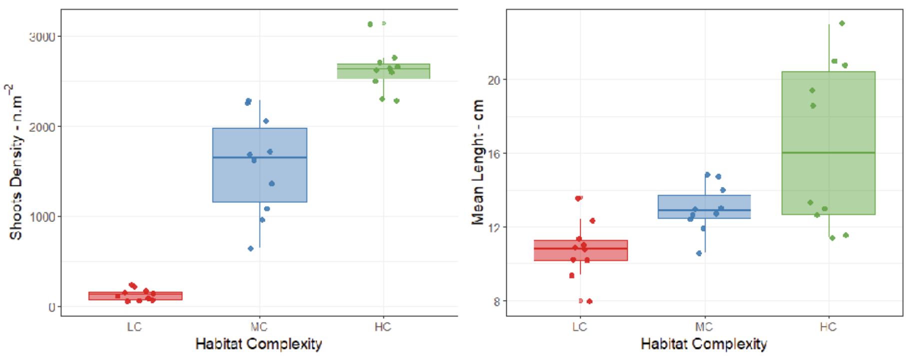

Figure 2 – Box-Plot (bounds from 25th to 75th percentile, median line and whiskers ranging from 5th to 95th percentile) and single points data of Shoot Density (n. of shoot per m^{-2}) and Canopy height (mean length in cm) calculated for the three Habitat Complexity levels (LC, MC and HC).

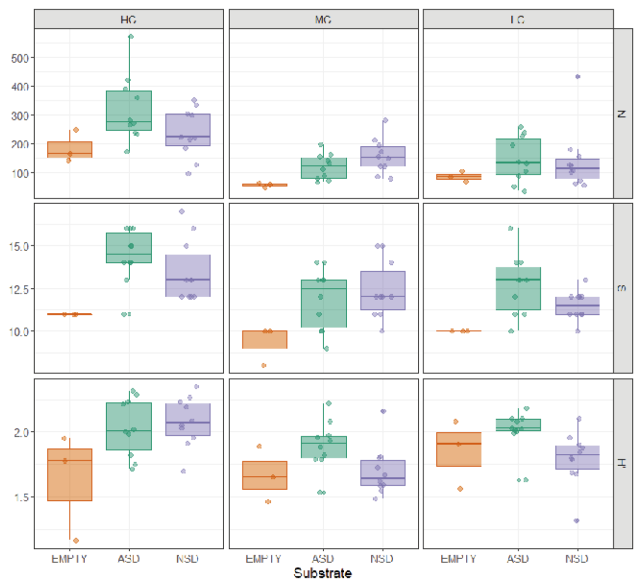

Figure 3 – Box-Plot (bounds from 25th to 75th percentile, median line and whiskers ranging from 5th to 95th percentile) and single points data of Diversity Indices (N, S, H') calculated for the Empty and filled litterbags (ASD and NSD).

More than 11 000 individuals (n = 11270) belonging to 26 taxa (including polychaetes, crustaceans, molluscs and chironomids larvae), were identified during the experiments. The number of individuals and species was significantly higher in the filled litterbags compared to the Empty ones ($p<0.001$), and a slightly more diverse assemblage was associated with the Artificial substrate (Figure 3).

PERMANOVA analysis did not identify significant differences for the *Habitat Complexity* x *Substrate* interaction ($p>0.001$), but a clear segregation is shown between empty and filled litterbags (Figure 4).

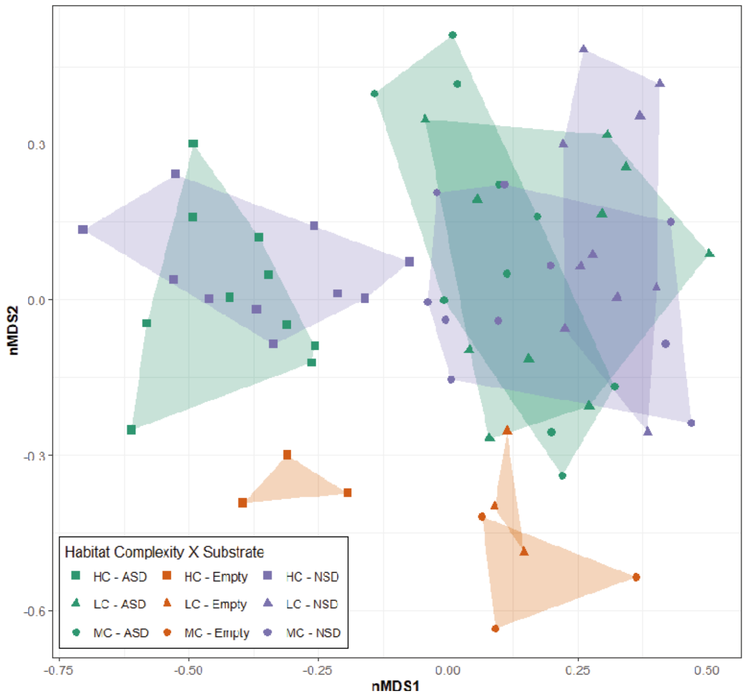

Figure 4 – nMDS ordination and convex hull areas calculated for the Empty and filled litterbags (ASD and NSD) for the three Habitat Complexity levels (LC, MC and HC).

Discussion

The aim of this study was to investigate the role of seagrass detritus as an attractor of invertebrates and the importance of the meadow habitat complexity in shaping the detritus colonising assemblages. To control for possible biases in the experimental procedures, we assess seagrass decomposition rates in the three habitat complexity areas and we used empty litterbags to control for the potential artefact effect due to the structure of the bag itself.

Seagrass decomposition showed no differences related to the complexity of the habitat, with results comparable to those reported for *Z. noltei* and *Z. marina* in other Mediterranean areas (0.015 ± 0.002 and 0.019 ± 0.001 d^{-1}; respectively) [20]. The empty litterbags were colonised only by very few taxa, showing that the detritus was the real faunal magnet [8, 11].

During the colonisation experiments, we deployed the litterbags within the seagrass meadow at different levels of Habitat Complexity and we found a decrease in the number of individuals and species from high to medium complexity treatment, where however few species were still present. In general, there was not a clear effect of the habitat complexity on the epifaunal colonisation of detritus, probably indicating a supply of larvae and juveniles from a further distance.

The artificial substrate was used to mimic the structure of the natural seagrass detritus while disentangling the effect of food attractiveness *vs.* physical habitat availability, and in our experiments both natural and artificial detritus attracted a diverse and variable epifaunal community with the epifauna not selecting one substrate more often than the other. Rather, some species opportunistically used either one or the other type of detritus, probably feeding also on the microbial biofilm growing on senescent leaves. Several mesograzers can show a low level of host-specificity and, rather, adaptability to different substrates, as found in two coexisting seagrass species, *Zostera caulescens* Miki, 1932 and *Z. marina* in northeastern Japan meadows [21].

On the whole, epifaunal distribution regardless of the substrate type showed that eelgrass detritus can be used uniquely as physical habitat by some species and also as a food source by others.

Conclusion

In conclusion, the colonisation appeared to be driven by the presence of detritus itself, with similar assemblages in the natural and artificial substrate, but with more individuals than the empty bags, used as controls. Using a seagrass meadow in Thau lagoon (France) as a case study area, this study provides new information about the role of habitat complexity in shaping the colonisation of seagrass detritus. It also shows that eelgrass detritus does not always attract invertebrates directly, letting us hypothesize that microbial biofilm growing on senescent leaves could be more important as a food attractor/resource for some epifauna species. These findings show that the detritus, acting as a faunal magnet, can be colonised by a rich and diverse benthic community, even in a short period of time, highlighting its important role in maintaining the biodiversity within the seagrass meadows.

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SPATIAL DISPLACEMENT OF NEARSHORE VEGETATION IN RESPONSE TO ARTIFICIAL CHANGES IN COASTAL MORPHOLOGY

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Abstract – The species composition of nearshore plant communities represents a continuous biological response to environmental gradients perpendicular to a marine shoreline. This response integrates individual adaptations, competition, abiotic variability, and chance events resulting in a definite 'optimum' band where a particular species attains highest density. Ultimately, this variation creates distinct vegetation zones where groups of species coincide in their optimum density. This study evaluated possible changes to nearshore plant communities in response to a change in shoreline. Surveys of vegetation assemblages were carried out in six coastal sites. Measurements of soil salinity and exposure to wind were also taken from each site. All six sites outcropped on the same bedrock and had a comparable overall seaward slope. Previous studies indicated that the species sequence was predictable: *Arthrocnemum macrostachyum* closest to the shoreline, with a *Limonium-Crithmum maritimum* zone adjacent in the inland direction. This was succeeded by a broader band of *Limbarda crithmoides* subsp. *longifolia*. Further inland, the subhalophilous assemblage dominated by *Thymbra capitata*, was the dominant cover. The perpendicular distance from the shoreline at which peak density of *L. crithmoides* was recorded, was taken as an indicator of the 'location' of the vegetation sequence. The variation in density of *L. crithmoides* perpendicular to the shoreline was unimodal and was modelled using a Gaussian 3-parameter distribution for each study site. The distance from the shore of the peak *L. crithmoides* density was positively correlated with the Thomas Exposure Index (adjusted $R^2 = 0.563$). These models were subsequently used to simulate the predicted shift of the vegetation sequence in response to a modified shoreline. The displacement in vegetation distribution following land reclamation is not necessarily subject to linear predictability. The abrupt change in shoreline morphology would modify the effects of environmental stressors, driving a displacement of nearshore plant communities towards the new shoreline. This displacement is unlikely to be either uniform or symmetrical, as the infill may have different sedimentological characteristics from the original substratum and initially will not have a persistent soil seed bank.

Introduction

The variation in species composition of nearshore plant communities represents a continuous biological response to environmental gradients perpendicular to the marine shoreline. This response integrates individual adaptations of vegetation, outcomes of competition, variability of environmental factors, and the occurrence of chance events, resulting in a definite 'optimum' band where a particular species attains highest density. The

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variation in selection pressure perpendicular to the shoreline creates distinct vegetation zones where different species coincide in their optimum density. This vegetation sequence, in terms of lifeform and adaptations, is broadly present throughout the Mediterranean littoral and differs from site to site in terms of species richness, identity of the characteristic species, substratum, and rate of change in abiotic gradients. The relative position and compression of the sequence is directly related to effective distance from the shoreline and sequence displacement has been observed or inferred following changes in coastal morphology. As such, this ecologically-predictable perpendicular zonation of vegetation would be expected to displace in response to changes in the position of the shoreline, migrating upshore in contexts where shoreline erosion exceeds deposition of sediment and vice-versa. This, in turn, can be used to construct broad predictions about changes in the conservation status of communities and species, if the position of the shoreline changes. The upshore or downshore migration of coastal communities is not a straightforward process, as different species will 'migrate' at different rates based on their dispersal, colonisation and establishment mechanisms. The present communities are the result of a dynamic equilibrium of species composition that can be shifted into a new stable state leading to possible extirpation of species. Whilst gradual changes in coastal conformation are often the result of natural cycles, the responses to anthropogenic processes are usually much more rapid. These include the redirection of rivers, and, therefore, of their sediment, for energy production, agricultural purposes and other reasons. In locations with limited land area, this also includes the deliberate reclamation of land from the marine environment. In such cases, the formation of a new shoreline displaced seaward relative to the previous one, would represent an abrupt modification of abiotic parameters, followed by migration of plants into the 'new' reclaimed areas. This study uses the central Mediterranean island of Malta as a case study for the characterisation of the coastal community and prediction of its responses. Malta is small, relative to its population size (316 km^2; 516000 persons), with its high population density (>1600 km^{-2} in December 2020) exerting extreme pressure on all its resources, including land area. There have been several recent indications that the island's government would consider land reclamation favourably, and, if implemented, this would occur along the shallower north-eastern coast of Malta. The vegetation sequence in Malta, syntaxonomically within the *Crithmo maritimi-Limonietea* alliance [4], occurs along much of the rocky coastline of the island. The band closest to the shore is colonised by halophytes and small chasmophytes whilst with increasing perpendicular distance this assemblage is replaced by a subhalophilous pulvinate assemblage. As such, this study aimed to predict the probable effects of changing coastlines on the distribution of halophytic communities and of protected species that occur in these zones. More specifically, the study aimed to accomplish the following:

(a) Determine the optima and limits of tolerance (in terms of perpendicular distance from the shoreline) of *Limbarda crithmoides*, an indicator species, in various areas along the coastline of Malta.
(b) Quantitatively predict plant community change in response to given changes in coastline extension.

The results of the study would subsequently inform conservation and restoration initiatives that should be associated with any land reclamation strategy.

Materials and Methods

The study was carried out in three coastal areas in Malta: Ghallis, Pembroke and Qalet Marku. These three sites were selected as they have been identified as possible sites for land reclamation by the Environment and Resources Authority of Malta. Where possible, sample sites with different aspects within the same area were identified and utilised, two such sites were selected at Ghallis, and three at Qalet Marku, giving six sample sites in total (Ghallis 'northwest', Ghallis 'east', Qalet Marku 'A', 'B' and 'C', and Pembroke). These sites will henceforth be referred to as Gh-NW, Gh-E, QM-A, QM-B, QM-C and PMB respectively.

The authors had access to detailed species occurrence and distribution records from three sites (QM-A, QM-B and QM-C) over a 5-year period (2015-2020) and this was used as a comparative baseline for the present study. A review of these previous studies indicated that the species sequence was predictable: *Arthrocnemum macrostachyum* colonising rock closest to the shoreline, with a *Limonium-Crithmum maritimum* zone adjacent in the inland direction. This was succeeded by a broader band of *Limbarda crithmoides* subsp. *longifolia*. Further inland, the subhalophilous assemblage dominated by *Thymbra capitata*, accompanied by *Crucianella rupestris*, *Cichorium spinosum* and other sprawling forms was the dominant cover. The nearshore community comprises several species with a restricted local distribution including endemic species (*Limonium zeraphae*, *L.melitense*, *Anthemis urvilleana*).

The surveys associated with this study required greater resolution of species distribution than was available in the baseline studies. Given the area of the sample sites, it was deemed feasible to carry out vegetation analysis using 'whole-site' orthophotos rather than limited linear transect samples. This necessitated detailed aerial surveys and photography for each study site. Aerial surveys were conducted using a DJI Mavic 2 Pro drone equipped with a Hasselblad L1D-20c camera, 1" CMOS, 20 million effective pixels sensor and lens of 35 mm Format-Equivalent 28 mm with Field of View (FOV) of approximately 77° and an f/2.8 aperture. The images produced by the drone were each 5472 x 3648 pixels in size. The flight plan was pre-programmed on Litchi Flight Planner [12]. Pilot studies indicated that photos taken at an altitude of 20 m retained sufficient ground resolution to permit individual large shrubs to be identified to species based on their habit and colour. The flight path constructed virtual transects 10 m apart or less to ensure an adequate area of overlap facilitating the accurate alignment of photos. The separate aerial photos were combined into an orthophoto using Agisoft Metashape Professional v.1.6.3 [1].

The regularity and predictability of the sequence of vegetation over the baseline period (2015-2020) suggested that the use of an indicator species to 'locate' the sequence was justified. The most suitable species for this purpose was *Limbarda crithmoides* subsp. *longifolia*. This plant was present in all study sites across all years of the baseline period, it is large and distinctive enough to be identified easily from aerial photographs, and it is sufficiently abundant and dense to form a well-defined zone. The population density of *L. crithmoides* in each study site was obtained from the orthophotos. The orthophotos were calibrated in FIJI [10] and a virtual grid of 1 m^2 squares overlain on each image. Random squares were used as the origin for a virtual 10 m^2 x10 m^2 quadrat in which all *L. crithmoides* individuals were counted. As many non-overlapping virtual quadrats as possible were taken for each site. The perpendicular distance from the shoreline at which peak density of *L.*

crithmoides was recorded in each site, was taken as an indicator of the 'location' of the vegetation sequence. These peak values were estimated by fitting a 3-parameter Gaussian distribution model to the data relating the density of the *L. crithmoides* population with distance from the shoreline:

$$f = ae^{-0.5(\frac{x-x_0}{b})^2}$$

In this model, f is the density of the *Limbarda crithmoides* population at distance x from the shoreline, a is the 'peak density', x_0 is the distance from the shoreline at which the peak density occurred and b is the width or 'tolerance' of the zone occupied by the species. These parameters were subsequently correlated with the values of the environmental factors measured from each site to assess the contribution of each of the plant's distribution. The principal environmental factors that were measured at each site included variation of soil salinity, slope, geographical aspect and exposure to wind and wave action. The geographical aspect of each site was read off from maps. The slope at each site was measured using a clinometer, with all required procedural precautions taken. The slope was measured at every break of slope perpendicular to the shoreline and an overall value for the slope in each site was obtained. For the assessment of soil salinity (measured as electrical conductivity), several samples of surface soil were collected from each of the study sites, at different perpendicular distances from the shoreline. Soil samples were taken to the laboratory immediately after collection and frozen at -20°C until processed. In the first step of processing, the soil samples were allowed to thaw at 25°C for 36 hours, after which 20g of soil from each sample was weighed and suspended in 100 mL deionised water. The suspension was mixed for 30 minutes and allowed to settle for a further 15 minutes. The electrical conductivity was then measured by taking several replicate readings using a TPS 90-FL desktop conductivity meter. The entire procedure was repeated twice per soil sample, and all necessary procedural precautions were taken [7]. The exposure of each site to wind and wave action was estimated using the Thomas Exposure Index (TEI) [11] which assumes that wave action can be predicted from wind direction, wind duration and velocity and accounts for direction, shape, and angle of exposure of the shore. It also accounts for wind fetch and bathymetry of the seabed. This was carried out using a 12-division, wind rose, overlain on a map of each site of study. The centre of the wind rose was placed over the point of interest. The parameters noted to determine the TEI were the Wind Energy (W) obtained from meteorological tables, Fetch (F), the distance from the shoreline to the nearest headland in nautical miles, calculated using the Navionics webapp online portal [9]. For open shorelines this was taken to be 100 nautical miles. The third parameter was the critical depth for shallow water, the distance in nautical miles from the shoreline to the 6m bathymetric line (Cs). These were also read from the Navionics webapp online portal [9]. The TEI was subsequently calculated using the following:

$$TEI = \sum logW \, log\left(1 + \frac{F}{C_s}\right)$$

Results

The variation in peak density (*a*), peak distance (x_0) and tolerance (*b*) of the *Limbarda crithmoides* population in each of the six study sites is given in Figure 1 and Table 1. As can be seen from the graphs, the peak distance x_0, varied from 28.7m (QM-A) to 51.5 m (QM-C). The tolerance of the fitted model was narrowest at PMB, Gh-E and QM-C, whilst it was much broader at the other sites.

The variation in TEI with peak distance and tolerance across sites is given in Figures 2 and 3. These data suggest that higher TEI is negatively correlated with tolerance ($r = -0.553$; $P = 0.255$) and positively correlated with peak distance ($r = 0.81$; $P = 0.052$)

The variation in the electrical conductivity of the surface soil across all sites is given in Figures 4 and 5. These data suggest a trend of decreasing median electrical conductivity and decreasing variance in the values of this parameter with greater distance from the shoreline even over such a narrow distance range. Although the median electrical conductivity varied across sites, there was no discernible pattern that correlated with any of the environmental factors considered during this study. In general, when taking all samples from all sites together, a distinct negative correlation between electrical conductivity and distance from the shorelines is evident ($r = -0.433$; $P < 0.0001$; $n = 328$).

Discussion

The data collected during this study confirmed the predictable sequence of the vegetation zones of the sloping rocky coasts of the Maltese Islands, but also established a relationship between the peak density and tolerance of the fitted distribution with the exposure to wind and wave action. The predictability of the vegetation zones is related to the degree of specialisation of the plant species concerned. Smooth, non-hirsute photosynthetic surfaces, such as those of *A. macrostachyum*, *L. crithmoides* and *Crithmum maritmum*, allow any saline aerosol that reaches the surface of the leaves to drain off rapidly. This avoids the risk of the plant retaining high levels of salt on the surface of the leaves, which would ultimately result in further osmotic stress. The reduction of leaves is evident in many species found in these areas including *A. macrostachyum*, where leaves are reduced to scales and in which the principal photosynthetic organ is the stem. The photosynthetic output of stems has been shown to be comparable to photosynthesis from leaves [3], however a photosynthetic stem also reduces the surface area to volume ratio compared to photosynthetic leaves. Reduction of leaves, and consequently of stomatal leakage, is an adaptation against dry conditions. On assessing succulence in the different species of interest it was noted that *L. crithmoides* had a much higher succulence than any of the other four species investigated for succulence. *A. macrostachyum* is a stem-succulent [8] unlike *C. maritimum* and *L. crithmoides* both of which are leaf-succulent species. The stem of *A. macrostachyum* is anatomically complex, with several structures requiring space [6]. Therefore, succulence in this species is limited by space. *C. maritimum* and *L. crithmoides*, both being leaf-succulents do not have the same restriction as *A. macrostachyum*, both recording a similar median water loss. However, the variation range of *L. crithmoides* was much larger than that of *C. maritimum* indicating that the former has a much larger range of tolerance as succulence is varied depending on the conditions present at the site in which the species is thriving [2].

Land reclamation studies which have been conducted in the past have shown that the coastal vegetation is somewhat altered following the process of land reclamation and immediately after the process of land reclamation, the seed bank and vegetation change from that originally established [5]. As a result, the coastal zone would undergo serial modifications as the vegetation starts to encroach into the new area from various zones, with some species outcompeting others. The trends shown by the fitted models suggest that any modification in the position of the shoreline would be accompanied by a corresponding shoreward shift of the vegetation sequence, indicated by the position of x_0, in all sites. The principal determinant seems to be the variation in TEI, which would also influence the median electrical conductivity of the soil at every given point. As such, the former shoreline areas would, following reclamation, have lower TEI, lower median electrical conductivity and less variability in this parameter. The authors' unstructured observations of colonisation processes involving plants from the coastal community suggest that *Limbarda crithmoides* is generally the pioneer species in a regenerant primary succession whilst the other characteristic species only establish much later. As such, the most likely proximal outcome of extending the shoreline seaward is a shoreward migration of the *Limbarda crithmoides* zone and the subhalophilous xerophyte zone (*Thymbra capitata* and other species). This would lead to gradual replacement of the existing Crithmo-Limonietum formation as the relative fitness advantage of the halophytes and chasmophytes in this zone would be reduced. Physiological constraints would limit the shoreward migration of the subhalophilous xerophyte-*Limbarda crithmoides* formation leaving a broad bare zone. This would later be colonised by extreme halophytes such as *Arthrocnemum macrostachyum*, chasmophytes such as *Limonium* spp. and succulent species including *Crithmum maritimum*. The stochasticity associated with this colonisation has not been evaluated. However, the migration/extirpation/recolonisation sequence related to the reclamation process might lead to the local extirpation of potentially vulnerable species, such as the endemic *Anthemis urvilleana*.

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Figures and Tables

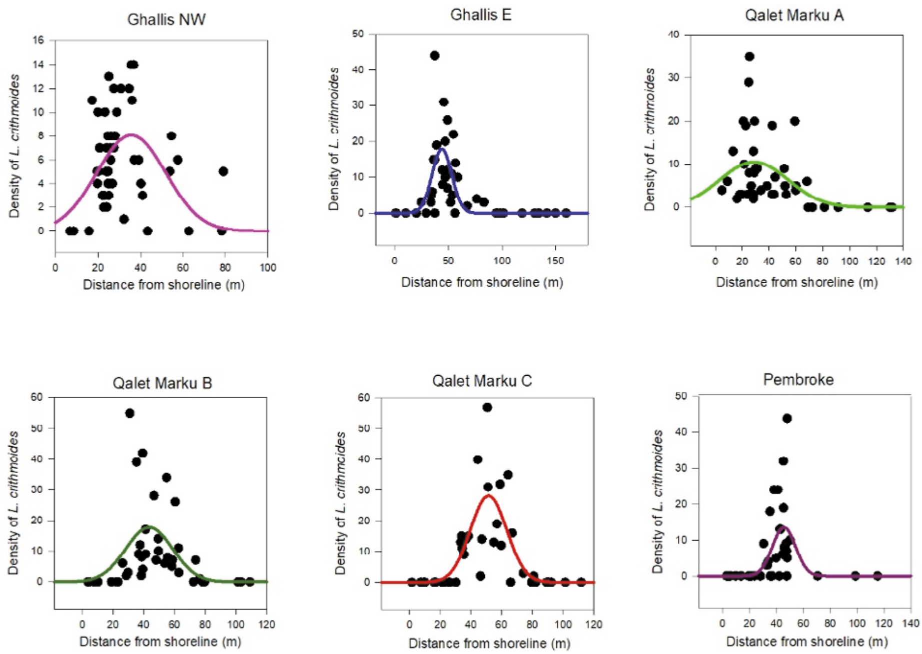

Figure 1 – Variation in population density of the *Limbarda crithmoides* population in each of the six study sites. The data points are measured values whilst the lines represent the fitted 3-parameter Gaussian model.

Table 1 – Summary of Gaussian model parameters (a, b, x_0) and TEI for each study site.

Site code	**TEI**	**Peak density (a)**	**Tolerance (b)**	**Peak distance (x_0) (m)**
Għ NW	11.52	8.1	16.3	35.6
Għ E	11.83	17.9	9.2	44.0
PMB	9.98	13.5	8.6	45.6
QM A	5.49	10.5	25.5	28.7
QM B	9.21	17.6	15.2	43.6
QM C	16.52	28.1	11.9	51.5

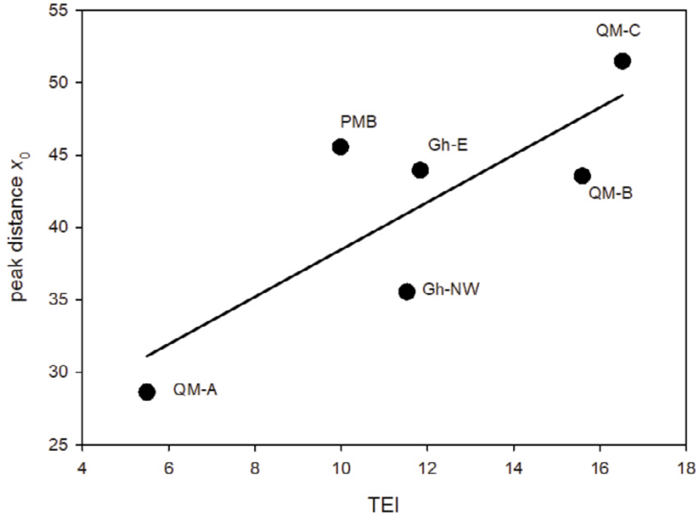

Figure 2 – Variation of peak distance (x_0) with TEI for all sites. R = 0.81; P = 0.052. Site codes – QM-A, Qalet Marku A; QM-B, Qalet Marku B; QM-C, Qalet Marku C, QM-C; Gh-NW, Ghallis northwest; GH-E, Ghallis east; PMB Pembroke.

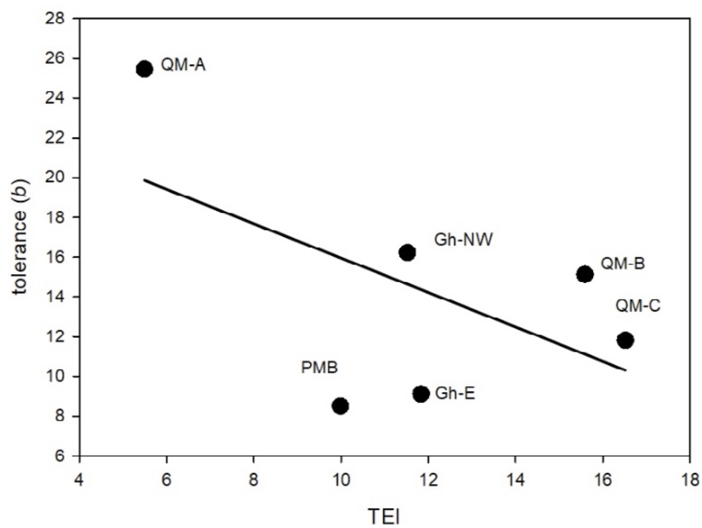

Figure 3 – Variation of tolerance (*b*) with TEI for all sites. r = -0.553; P=0.255. Site codes – QM-A, Qalet Marku A; QM-B, Qalet Marku B; QM-C, Qalet Marku C, QM-C; Gh-NW, Ghallis northwest ; GH-E, Ghallis east ; PMB Pembroke.

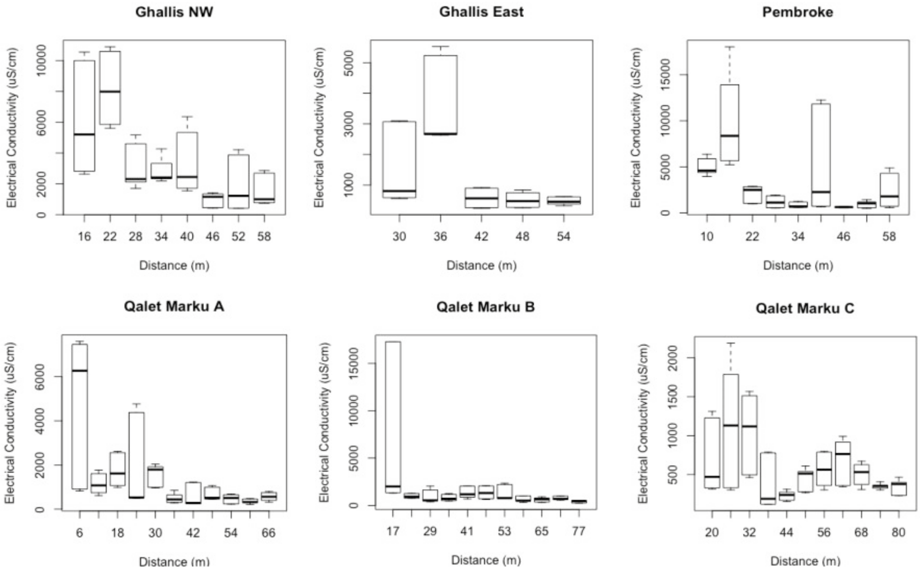

Figure 4 – Variability of median electrical conductivity in each site with distance from the shoreline. The upper and lower bounds of each boxplot represent the 75th and 25th percentiles respectively. Upper and lower error bars are situated at the 95th and 5th percentiles respectively.

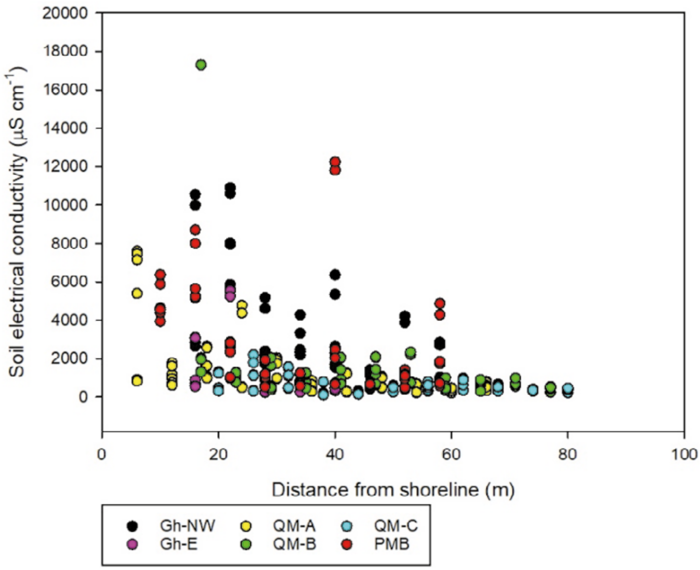

Figure 5 – Variation of electrical conductivity with distance from shoreline for all sites.

THE ROLE OF SCIENTIFIC DIVERS IN THE ADRIREEF PROJECT: ARPA PUGLIA ACTIVITIES

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Abstract – The ADRIREEF project (INTERREG Italy-Croatia 2014-2020) was targeted to valorization of the natural and artificial reefs in the Adriatic Sea according to the principles of the Blue Growth. The project also includes the development and testing of suitable low-impact technologies for underwater monitoring. As project Partner, the Apulian Regional Agency for the Prevention and Protection of the Environment (ARPA Puglia) identified the coralligenous reef in the Marine Protected Area of Torre Guaceto (Brindisi, Italy) as a case study for the project purposes. According to the project objectives, ARPA Puglia selected some low-impact monitoring methods, in particular, the Agency's scientific divers team applied a standard photographic sampling method for the benthic communities and the visual census (VC) method to describe the fish assemblages. A Remote Operative Vehicle (ROV) was used also in order to test the applied methods and compare the obtained data.
At present, in collaboration with MPA, a *vademecum*, a sort of Guideline, is being published on the sustainable use of the submerged area by recreational divers.

Introduction

Coralligenous habitat is considered the second most important subtidal "hot spot" of biodiversity in the Mediterranean Sea after the *Posidonia oceanica* meadows (Boudouresque 2004). For the many environmental and biological valuable characteristics this habitat has been included in the Habitat Directive (EEC Reg. 1992/43, Annex I; Habitat code: 1170 Reefs), as well as it is monitored by the Water Framework Directive (2000/60/CE) and by Marine Strategy Framework Directive (EC Reg. 2008/56). Coralligenous bioconstructions could build ups into two main different geo-morphologies: rims-structures on submarine vertical cliffs and banks-flat frameworks over horizontal substrata (Pérès and Picard 1964; Laborel 1987; Ballesteros 2006; Bracchi *et al.* 2014). The apulian continental shelf, as in the case of Torre Guaceto MPA, is characterized mostly by the second morphology (Piazzi *et al.* 2019). This kind of bioconstruction is generically called "bank-type" coralligenous biogenic reefs.

The main aim of the case study is to characterize the natural reef selected using low-impact monitoring methods. In particular, the ARPA's scientific divers team applied a standard photographic sampling method for the benthic communities and a visual census (VC) method to describe the fish assemblages. A Remote Operative Vehicle (ROV) was used also in order to test the applied methods and compare the obtained data. These technical methodologies is often used for the ecological characterization of the sea-bottom protected

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habitats and submerged environments affected by pre- and post-construction monitoring activities. Natural and artificial reefs are priceless elements for the scientific community and key resources for Blue Growth. By mapping and monitoring Adriatic reefs and involving relevant stakeholders, Adrireef aims to provide guidelines and a code of conduct illustrating sustainable exploitation models of marine reefs. In Adrireef project, other partners have worked, applying the same techniques, to characterize the artificial reef, for example the wreck of the Paguro offshore oil platform, with the aim of rendering video in post-production and making it possible to dive while staying dry. This is another example of application of the Blue Economy and of what the knowledge of marine resources can be shared in a new and easily usable way with the aim of safe marine environment. The usability of resources combined with knowledge and awareness were the reasons why Arpa Puglia involved and created a working group of scientific divers and chose a PMA as a case study, sharing knowledge, making it accessible to everyone, is the first step to stimulate an ethic of respect and protection.

Materials and Methods

The natural and artificial reefs of the Adriatic Sea are the focus of the ADRIREEF project, financed by INTERREG Italy-Croatia 2014-2020 Program, with the aim to valorize them according to the principles of the Blue Growth. As project Partner, ARPA Puglia identified the coralligenous reef the Marine Protected Area of Torre Guaceto (Brindisi, Italy) as a case study for the project purposes. The MPA of Torre Guaceto is located in the South Western Adriatic Sea of the Puglia Region (Italy); it was formally established in 1991, but entered into force in 2001. The MPA total area is approximately 2227 ha and it is divided into three zones according different protection regime: zone A (total protection, two areas); zone B (general reserve area);-zone C (partial reserve area) (Figure 1).

Figure 1 – Marine Protected Area of Torre Guaceto.

The MPA coast, mainly rocky with some small beaches, is characterized by a rocky plateau that slopes from the shore up to about 10-12 m of depth. Rocky bottoms alternate with sandy areas and *Posidonia oceanica* seagrass beds. From about 20 to 35–40 m depth, coralligenous formations alternate with sand-detritic substrate, while detritic–muddy sediments widely dominate at deeper bottoms (Guidetti *et al.*, 2010). The presence of coralligenous bioconstructions as natural reef, makes the Torre Guaceto MPA a suitable site to achieving the goals of ADRIREEF Project.

To identify the most suitable study area for the project, the first step was to collect the cartographic data available from the BIOMAP Project (BIOcostruzioni MARine in Puglia), promoted by the Puglia Region (Italy). The aforementioned project has mapped and classified most of the Apulian coralligenous reefs, including those of the MPA Torre Guaceto.

To better define the morphological characteristics of the sea bottom in the study area, a Digital Terrain Model (DTM) in raster format was developed. The DTM was subsequently managed with GIS software (Q-GIS ver. 3.16.0-Hannover) using which the isobaths with an interval of 1 meter have been extracted. So, it was possible to identify a potential study area which was subsequently investigated by underwater pre-surveys.

An underwater cliff was chosen as the study area, located 2 km from the ancient "Watchtower", following a path of 60° N (Figure 2). The total area of the coralligenous reef chosen was estimated of about 6700 m^2, its perimeter is about 350 m and the longest axis is 140 m. It is composed of numerous coastal-type coralligenous outcrops that create a raised structure of an overall elliptical shape, north-south oriented. The reef and its bioconstructions is placed at 27-29 m depths with the top that rises 24-25 m depths. On the east side there is a discontinuous vertical wall 3-4 m high.

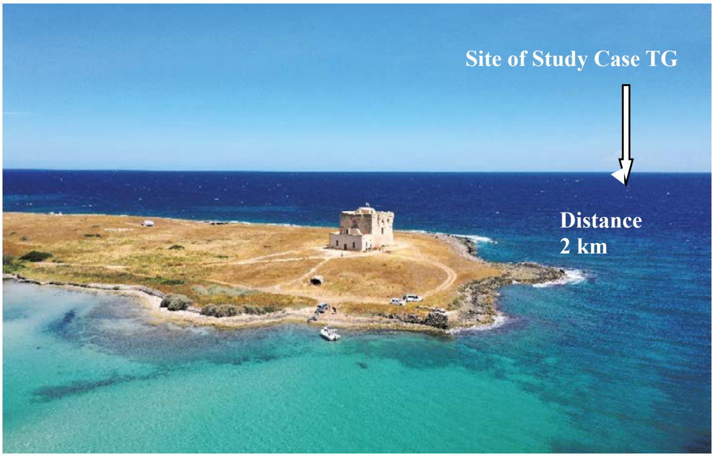
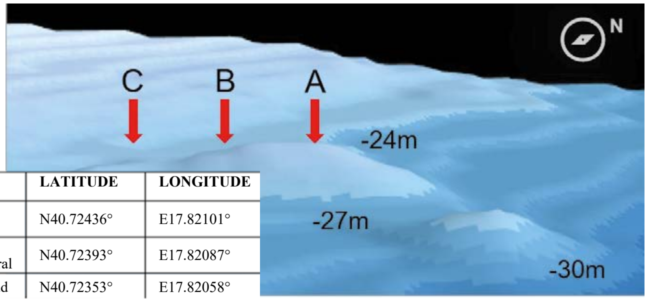


Figure 2 – Location of the natural reef identified.

Three sampling stations have been identified along the longest axis (with NS gradient) of the reef as shown in Figure 3. Sampling stations A, B and C were located along a 100 m bottom transept on the east side of the reef. The stations were placed along the longest axis of the study area with a distance among them of 50 m, at a depth of 24-25 m. Once the sampling station have been defined, the planned monitoring was carried out in 4 scientific surveys, two in the autumn period (15/10/2019 - 12/11/2020) and two during the summer season (23/07/2020 - 08/07/2021).



Site ID	LATITUDE	LONGITUDE
Station A, Nord	N40.72436°	E17.82101°
Station B, Middle/Central	N40.72393°	E17.82087°
Station C, Sud	N40.72353°	E17.82058°

Figure 3 – Q-Gis elaboration showing the DTM and the survey stations localization.

In each station, two low impact sampling methods were performed: the first method was a photographic one for the benthic community settled on the reef, while the other was the visual census to evaluate the fish assemblages.

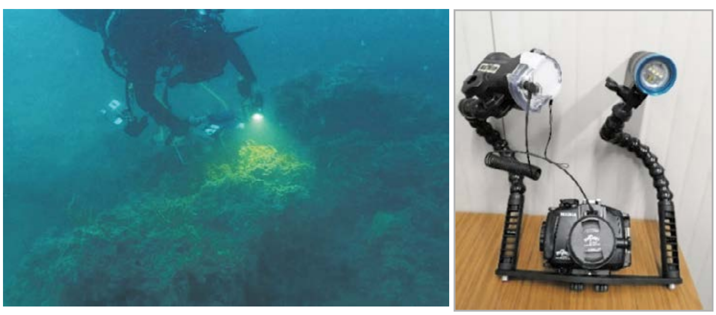


Figure 4 – ARPA Puglia SD during the photographic sampling survey and the Sony RX-100 VI camera used.

With regard to the first method, six photos (3 on the vertical face and 3 on the horizontal face of the reef) were taken in sampling stations A, B and C, using a Sony RX-100 VI camera shooting a standard frame of 21x29 cm; a total of 72 photos were acquired during the four surveys made (Figure 4). PhotoQuad v1.4 software was used for image analysis; in order to estimate the surface occupied by the single species, the "grid cell counts" method was selected (Trygonis and Sini, 2012). For each recognized species, the results include the area occupied by the species as well as their cover percentage.

Figure 5 – Scientific Diver during the Visual Census method.

The other methodology, applied to describe the fish assemblages, give as result the counting of recognized species in the fixed monitoring stations (A, B, C). The underwater activity involved 3 scientific divers at the same time. In each fixed stations, the monitoring surveys lasted 5 minutes for each direction N-E-S-W, for a total time of 20 minutes (Figure 5).

In order to develop and to test the application of an alternative technology for monitoring, a ROV was used also, and the acquired data were compared with the data from the standard methods applied (see above).

The ROV was used according to the same visual census methodology applied by scientific divers, with the aim of evaluating any differences and / or prons and cons. The ROV visual census was carried out in the 3 stations using a 360° camera mounted on the vehicle (Figure 6), and the total observation time was 15 minutes.

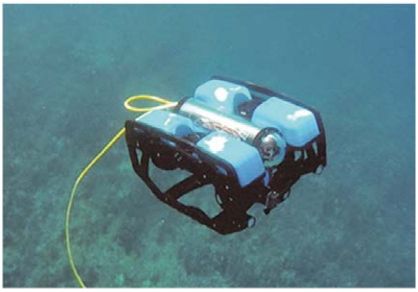


Figure 6 – ROV activity.

Results

The video-analysis of 72 photographic shootings highlighted the presence of 61 benthic taxa (Figure 7). The most represented taxa were the red macroalgae (Rhodophyta) of the genera *Mesophyllum* and *Peyssonnelia*, considered the main builders of coralligenous bioconstructions. Furthermore, the filamentous algae (AF), the so-called "Turf", are the third recognized group, mostly in the images from the summer surveys. Porifera is represented with 23 different species, and mostly of them are erect species such as *Axinella cannabina*, *A. damicornis* and *A. polypoides*. Another commonly recorded porifer is an encrusting one, *Spirastrella cunctatrix*. Several erect Bryozoa have also been identified, the most common being *Myriapora truncata* and *Pentapora fascialis*. As concerns the Cnidaria identified, *Parazoanthus axinellae* and *Leptopsammia pruvotii* are very interesting species for recreational diving.

Among the full set of recognized species, the invasive green alga *Caulerpa cylindracea* is the only alien species.

As regards the Visual Census on ichthyofauna, 18 taxa have been identified, all species are typical of Mediterranean coralligenous habitat. Obviously this data represent only a part of what could be the total species and the biomass that characterizes the area. Nevertheless, all the components of the trophic network are well represented, from the benthic to the nectonic species. An indicative element about the good state of health of the area and a good result for an MPA. Moreover, also the number of observed individuals belonging to the single taxa are representative of the ecological habits related to the species themselves, in fact we find gregarious species (high number of individuals) represented graphically (fig. 8) by a very high column (*Chromis chromis*) and more solitary and/or territorial represented by almost imperceptible columns (1-2 individuals of *Dentex dentex*).

The most represented species in the monitoring was *Chromis chromis*, present in all the four surveys with a total of 2572 individuals observed. *Diplodus vulgaris* was another frequently found species, with a total of 110 individuals observed. Several species with a very low number of individuals have been recognized, as in the case of *Dentex dentex*, *Muraena helena*, *Pagrus pagrus*, *Serranus hepatus*, *Spondyliosoma cantharus* and *Trypterigion melanurus*.

Other species have been found in some surveys only, such as *Diplodus annularis*, *Spicara maena*, *Serranus cabrilla* and *Coris julis* even if the number of individuals was seasonally significant (Figure 8).

Most of the species appear to be sedentary or in any case closely linked to the presence of outcropping coralligenous, like a *Diplodus vulgaris* and *Diplodus sargus*.

Flag species such as *Dentex dentex*, *Sciaena umbra* and *Pagrus pagrus* were observed, confirming the importance of the reef investigated as a valuable natural habitat and biodiversity hot spot, useful for sustainable recreational diving.

As regards the use of ROVs during the visual census of the fish community, some critical issues were highlighted due to the disturbance of the electric motors (noise) and artificial lights, however the data obtained in the observation with the 360° camera are similar to the data obtained using standard methods by scientific divers.

Regarding the ASPIM benthic species or benthic species of interest for diving, some differences were highlighted depending on the method used. The greatest number of identified specimens was recorded with the ROV, then with the video camera held by the divers and then by the divers in real time (Figure 9). However, 7 ASPIM species have been identified in the study area: *Axinella cannabina, Axinella polypoides, Cladocora caespitosa, Hippospongia c.ommunis, Paracentrotus lividus, Sarcotragus foetidus, Spongia officinalis.*

Figure 7 – Natural reef's benthic species cover percentage into the A, B, C sampling sites, over the 4 surveys. AF = Filamentous algae; NC = Not classified, MA = Mucilaginous algae.

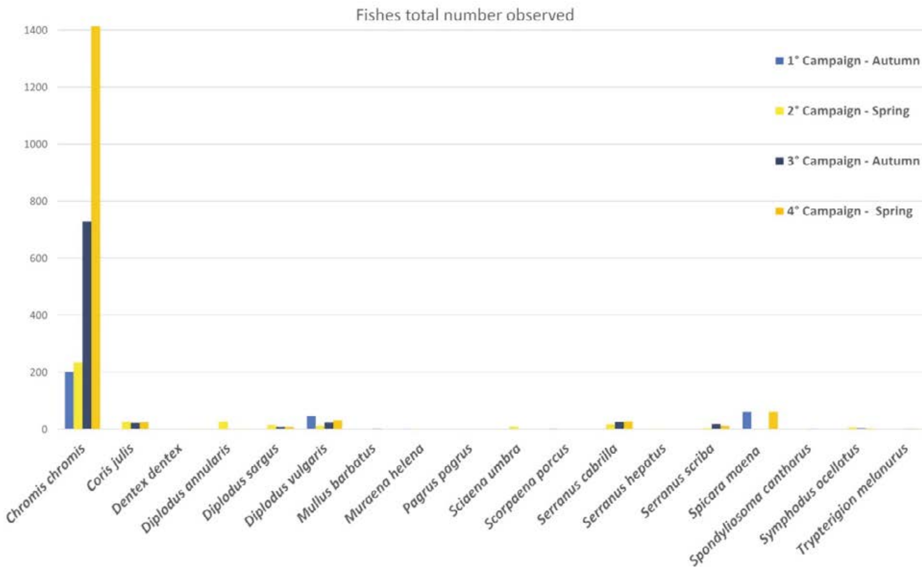


Figure 8 – Fishes total number observed during the 4 surveys.

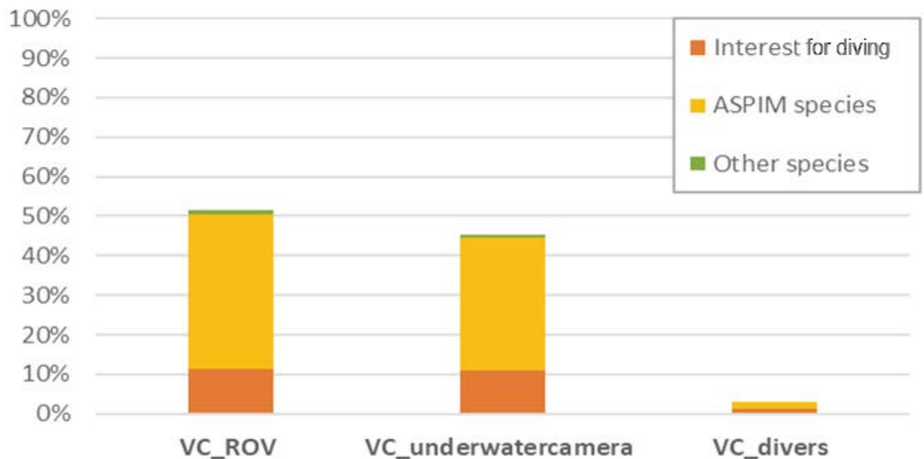


Figure 9 – Percentage of species identified using different VC monitoring methods.

Discussion and Conclusion

Considering the results of the case study and the monitoring sampling strategy applied, the selected site fulfills the purpose of the project and can be considered highly suitable for future tourist exploitation, especially for recreational divers.

From the point of view of natural beauty, the site shows some interesting features such as valuable marine landscapes and different formations such as ravines and cavities created by bioconstructions, very attractive for recreational underwater activities.

The analysis of the benthic community highlights a reef characterized by numerous species typical of the bioconstruction of the coralligenous habitat such as calcareous and poriferous algae, bryozoans, etc.; in particular, sponges of the *Axinella* genus are frequent, creating a sort of wood, which could be very interesting for divers. These species are a source of attraction for divers as they can have different shapes and host different associated organisms, such as nudibranchs (i.e. *Phyllidia flava*). However, it is worth noting the abundant presence of filamentous algae on the bio-construction of the bank, as well as a reduced presence of gorgonians.

The relatively large number of ASPIM species identified could be of interest for the development of some citizen science projects that combine MPA's new coralligenous reef exploration and underwater activities.

Regarding the fish assemblages and the application of the visual census method, the data show variations among species and the number of individuals observed. These results could be attributed both to natural factors (e.g. environmental conditions, biology, ecology and population dynamics of the species) and to limitations of monitoring methodologies. In fact, the direct observation of the diver in real time, to date, is still the best method. The Scientific Diver, while identifying a lower number of species than the ROV, has a greater accuracy in recognizing them. However, the use of underwater vehicles and the development of specific software dedicated to the identification of the species including their sizes are quickly increasing, so there is a reasonable hope for the improving of underwater monitoring techniques in the future.

Acknwoledgements

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MERCURY CONCENTRATIONS AND TRANSFERS IN PHYTO- AND ZOOPLANKTON COMMUNITIES IN A COASTAL MEDITERRANEAN ECOSYSTEM (BAY OF TOULON, FRANCE)

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Abstract – Planktonic organisms, at the basis of marine trophic networks, play an essential role in the transfer of energy and matter, including contaminants, from the environment to marine organisms. However, only few studies focus on the planktonic compartment as a whole and on the influence of its structure and composition on trophic networks functioning and transfers of contaminants. The accumulation of mercury causes organisms health problems. So, fishes' mercury contamination has widely been studied but the role of the first trophic levels in its intake and transfers is yet to be investigated. The Bay of Toulon is known for its high concentrations of mercury in sediments, thus it is a perfect site to focus on mercury contamination of the planktonic compartment as a continuum. The aim of this study was to characterize the whole plankton continuum (from pico-, nano- phytoplankton to meso-zooplankton) from a taxonomic point of view, its trophic organization and mercury contamination. Monthly samples were collected in the Bay of Toulon, from September 2020 to September 2021, by horizontal plankton net traits, sieved through different mesh size to collect 4 size classes (>500, 500-200, 200-100 and 100-20 µm). The last fraction (<20 µm) was collected by concentrating the smallest fraction by centrifugation. Taxonomic analysis were carried out for each separated fraction. Mercury analysis were performed with an AMA 254 mercury analyzer. Results showed a higher abundance of zooplankton, pico-, nano-phytoplankton and bacteria in the Little Bay, and micro- phytoplankton in the Large Bay. Overall, mercury concentrations were higher in the LiB. Contrarily to the standard mercury biomagnification pattern commonly observed in higher trophic levels, in this study, the smaller size classes (<20 and 100-20 µm) presented higher mercury concentrations decreasing while size increased (until 200-100 µm), followed by an inversion of the trend between the two largest size classes (500-200 and >500 µm).

Introduction

Planktonic organisms, at the interface between the biotic and abiotic compartments, occupy a key position in the organic matter, energy and contaminants transfers in marine biota [1]. The structure, composition and dynamics of planktonic communities may be highly impacted by variations of climatic and hydrological conditions or concentrations in

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contaminants [18]. These variations may significantly affect the functioning of marine ecosystems and induce modifications in marine trophic networks [10].

Zooplanktonic organisms and fishes have widely been studied as models of metal transfers, contrary to smaller organisms such as phytoplankton [2]. The Mediterranean Sea is known for its history of mercury inputs from natural and anthropic origins. The accumulation of mercury, more specifically methylmercury, causes organisms numerous health problems [3]. So, fishes' mercury contamination has widely been studied [7] but the role of the first trophic levels in its intake and transfers is yet to be investigated [4]. The Bay of Toulon is known for its high concentrations of mercury in sediments, thus it is a perfect site to focus on mercury contamination of the planktonic compartment as a continuum.

In a global context of questioning on the influence of the structure and organization of planktonic communities on the integration of contaminants and their transfers in marine trophic networks, the objectives of this study were to: *i)* collect, separate and identify planktonic matter in size classes representative of the trophic organization of the planktonic communities; *ii)* characterize the levels of mercury contamination in planktonic trophic networks in a Mediterranean coastal bay. To achieve this, samples of the planktonic compartment were fractionated in different size classes, each one taxonomically identified and their total mercury levels measured.

Materials and methods

The Bay of Toulon is divided in the Little Bay (LiB), semi-closed and characterized by high levels of anthropic activities and the Large Bay (LaB) open on the sea and less impacted by anthropic activities [15]. Samples were collected monthly, from September 2020 to September 2021, in the LiB (start Lat.: 43°06′30″N, Long.: 05°55′00″E) and the LaB (start Lat.: 43°05′45″N, Long.: 05°56′30″E). They were collected with horizontal plankton net traits (mesh size 80 µm, 0,5 m diameter and 2,5 m long) hauled outside the wake of the boat (1,8 knots, 45 minutes). Samples were sieved through different mesh sizes (500, 200, 100 and 20 µm) to collect 4 size classes (fraction 1: >500 µm; fraction 2: 500-200 µm; fraction 3: 200-100 µm and fraction 4: 100-20 µm). The remaining fraction was centrifuged (15 min, 3000 rpm) to concentrate and retrieve fraction 5 (<20 µm). For fractions 1 to 4, aliquots were retrieved to taxonomically identify the phyto- and zooplanktonic communities, respectively preserved using a 0.3 % lugol and 4 % buffered formaldehyde solutions. For fraction 5, aliquots were fixed with a 0.25 % glutaraldehyde and 0.01 % pluronic acid solution. Samples were frozen, freeze dried and homogenized by grinding before analysis. Zooplankton taxonomic identifications were accomplished according to Folsom's method [11] using a binocular magnifier Leica® M125C and the phytoplankton ones as per Utermöhl's method [17] using an inverted epifluorescence microscope Olympus® IMT2. For fraction 5, flow cytometry was used to identify organisms with an Accuri C6 BD Bioscience® [9]. Mercury levels analysis were carried out using a semi-automatic mercury analyzer ALTEC® AMA 254 [7].

RStudio and R version 4.2.0 were used to carry out the statistical analysis [12]. The Shapiro-Wilk test was used to evaluate normality. Total abundance and mercury levels were compared using the Wilcoxon signed-rank test. Non-parametric data between fractions were evaluated using ANOVA Friedman test and a post hoc Wilcoxon pairwise test with

Benjamini-Hochberg corrected p values. Parametric data between fractions were evaluated using ANOVA and a post hoc Tukey's test.

Results

The mean abundance of the meso- zooplanktonic communities was almost 2 times higher in the LiB than in the LaB (Wilcox. test, $p<0,05$). In the LiB, there were significantly more organisms in fractions 1 (>500µm), 2 (500-200 µm) and 3 (200-100 µm) than in the smallest fraction (4: 100-20 µm). In the LaB, similar observations showed significantly more zooplankton in fractions 1, 2 and 3 than in fraction 4, but also more in fractions 1 and 2 than in fraction 3 (ANOVA, Wilcox. corr. BH, $p<0,05$; Figure 1).

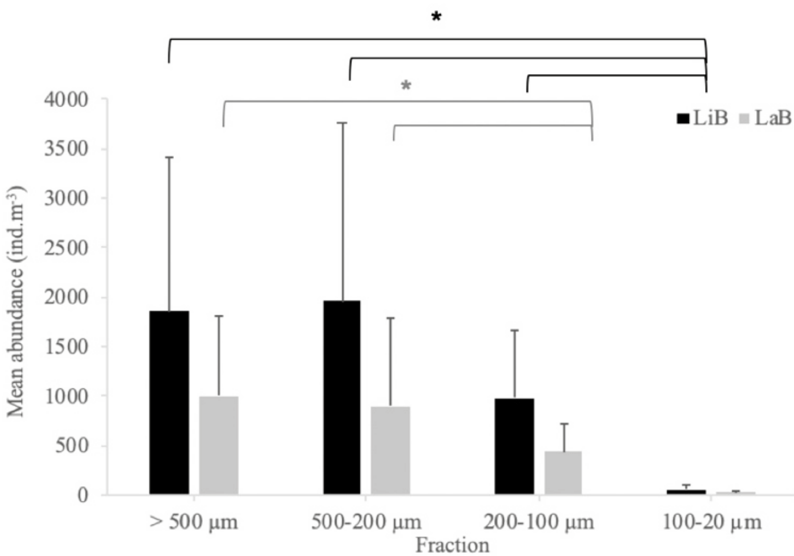

Figure 1 – Zooplankton mean abundance in fractions 1 to 4.

The abundance of Protista, Mollusca, Calanoïda and Cyclopoïda was significantly higher in the LiB (Wilcox. test, $p<0,05$), for the other taxa a similar trend was also observed. In the LiB, there were significantly more Protista and Mollusca in fraction 4 than in fractions 1, 2 and 3. Calanoïda and Cyclopoïda were more abundant in fractions 1 and 2 than in fractions 3 and 4. Finding in the LaB were comparable: Protista were dominant in fraction 4, Calanoïda and Cyclopoïda in fractions 1 and 2 (ANOVA, Wilcox. corr. BH, $p<0,05$; Figure 2). Overall, the most abundant taxa were Calanoïda and Cyclopoïda, representing more than 70 % of the communities.

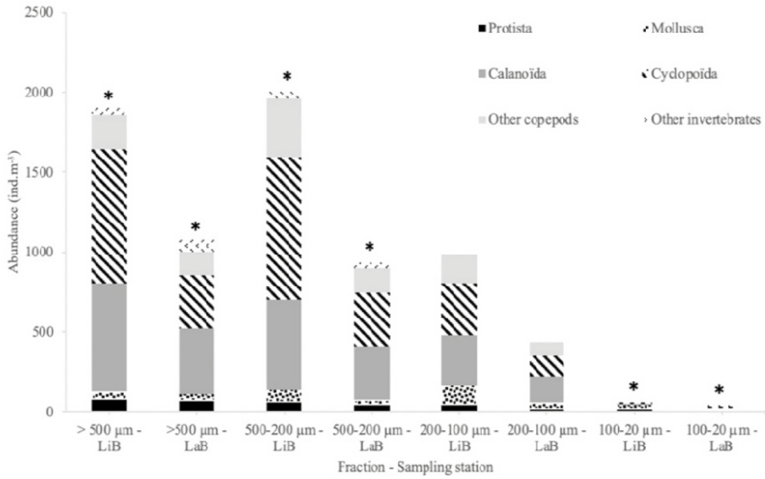

Figure 2 – Proportion of zooplanktonic taxa in fractions 1 to 4.

The mean abundance of the phytoplanktonic communities was almost 2 times higher in the LaB (Wilcox. test, $p<0,05$). In the LiB, there was drastically more phytoplankton in the smaller fractions (3 and 4) than in the biggest fractions (1 and 2). In the LaB, corresponding findings showed more phytoplankton in fractions 3 and 4 than in fractions 1 and 2, but also in fraction 4 than in fraction 3 (ANOVA, Wilcox. corr. BH, $p<0,05$; Figure 3).

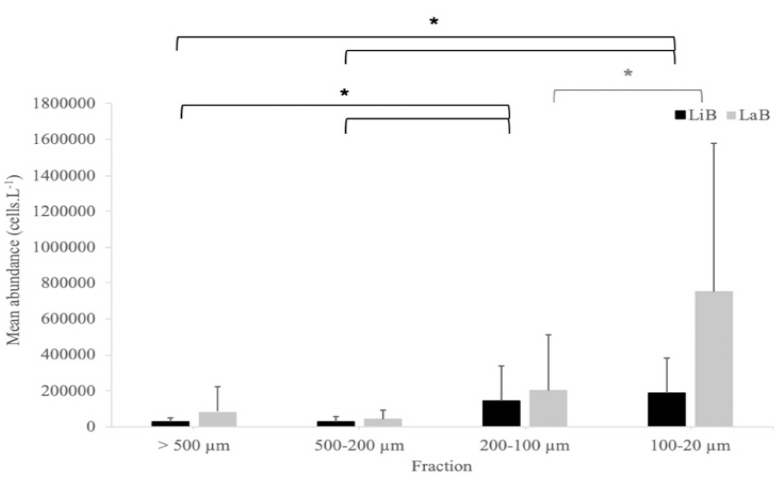

Figure 3 – Phytoplankton mean abundance in fractions 1 to 4.

The abundance of Bacillariophyceae was significantly higher in the LaB (Wilcox. test, $p<0,05$), for the other taxa an analogous trend was also observed. Bacillariophyceae were drastically more abundant in fractions 3 and 4 than in fractions 1 and 2 in the LiB, whereas in the LaB they were only predominant in the fourth fraction (ANOVA, Wilcox. corr. BH, p<0,05; Figure 4). A trend of greater Dinophyceae and other flagellates abundance in the smaller size classes was also identified in both bays.

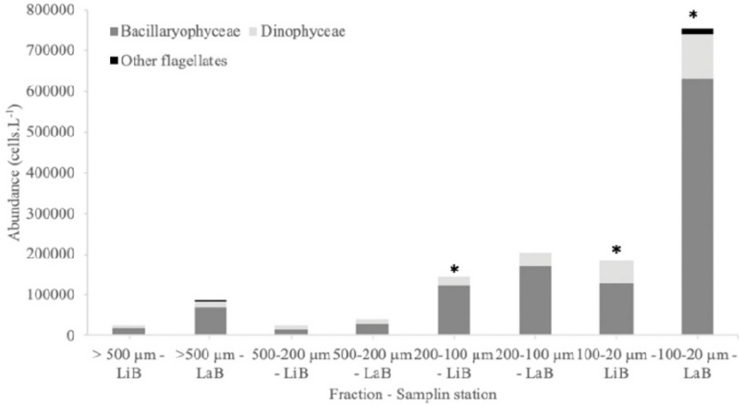

Figure 4 – Proportion of each phytoplankton taxa in fractions 1 to 4 in the LiB and the LaB.

The mean abundance of the pico-, nano- phytoplanktonic and bacterial communities was almost 4 times greater in the LiB than in the LaB (Wilcox. test, p<0,05; Figure 5).

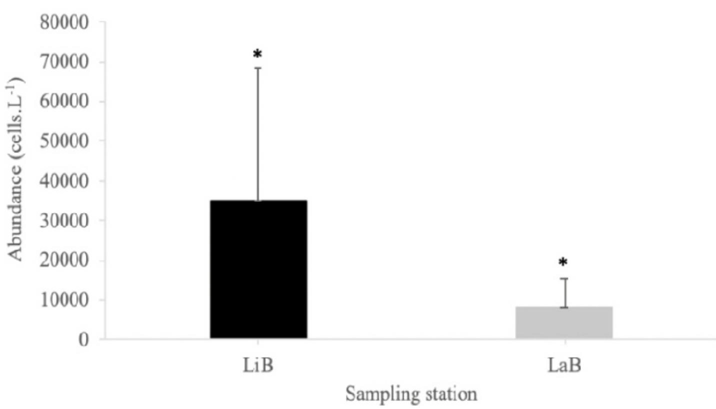

Figure 5 – Pico-, nano- phytoplankton and bacterial mean abundance in fraction 5 in the LiB and the LaB.

Overall, Synechococcus and Bacteria were the most abundant taxa in both bays. The abundance of Prochlorococcus, Picoeukaryots, Nanoeukaryots and Cryptophyceae was significantly more important in the LiB, and the same trend was observed for Synechococcus and Bacteria (Wilcox. test, p<0,05, Figure 6).

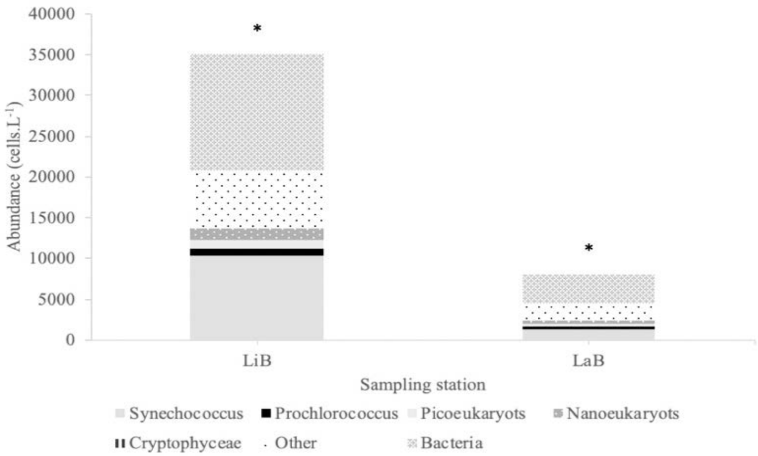

Figure 6 – Proportion of each pico- nano- phytoplanktonic and bacterial taxa in fraction 5 in the LiB and the LaB.

Mercury concentrations in each fraction were almost twice as important in the LiB than in the LaB (Wilcox. test, p<0,05). In the LiB, they were critically more important in fractions 5 and 4 than in fractions 1, 2 and 3 (ANOVA, Tukey, p<0,05, Figure 7). The smallest size classes were the most contaminated, a trend of biodilution was remarked from fraction 5 through 2 followed by an inversion of the trend with an onset of biomagnification between fractions 1 and 2.

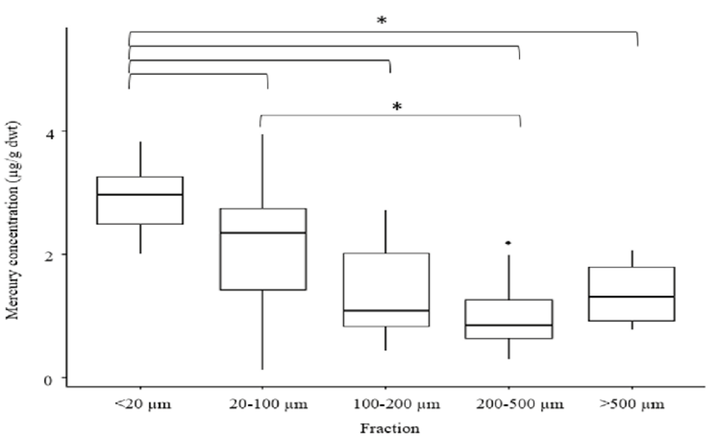

Figure 7 – Mercury concentrations in each fraction in the LiB.

In the LaB similar observation showed higher mercury concentrations in fractions 5 and 4, but in fraction 1 than in fraction 2 (ANOVA, Wilcox. corr. BH, p<0,05; Figure 8). In the LaB too, the smallest size classes were the most contaminated in mercury and a trend of biodilution could be observed between fraction 5 and fraction 3 followed by an inversion of the trend with an onset of biomagnification between fractions 1 and 2.

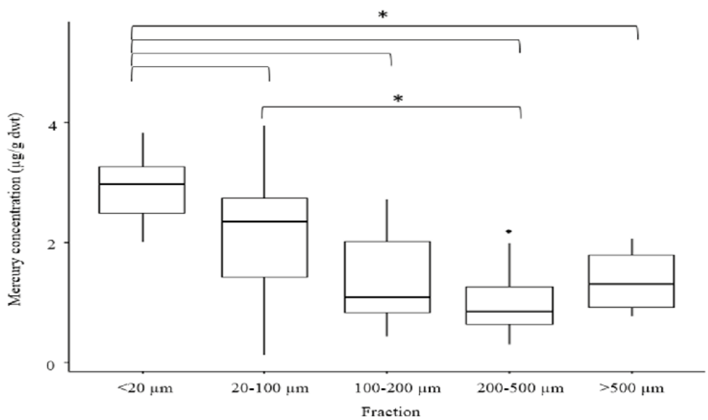

Figure 8 – Mercury concentrations in each fraction in the LaB.

Discussion

Firstly, observations showed that zooplankton, pico,- nano- phytoplankton and bacteria were more abundant in the LiB but micro-, phytoplankton were more abundant in the LaB. These results are coherent with previous observations for every community except the micro- phytoplanktonic community. Indeed, between 2006 and 2007, Rossi and Jamet [14] described a more abundant phytoplanktonic community in the LiB. This dissimilarity could be explained by the distinct composition and size structure of communities in both bays. Secondly, the results indicated that Copepods, Bacillariophyceae and Synechococcus were the dominant taxa in their respective communities and were consistent with previous observations at the study site by Serranito *et al*. [15], Rossi and Jamet [13] and Coclet *et al*. [5], respectively.

The mercury concentration in this study were greater than those in other studies conducted in the Gulf of Lion and in the Bay of Biscay [6, 7]. The higher levels of mercury recorded in all the fractions in the LiB could be attributed to the historical contamination of mercury in the LiB [16]. These differences could also be attributed to the specific trophic status in each bay and their impacts on the functioning of the ecosystems resulting in the distinct patterns of mercury integration in planktonic organisms observed during this study. The results also showed that the smallest fractions are the most contaminated by mercury. The smaller size classes could be the place of the beginning of integration of mercury in the planktonic trophic networks. The first part of the mercury levels quantification shows an absence of mercury biomagnification, or more likely, an apparent biodilution in the smaller size classes (< 20 µm to 200-100 µm), these results are in stark contrast to the traditionally accepted mercury transfer scheme in marine ecosystem, where mercury biomagnifies with the increase of trophic levels [8]. But, the second part of the results (between 200-100 µm and > 500 µm), were congruent with conventional patterns of mercury biomagnification between higher trophic levels. The results raise the hypothesis of distinct mercury integration schemes in phyto- and zooplanktonic organisms and highlights the importance of the trophic functioning of the studied ecosystems.

Conclusion

This study allowed to characterize the composition and structure of the planktonic compartment in the Bay of Toulon (LiB and LaB). The zooplanktonic, pico,- nano-phytoplanktonic and bacterial communities were more abundant in the LiB but the micro-, phytoplanktonic community was most present in the LaB. The zooplanktonic community was dominated by Copepods, Bacillariophyceae and Synechococcus were the most abundant micro- and pico- nano- phytoplanktonic taxa, respectively. Mercury concentration were greater in the LiB than in the LaB. Contrarily to the standard mercury biomagnification pattern commonly observed in higher trophic levels, in this study, the smaller size classes (<20 and 100-20 µm) presented higher mercury concentrations decreasing while size increased (until 200-100µm), followed by an inversion of the trend between the two largest size classes (500-200 and >500 µm). This raises the hypothesis of distinct mercury integration schemes in phyto- and zooplanktonic organisms and highlights the importance of the trophic functioning of ecosystems.

Acknowledgements

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RENATURALIZATION INTERVENTIONS WITHIN A REGIONAL FOREST COMPLEX LOCATED IN A COSTAL PINE FOREST IN THE SOUTH OF ITALY

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Abstract – The spontaneous vegetation of the Alimini district (south Italy) is represented by plant communities that vary in relation to geology and distance from the coastline: garrigue, scrub, scrub forest and Holm Oak forest, reforestation of Pinus halepensis and Pinus pinea. In the definition of the thinning treatment to be proposed, the identification of the chosen trees for the cutting was done not only based on their vegetational, morphological and phytosanitary features of the single plant, but, primarily keeping in mind the influence exerted by each arboreal element, in terms of biospace, to the underlying layers. Silvicultural interventions have also been defined to contrast the drought phenomenon, desertification and fires, through the planting of broadleaved trees, providing more species, both indigenous primary (arboreal) and secondary (shrub-like).

Introduction

The spontaneous vegetation of the Alimini district, which includes the aim of the study areas, is represented by plant communities that vary in relation to geology and distance from the coastline. Proceeding from the sea towards the inland, the vegetation landscape changes continuously, due to natural facts, or caused by anthropozoogenic actions. In fact, you can find natural origin entities (garrigue, scrub, scrub forest and Holm Oak forest) to reforestation of Aleppo Pine (*Pinus halepensis* Miller) and Stone Pine (*Pinus pinea* L.). The vegetation of natural origin is attributable to what remains of the Great forest of Lecce, which in the Fourteenth Century stretched for 75 km along the Adriatic Coast of Salento proceeding from North to South, between the locality Fontanelle (Brindisi) and the northern outskirts of Otranto, pushing itself inside and including also pastures and swamps (MAINARDI, 1989). In the following centuries the ancient forest was affected by a series of vicissitudes that reduces its surface and consistency. The "Frassanito" forest complex is currently consisting of Mediterranean conifer forests, deriving from planting, mainly composed of Aleppo pine, or Stone pine. The reforestation activities in the area behind the dunes, for about one km and for an average depth of about 700 m towards the hinterland, began in 1930 on land mainly consisting of xeric grasslands, created by the Ripartimental Inspectorate of Forests of the State Forestry Corps (CFS), with funding from the Ministry of Agriculture and Forests and the Fund for the South. The studies carried out show that once, very probably, the Alimini district was characterized by the presence of extensive scrub-forests, mainly of Kermes Oaks (*Quercus coccifera* L.), alternating with Holm Oak forests (*Quercus ilex* L.), limited to microenvironments marked by stationary conditions, mostly of a pedogealogical nature, which satisfied the temperament and needs of the Holm Oak and its companion species.

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The remarkable diffusion of the Kermes Oak, typical of mesomediterranean plain, is due to the high elasticity of adaptation of the ontogenetic cycle of the species to the bioclimatic one (BIANCO, 1960). The silvicultural interventions outlined in the study are aimed at bringing the artificial population, represented by an adult high forest mainly of Stone Pine with the presence of Aleppo Pine, towards more natural and resilient structural settings, simultaneously reducing the amount of necromass in the woods. Analysing the distribution of the number of trees in the diameter classes, it's clear that this is a pine forest of the same age mainly of Stone Pine with presence of Aleppo Pine (Table 1).

Table 1 – Distribution of the number of trees per hectare by diameter classes.

Diametric classes	**Total population**	
cm	*no./ha*	*%*
10	11	1.5
15	85	11.9
20	144	20.1
25	148	20.7
30	90	20.7
35	46	12.6
40	30	6.4
45	22	3.1
50	16	2.2
55	6	0.8
TOTAL	**716**	**100.0**

In order to normalize the distribution curve, it is necessary to perform moderate cutting operations from below, mainly affecting the smaller diameter classes, 10-15 and 20 cm, represented by arboreal elements denominated dry and with no future. The various forms of cultivation for the improvement and conservation of the few Mediterranean forest realities must therefore be differentiated in relation to the aims to be pursued, avoiding all sorts of generalization (GUALDI, 1998). So, in the definition of the thinning treatment to be proposed, the identification of the chosen trees for the cutting was done not only based on their vegetational, morphological and phytosanitary features of the single plant, but, primarily keeping in mind the influence exerted by each arboreal element, in terms of biospace, to the underlying layers.

As a consequence, the thinning treatment proposed in favor of the arboreal layer elements fell back almost exclusively on dominated elements and on a few intermediates affected by pathogen or mechanical trauma due to the strong action of sea winds. As regards the intensity and frequency of the interventions in question, a moderate intensity intervention was planned. Silvicultural interventions have also been defined to contrast the drought phenomenon, desertification and fires, through the planting of broadleaved trees, providing more species, both indigenous primary (arboreal) and secondary (shrub-like), suitable for the environmental and climatic conditions of the intervention area (Regional area of the Salento Peninsula). The intervention will affect the areas of the pine forest characterized by an incipient or almost completely absent undergrowth, foreseeing the planting of 150 elements per hectare. The chosen species for thickening are evergreen, xerophilous and reproductive, therefore able to better withstand fires, represented both by arboreal species of sclerophyll, with a percentage of about 70 %, and by shrub species, for the remaining 30 %. The aim of this intervention was to obtain: balanced and adequate distribution of the used species, regular lighting of the plants, easy management of the forest. Considering the purposes of the thickening interventions that were proposed, mainly based on environment, landscape and contrast to the propagation of fires, it was planned an irregular arrangement of the plants, by groups, using native species, coming from propagation material originated from seed woods of Puglia Region, in the following percentage: Holm oak 70 %, Strawberry tree 15 %, Mastic tree 15 %.

Materials and Methods

The pine forest under consideration is located in "Frassanito," Otranto (LE), not far from the coastline and about 8 km from the town of Otranto, within the Alimini SCI area (Site of Community Importance). IT for an extension of about 30.00 ha.

Thermo-pluviometric data collected by the Bari Hydrographic Office at the Otranto station were analyzed as a priority. The examination and further processing of the data resulted in the following reflections:

- the value of the average annual temperature is 16.5 °C
- the coldest month in the study area is January, at 9.6 °C
- the hottest month turned out to be August, with average monthly temperature values of 24.8 °C
- rainfall, measured by the amount of fallen rain, expressed in mm, is characterized by fairly high values; the annual average is, 845.90 mm, concentrated in the autumn-winter period
- the drought period runs from late April to mid-September
- the pluviometric cycle is characterized by a rainfall falling between the equinoctial and solstitial types, with an absolute maximum in November and a relative maximum in March, the latter resulting from disturbances in the Balkans that last until late spring. Particularly pronounced is the action exerted by winds from the northern and eastern quadrants (the Tramontana from the north and the Levante from the east).

The vegetation type was then assessed by surveying the actual vegetation, the species and cover (%) of the tree layer, the main species and cover (%) of the shrub layer, and finally, the main species of the herbaceous layer.

From the physiognomic point of view, the actual vegetation of the considered geographical (bearing in mind what is reported in the map of the actual vegetation of FENAROLI (1970), as it falls into the area of the evergreen sclerophylls of the Basal Plain, with sub-littoral Mediterranean vegetation) is represented (by what has been directly observed in the field by the writers) by a "predominantly Stone Pine forest, with the presence of Aleppo Pines of artificial origin about 65 years of age, characterized by the spontaneous diffusion within it of an incipient undergrowth with established patches of evergreen sclerophylls (Figure 1).

In the areas closest to the coastline, Aleppo Pines almost entirely replace the Stone Pines, and the undergrowth appears to be highly developed (Figure 2).

Figure 1 – Example of sample plot area in the pine forest of Stone Pine in Frassanito locality (Otranto – Le).

Figure 2 – Contact area between predominantly Stone Pine and Aleppo Pine Forest in Frassanito locality (Otranto - Le).

In order to identify the vegetation stage that potentially distinguishes the area under consideration, it was necessary to consider EMBERGER's climograph and modify it according to QUEZEL's (1976) methodology through the schematic localization of the bioclimatic area of spread of certain species and plant combinations of the Mediterranean forest. This is verified by ascertaining that the forest in question falls in the temperate variant of the "Upper Thermomediterranean" humid stage (altitudinally speaking), characterized, potentially by the Thermomediterranean forest, being generally "sclerophyllous," consisting mainly of evergreen quercus species, especially the Holm Oak and Kermes Oak.

The above is confirmed by the fact that within the pine forest, there is an established diffusion of arboreal and shrubby elements of evergreens sclerophylls such as the Kermes Oak, Holm Oak, Mastic tree (*Pistacia lentiscus* L.), Myrtle (*Myrtus communis* L.), Buckthorn (*Rhamnus alaternus* L.), Green Olive tree (*Phillyrea latifoglia* L.), Strawberry Tree (*Arbutus unedo* L.), etc. The same species, together with Heather (*Erica arborea* L.), characterize a patch of scrub forest located between the pine forest and the first dune cordon.

In order to determine the estimated woody mass of the intercropped stand resulting from the thinning intervention within the identified typologies, a total number of 10 sample plot areas were defined and reported on the ground with one for every 3 hectares or so of wooded area, in implementation of Apulia Region Reg. No. 10/2009 "forest cuts" and subsequent amendments and additions. These circular-shaped areas have a diameter of 35.69 meters and each an area of 1000 m².

The delineation of the areas was carried out using metric tape, and horizontal yellow strokes were affixed to the stems of trees vegetating in their immediate vicinity to make it easeir to find the test areas. Progressive numbers from 1 to 10 were also painted on the stem of a plant present in the centerline of the test area.

Next, all tree elements growing in each area with stem diameters greater than 7.5 cm (diametric class 10 cm) were numbered at 1.30 m above the ground.

Field operations were concluded with the selection of the elements to be subjected to cutting. For each of the tree elements in the group, data were recorded for the following dendrometric parameters:

Stem:

- no. 2 orthogonal diameters, measured at 1.30 m from the ground, through the use of an aluminum PONCET dendrometer mount;
- dendrometric heights of no. 3 tree elements of the total stand, with diameters close to or equal to the mean diameter, no. 3 tree elements of the intercalated stand, with diameters close to or equal to the mean diameter. The heights were measured using the BLUME LEISS hypsometer.

The data collected in the forest were later processed by default.

For each element surveyed in the test areas, the dendrometric parameter values deemed most significant were determined

Stem:

- average diameter (dg), at 1.30 m above the ground, obtained from the average of the two measured diameters;
- basal area (G).

Furthermore, after the tree elements were grouped withing each type into diameter classes of 5 cm width (always measured at 1.30 m from the ground), the values referring to the area of a hectare, the number of trees (Nha), basal area (Gha), and volume (Vha), as well as those of the average height of each diametric class, were determined for both the total stand and the interplant stand to be exported by phytosanitary cutting.

Results

The identified vegetation type is mainly characterized by three vegetation layers detailed below:

- arboreal layer, predominantly Stone Pine with the presence of Aleppo Pine, covering of 90-100 % of the total;
- shrub layer, absent or incipient, with a maximum cover of 10 %;
- herbaceous layer with 2 % coverage.

Stone Pine elements, constituting a large part of the tree layer, have upper heights of between 14 and 20 meters, with fairly regular stem forms, growing in good condition.

Numerous dry tree elements are still standing, broken by wind action, or lying on the ground. Tree and shrub elements are absent or incipient. The species present are Prickly asparagus, Wild madder, Mastic tree, and Myrtle.

The herbaceous layer, less than 0.30 m in height, consists exclusively of sporadic elements of Mediterranean sedges.

Near the coastline, the tree layer is represented almost exclusively by Aleppo pines with the sporadic presence of Stone pines. The arboreal stand is sparser, covering 70 % of the total area. The arboreal and shrub layers appear to be established, and in some places, highly developed, covering 70 %. The herbaceous layer, which is sparsely present, has an estimated cover of 5 %.

Analysis of the distribution of the number of trees in the diametrical classes shows that this is an even-aged pine forest with a predominance of Stone Pines with the presence of Aleppo Pines. In order to normalize the distribution curve, it is necessary to carry out moderate cutting interventions from below, mainly targeting the smaller diametric classes of 10-15 and 20cm, represented by dominated, dry, and unbecoming tree elements. In defining the thinning model to be proposed, it was realized that, in this specific case, interventions must be applied with a high degree of elasticity in the sense that the identification of the trees selected for cutting is to be done not only on the basis of the vegetational, morphological, and phytosanitary characteristics of the individual plants, but, primarily, examining the influence exerted by each tree element in terms of biospace on the underlying strata. As a result, the proposed thinning in favor of the elements of the tree layer almost exclusively involved dominated elements and some plants affected by pathogens or mechanical trauma caused by wind action. Regarding the intensity and frequency of the interventions under consideration, it should be noted that, in this case, a moderate intensity intervention was budgeted.

These are silvicultural interventions aimed at bringing the considered stand, represented by a mature group of predominantly domestic pines with the presence of Aleppo pines, towards more natural and resilient compositional structural arrangement, while at the same time, reducing the amount of necromass in the forest.

In the tables below is respectively reported the estimated wood mass of Stone Pine (Table 2) and Aleppo Pine (Table 3) from the thinning intervention, divided by diametric classes.

Table 2 – Estimated wood mass of Stone Pines from the thinning intervention, divided by diametric classes.

Diametric classes	Trees	Basal area	Average heigh	Dendrometric volume	Specific weight of timber	Quantity of retractable timber	Quantity of retractable timber/ha
cm	*no.*	*m²*	*m*	*m³*	*kg/m³*	*q*	*q/ha*
10	210	2.022	17.43	21.146	900	190.31	6.34
15	2340	47.613	17.43	497.936	900	4 481.43	149.38
20	2580	81.165	17.43	848.823	900	7 639.41	254.65
25	1710	55.545	17.43	580.244	900	5 228.01	174.27
30	360	27.084	17.43	283.491	900	2 549.20	84.97
35	90	8.844	17.43	92.491	900	832.41	27.75
40	30	4.155	17.43	43.453	900	391.08	13.03
					TOTAL	**21 311.86**	**710.39**

Table 3 – Estimated wood mass of Aleppo Pines from the thinning intervention, divided by diametric classes.

Diametric classes	Trees	Basal area	Average heigh	Dendrometric volume	Specific weight of timber	Quantity of retractable timber	Quantity of retractable timber/ha
cm	*no.*	*m²*	*m*	*m³*	*kg/m³*	*q*	*q/ha*
10	60	0.498	17.43	5.208	650	33.85	1.12
15	210	3.957	17.43	41.382	650	268.98	8.96
20	390	12.384	17.43	129.511	650	841.82	28.06
25	180	8.976	17.43	93.871	650	610.16	20.33
30	150	10.473	17.43	109.526	650	711.92	23.73
40	90	8.427	17.43	88.129	650	572.84	19.09
					TOTAL	**3 040.00**	**101.32**

To improve the structure and stability of the tree layer and the structure of the entire community of plants - including arborescent and shrubby ones - whose main dendrometric parameters are illustrated in the table below (Table 4), a moderate thinning from below has been proposed. This thinning would lead to the results expressed by the values relating to the same parameters considered for the total population, referring to the interlayer tree stands (Table 5) and main (Table 6).

Table 4 – Total population.

<u>Aleppo Pine</u>		
Number of trees	No./ha	120
Basal area	m^2/ha	9.8177
Volume	m^3/ha	115.40
<u>Stone Pine</u>		
Elements	No./ha	596
Basal area	m^2/ha	37.1664
Volume	m^3/ha	436.85
Total: Aleppo Pine + Stone Pine		
Elements	***No./ha***	***716***
Basal area	***m^2/ha***	***46.9841***
Volume	***m^3/ha***	***552.25***

Table 5 – Intercropping tree stand (to be cut with the proposed improvement intervention).

<u>Aleppo Pine</u>		
Number of trees	No./ha	36
Basal area	m^2/ha	1.4905
Volume	m^3/ha	15.59
<u>Stone Pine</u>		
Elements	No./ha	226
Basal area	m^2/ha	7.5476
Volume	m^3/ha	78.93
Total: Aleppo Pine + Stone Pine		
Elements	***No./ha***	***262***
Basal area	***m^2/ha***	***9.0381***
Volume	***m^3/ha***	***94.52***

Table 6 – Main tree stand (after cutting).

<u>Aleppo Pine</u>		
Number of trees	No./ha	84
Basal area	m^2/ha	8.3272
Volume	m^3/ha	99.81
<u>Stone Pine</u>		
Elements	No./ha	370
Basal area	m^2/ha	99.6188
Volume	m^3/ha	357.92
Total: Aleppo Pine + Stone Pine		
Elements	***No./ha***	***454***
Basal area	***m^2/ha***	***37.946***
Volume	***m^3/ha***	***457.73***

Discussion

Examination of the dendrometric data collected and processed shows that there is a need to take action with appropriate silvicultural interventions aimed at bringing the stand under consideration, represented by a mature forest with a predominance of Stone Pine with the presence of Aleppo Pine, towards more natural and resilient compositional structural arrangements while simultaneously reducing the amount of necromasses present in the forest. The intervention is to be carried out on a total area of **300 000 square meters** and will affect the entire forest area. The thinning intervention is to be implemented through the following processing steps:

1) Selective thinning to be carried out on mature forest of resinous trees of variable age, having a diameter (at 1.30 m from the ground) of 10-20 cm, by cutting at the base. The work includes limbing, collection and transport or accumulation of the resulting material (brushwood) in a suitable place to be carried out on an area of **30.00 ha.**
2) Setting up, concentrating, and hauling the woody material that can be used with the logging intervention, amounting to **2 835.60 m^3**. In addition, the intervention includes land clearing, collection, and transport of the woody material from the stand (in the forest) to the truck road.
3) Wood chipping of brushwood and logs (less than 10 cm in diameter) in resinous forest subject to thinning, for the purpose of fire prevention, including the distribution of residual chipped plants around the area of intervention, an estimated quantity of chipping material equal to **7 138 q**, of which 4 870 q derived from cutting operations, and the remaining 2 268 q derived from dry material on the ground.
4) The actual harvestable and marketable timber is **19 482.00 q**.

In addition to the thinning intervention, silvicultural interventions against the phenomena of drought, desertification, and fires have also been envisaged via the planting of broadleaf trees, providing more native species, both main (tree) and secondary (shrub), adapted to the environmental and climatic conditions of the intervention area (Regional area of the Salento Peninsula), aimed at increasing resilience to fires and climate change. Forest propagation materials to be used must be accompanied by certifications of origin and phytosanitary certifications. The native species to be used must come from seed forests in the Apulia Region. Moreover, bearing in mind the limitations established by Article 10 of Regional Law No. 4 of 29/03/2017 "Management of Xylella fastidiosa bacteriosis in the territory of the Apulia Region", the intervention will affect only those areas of the pine forest characterized by incipient or almost completely absent undergrowth. The planned number of plants, on a total area of about 170 000 square meters, amounts to 2550 elements, about 150 plants per hectare, in view of the density of the area affected by the intervention. The species of choice for replanting shall be evergreens, xerophilous, and polliniferous, thus more able to resist fire. The planned 2550 elements are represented by both sclerophyllous tree species in the proportion of about 70 %, and shrub species for the remaining 30 %. With regard to the planting layout, it was defined on the basis of various criteria, including the area of intervention, its slopes, the nature of the soil and its variability within the areas under intervention, the species to be planted, the ease replanting, and the area of gaps present within the forested areas. The intervention aimed to achieve a balanced spatial distribution appropriate to the species to be used, regular lighting of the seedlings, and ease of forest management. In view of the purposes of the proposed replanting interventions, which are mainly environmental, landscaping, and combating the spread of fires, an irregular planting arrangement in groups was planned. To replant the Pine forest, bearing in mind the pedoclimatic characteristics of the station, both the use of sclerophyll tree species, in the percentage of about 70 %, and the use of shrub species for the remaining 30 %, to be comprised of 70 % Holm Oak, 15 % Strawberry Tree, and 15 % Mastic tree were planned for the realization of the renourishments within the Pine Forest.

Conclusion

The results show that the assumed phytosanitary cutting in the typology under consideration would affect 36.59 % of the number of trees, 19.24 % of the basal area, and 17.11 % of the volume present before the intervention. It should be emphasized that this is a cut that will mainly affect standing dead trees, as well as withered, dominated, and some intermediate trees that are unable to grow, or otherwise hindered in their normal development by the underlying tree and shrub elements. The analysis of the distribution of the number of trees in the diametrical classes shows that that this is a coetaneous pine forest with a predominance of Stone Pines with the presence of Aleppo Pines that has lacked appropriate silvicultural interventions that should have been carried out over time. Therefore, to normalize the distribution curve, it is necessary to carry out moderate cutting interventions from below, concentrating on the smaller diametric classes of 10-15 and 20 cm, represented by dominated, dry, and unbecoming tree elements. High flexibility was kept in the definition of the thinning model to be proposed, considering not only the vegetational, morphological, and phytosanitary characteristics of individual plants but also the influence exerted by each tree element in terms of biospace on the underlying strata. Following these principles, the proposed thinning mainly affected the dominated tree layer elements and some intermediate ones affected by pathogens or mechanical trauma due to wind action. Regarding the intensity and frequency of the interventions under consideration, the intervention is of moderate intensity. Ultimately, the choice was made to carry out silvicultural interventions aimed at bringing the considered stand, represented by a mature forest of predominantly Stone Pines with the presence of Aleppo Pines, toward more natural and resilient compositional structural arrangements while simultaneously reducing the amount of necromass present in the forest.

In addition to the thinning intervention, silvicultural interventions against the phenomena of drought, desertification, and fires have also been envisaged via the planting of broadleaf trees, providing more native species, both main (tree) and secondary (shrub), adapted to the environmental and climatic conditions of the intervention area, aimed at increasing resilience to fires and climate change.

The intervention will affect only those areas of the pine forest characterized by incipient or almost completely absent undergrowth. The planned number of plants, on a total area of about 170 000 square meters, is 2550 elements, about 150 plants per hectare.

The species of choice for replanting shall be evergreens, xerophilous, and polliniferous, thus more able to resist fire. The planned 2550 elements are represented by both sclerophyllous tree species in the proportion of about 70 %, and shrub species for the remaining 30 %.

The intervention aimed to achieve a balanced spatial distribution appropriate to the species to be used, regular lighting of the seedlings, and ease of forest management.

In view of the purposes of the proposed replanting interventions, which are mainly environmental, landscaping, and combating the spread of fires, an irregular planting arrangement in groups was planned.

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FUNGI FROM THE SEDIMENTS OF THE HARBOUR OF LIVORNO AS POTENTIAL BIOREMEDIATION AGENTS

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Abstract – Due to anthropogenic activities, the harbour's sediments are among the biotopes most affected by pollutants (both organics and inorganics). Therefore, the polluted sediments are subjected to regular dredging that require remediation treatments. However, the growing ecological issue of sediment contamination leads to the need for economic and eco-friendly treatments. Bioremediation could be an efficient solution and fungi are among the most promising as bioremediation agents, thanks to their ability to produce extracellular enzymes such as lignin-modifying enzymes. The main objectives of this work were: i) to perform a preliminary screening on 74 fungi previously isolated in the polluted sediments of the harbour of Livorno; ii) to identify those endowed with oxidative capabilities, using MS-GP agar media supplemented with guaicol, syringaldazine and ABTS with or without seasalts; iii) to assess the production of enzymes such as laccases and/or peroxidases. The results have shown that 26 (35.1 %) out of 74 fungi produced positive oxidation signal on at least one media and 4 taxa displayed a positive oxidation of all the three indicators used, both in salt and saltless contitions, indicating their potentiality also in environments with high salt concentrations, such as the marine sediments. However, further studies are needed to fully identify the enzymes and their degradative capabilities.

Introduction

The Mediterranean Sea is strongly influenced by human activities with consequent pollution of the coastal marine environment. The seabed of harbours is continuously exposed to the effects of this type of pollution. In fact, these sediments store a wide range of pollutants (e.g. polycyclic aromatic hydrocarbons, PAHs, or heavy metals), derived from several activities [1]. To maintain the harbour depth suitable for navigation, these sites are subjected to regular dredging. However, the dredged polluted sediments require remediation treatment to be recovered. Generally, physico-chemical remediation techniques are used but they can be very costly and have several environmental drawbacks. Therefore, it is necessary to find more economic and environmentally-friendly remediation solutions. The biological remediation techniques could guarantee these prerogatives and the components of this biodegradation process are mainly bacteria and fungi [2].

Although most of the literature concerning organic pollutants biodegradation is focused on bacteria [3–5], fungi have become of great interest for bioremediation purposes, both in soil and marine habitats [6]. Indeed they are able to transform and/or degrade many hazardous

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and polluting chemicals thanks to their wide enzymatic production [7], to explore (contaminated) sediments thanks to the apical growth of their hyphal network [8] and adsorb hydrocarbons in low nutrient and pH environments [9]. Several genera of marine fungi have shown the ability to degrade recalcitrant compounds like aliphatic and aromatic hydrocarbons [10], while others (mainly earthborne basidiomycetous white rot fungi-WRF) have already been used for decontaminating polluted sites [11]. Indeed fungi isolated from the sea can be effective in the degradation of petroleum hydrocarbons [12], and, although poorly represented in marine environment, Basidiomycota might have a great biotechnological potential [13]. Hydrocarbon degradation, in aerobic conditions, involves a wide array of enzymes, the most studied of whitch are P450 monooxygenases and alkane-oxygenases. However the extracellular enzymes are the most promising for biodegradation purposes, particularly the lignin-modifying enzymes (LMEs) of the WRF [14]. The main LMEs enzymes are lignin-peroxidase (LiP), manganese-peroxidase (MnP), as regards peroxidase and laccase, divided into low potendial (LP) and high potential (HP) laccase according to their oxidative potential. As reported by Panno et al.[15], marine fungi can produce them in high-salinity conditions, such as marine sediments.

To assess the production of LMEs, it is common to use indicators capable of showing the oxidative abilities of fungi following colour shift of their growth media. Examples of indicators are 2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), guaiacol (GCL), syringaldazine (SGZ) and, industrial dyes (e.g. Remazon Brilliant Blue R, Malachite green) [16]. Dyes are both indicators for these screenings, and pollutants. They have been known and used for long time, and in the last century many new dyes have been produced by chemical synthesis. Therefore, whether the final purpose is the remediation of marine sediments or the decolouration of industrial dyes, fungi have proved to be interesting organisms endowed with metabolic and enzymatic abilities adaptable to these purposes. In particular for port sediments, researchers share the idea that new fungi potentially exploitable for bioremediation applications, should be sought in the polluted sediments (or sites) themselves, as they should be adapted to the stresses and contaminants present [17,18].

The purpose of this work is: i) to perform a preliminary screening on fungi previously isolated from the sediments of a polluted port area, in order to identify fungal strains endowed with oxidative abilities; and ii) to evaluate the producers of metabolites or enzymes of interest, for applications in future environmental bioremediation.

Materials and methods

Sediment sampling and characterization

Marine sediment of the Yacht Club in the harbour of Livorno (43°33'00.1" N 10°17'51.8" E) were sampled by the “Interuniversity Consortium of Marine Biology G. Bacci, CIBM” of Livorno. Fungi were isolated and identified, according to Bovio et al. [19], at the *Mycotheca Universitatis Taurinensis* (MUT, University of Torino) and 74 strains (Table 1) were screened for LMEs production. The chemical analysis of the sediments was performed by CIBM (Table 2). Polycyclic aromatic hydrocarbons (PAHs as total content and 16 EPA congeners), and polychlorinated biphenyls (PCBs as total content) were extracted according to Salem et al. [20]. The extracts were then processed according to the method EPA 8270E [21].

The LOD was 0.5 µg/kg. The recovery rate was always over 89 %. Low molecular weight hydrocarbons (C<10) were determined following the method EPA5021A [22] and EPA 8015C [23]. High molecular weight hydrocarbons (C>10) were extracted and measured according to the method ISO 16703 [24] for mineral oils. C<10 and C>10 analyses were performed with a GC Trace 1300 (Thermo Scientific) equipped with a TG-5SilMS column (Thermo Scientific). The GC was coupled to a TriPlus RSH autosampler and flame ionization detector (FID). In all cases highly pure helium was used as carrier gas. For C<10 the LOD was 0.5 µg/kg, for C>10 the LOD was 1.6 mg/kg. The recovery rate was always over 90 %.

Table 1 – Fungal strains tested for LMEs production.

Acremonium pilosum	*Dichotomopilus funicola*	*Penicillium* sp.
Acrostalagmus luteoalbus	*Discula destructiva*	*Phaeosphaeriaceae* sp.
Alternaria alternata	*Emericella pluriseminata*	*Pholiota gummosa*
Amesia nigricolor	*Emericellopsis minima*	*Preussia* sp.
Annulohypoxylon multiforme	*Eupenicillium crustaceum*	*Pseudeurotium bakeri*
Ascomycota sp. 1	*Exophiala xenobiotica*	*Pseudeurotium ovale*
Ascomycota sp. 2	*Gaeumannomyces graminis*	*Pyrenochaetopsis tabarestanensis*
Ascomycota sp. 3	*Massarina* sp.	*Sporothrix inflata*
Ascomycota sp. 4	*Microascus paisii*	*Stachybotrys chlorohalonata*
Ascomycota sp. 5	*Microascus* sp.	*Stachylidium bicolor*
Aspergillus aureolatus	*Neocosmospora solani*	*Talaromyces flavus*
Aspergillus flavipes	*Parasarocladium debruynii*	*Talaromyces minioluteus*
Aspergillus fumigatus	*Parasarocladium radiatum*	*Talaromyces minioluteus*
Aspergillus heyangensis	*Parasarocladium wereldwijsianum*	*Talaromyces versatilis*
Aspergillus pseudodeflectus	*Penicillium antarcticum*	*Talaromyces wortmannii*
Aspergillus pseudoglaucus	*Penicillium crustosum*	*Talaromyces wortmannii*
Aspergillus tabacinus	*Penicillium fellutanum*	*Thelebolus* sp.
Aspergillus templicola	*Penicillium glabrum*	*Tilachlidium brachiatum*
Aspergillus terrreus	*Penicillium janczewskii*	*Trematosphaeria grisea*
Aspergillus ustus	*Penicillium javanicum*	*Trematosphaeria grisea*
Aspergillus versicolor	*Penicillium menonorum*	*Trichoderma harzianum*
Auxarthron thaxteri	*Penicillium paneum*	*Trichoderma longibrachiatum*
Beauveria felina	*Penicillium parvulum*	*Wardomycopsis humicola*
Cladosporium asperulatum	*Penicillium restrictum*	*Westerdykella dispersa*
Cladosporium cladosporioides	*Penicillium simplicissimum*	

Table 2 – Organic chemicals in sediments (LOD, limit of determination, for PAHs and PCBs 0.5 µg/kg, C >10 5 mg/kg, C<10 0.5 µg/kg ; U.O.M = unit of measurement).

Parameter	U.O.M. d.w.	Harbour
Σ PAHs	µg/kg	577.2
Acenaphtene	µg/kg	< LOQ
Acenaphthylene	µg/kg	4.1
Anthracene	µg/kg	3.9
Benzo[*a*]anthracene	µg/kg	40.4
Benzo[*a*]pyrene	µg/kg	51.2
Benzo[*b*]fluoranthene	µg/kg	120.4
Benzo[*ghi*]perylene	µg/kg	53.2
Benzo[*k*]fluoranthene	µg/kg	43.4
Chrysene	µg/kg	45.8
Dibenz[*a,h*]anthracene	µg/kg	34.5
Fluoranthene	µg/kg	55.9
Fluorene	µg/kg	< LOQ
Indeno[1,2,3-*c,d*]pyrene	µg/kg	81.2
Naphthalene	µg/kg	< LOQ
Phenanthrene	µg/kg	4.6
Pyrene	µg/kg	38.4
Σ PCBs	µg/kg	19.1
Hydrocarbons > 10C	mg/kg	116.5
Hydrocarbons < 10C	µg/kg	12.6

LMEs production screening

The screening was conducted using MS-GP agarised solid media (5.0 g/L glucose, 5.0 g/L peptone, 1.0 g/L KH_2PO_4, 1.0 g/L ammonium acetate, 0.01 g/L $MgSO_4$, 0.01 g/L $CaCl_2$, 0.001 g/L $MnSO_4$, 0.001 g/L $FeSO_4 \bullet 7H_2O$, 0.0005 g/L $CuSO_4$, 3 % agar, at pH 6.0), in salted (40 g/L Sea Salts) and saltless lines, supplemented with different indicators: 1 mM SGZ, 1 mM ABTS or 1 mM GCL (redox potential 0.39 V, 0.48 V and 0.8 V, respectively). The LMEs production activity was defined as low (+, barely detectable), medium (++, clear and measurable halo) and high (+++, fully extended and intense halo) depending on the colour shift due to the enzyme activities. Fungi were inoculated by agar plugs of about 3 mm diameter into 35 mm Ø 6 wells plates and incubated at 25 °C. Plates were checked at days 1, 3, 6, 8 and 14; oxidation halos were measured where present. All the chemicals were purchased from Sigma-Aldrich (Merck Group KGaA, Darmstadt, Germany). All further analyses and graphics were performed using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). All fungal strain that displayed positive result is currently preserved at MUT (http://www.tucc.unito.it/it/content/collezione-mycotheca-universitatis-taurinensis) for further investigations.

Results and discussion

Seventy-four fungal strains were screened for their LMEs production and 26 of them (35.1 %) gave positive oxidation signal on at least one of the media supplemented with the three different indicators, revealing LME production both in salted (SS+) and saltless (SS-) media (Table 3).

Eleven fungi (42.3 %) were considered LP laccases producers following the oxidation of SGZ in the SS- line, and 6 of them were able to produce these enzymes also in the SS+ line. In particular, *Westerdykella dispersa* and *Alternaria alternata* showed similar production in SS- and SS+ lines, indicating that these fungi, regarding the LP laccases production, were unaffected by the osmotic stress in the SS+ lines. Twenty-three fungi (88.5 %) were considered HP laccases producers following the oxidation of ABTS in the SS- line, and 16 were able to produce these enzymes also in the SS+ line. Interestingly, almost all the fungi investigated produced this class of enzymes, and only three (*Ascomycota* sp.2, *Penicillium antarcticum* and *Trichoderma harzianum*) produced peroxidases, which have higher potential than the HP laccases. Seven strains (*Penicillium fellutanum*, *Pyrenochaetopsis tabarestanensis*, *Acrostalagmus luteoalbus*, *Emericella pluriseminata*, *Microascus* sp., *Ascomycota* sp.4 and *Alternaria alternata)* showed similar performances in the SS- line and SS+ line, indicating their activity, in producing HP laccases, despite the osmotic stress. Finally, 15 fungi (57.7 %) were considered peroxidases producers following the oxidation of GCL in the SS- line, and 8 were able to produce these enzymes also in the SS+ line. Among the latter, 4 fungi (*Trichoderma harzianum*, *Ascomycota* sp.2, *Microascus* sp. and *Acrostalagmus luteoalbum*) performed similarly in the SS- than SS+ lines. Extremely interesting is *Alternaria alternata*, which displayed an higher peroxidase producion in the SS+ line in comparison to the SS- line, underlining its adaptation to the marine environment, as the high salt concentration has promoted its enzymatic production.

Among the LMEs producing strains, eight (*Westerdykella dispersa*, *Acrostalagmus luteoalbus*, *Emericella pluriseminata*, *Microascus* sp., *Stachybotrys chlorohalonata*, *Pholiota gummosa*, *Ascomycota* sp. 4, *Alternaria alternata*) displayed a positive oxidation of all the three indicators used, thus indicating the production of LP laccases, HP laccases and peroxidases in saltless conditions. Of these, four (*Westerdykella dispersa*, *Acrostalagmus luteoalbus*, *Microascus sp*., *Alternaria alternata*) produced the three classes of enzymes also in the SS+ lines, indicating the ability to produce LMEs also in environments characterised by high saline concentration (Table 3). Ascomycota are commonly associated with decaying mangroves leaves and seagrasses in marine environment and some of them are well-known producers of LMEs [25,26]. In line with this, among the best performing fungi here reported, seven trains out of eight are Ascomycota. Many recent works highlight LMEs production and potential applications of their enzymes. Toker *et al.* [27], assessed the dye decolourisation performances of six fungal strains (*Phoma* sp.1, *Phoma* sp.2, *Alternaria* sp.1, *Alternaria* sp.2, *Cadophora* sp. and *Cadophora luteo-olivacea*) isolated from surface water, sediment, algae and woody root samples collected in a lagoon. Interestingly, fungi belonging to the same genera (or specie) have been sampled by this work too, and exactly as Toker's research, one *Alternaria* is among the most promising strains, suggesting a high LMEs production by marine fungi belonging to this genus. No literature assessed *E. pluriseminata* LMEs production, although two works [28] confirmed high LiP, laccase and lignin degrading activity in soilborne *E. nidulans*, a close relative. Hence, the genus *Emericella* could be worth

Table 3 – Fungal taxa positive for LMEs production) in SS± and intensity of their activities (reported as low +, medium ++, or high +++). (LP lac = LP laccase, HP lac = HP laccase, Peroxi = peroxidase.

TAXA	**SS- ENZYMES**	**SS+ ENZYMES**
Acrostalagmus luteoalbus	LP lac +++ HP lac +++ Peroxi +	LP lac ++ HP lac +++ Peroxi +
Alternaria alternata	LP lac +++ HP lac +++ Peroxi +	LP lacc +++ HP lac +++ Peroxi +++
Amesia nigricolor	HP lac +	-
Ascomycota sp. 2	Peroxi +++	Peroxi +++
Ascomycota sp. 4	LP lac + HP lac+++ Peroxi+++	HP lac +++ Peroxi+
Ascomycota sp.5	LP lac + HP lac +++	HP lac +
Aspergillus pseudodeflectus	HP lac+++	HP lac +
Cladosporium asperulatum	HP lac +++	HP lac +
Cladosporium cladosporioides	LP lac ++ HP lac +++	LP lac + HP lac +
Discula destructiva	HP lac +++ Peroxi +++	HP lac + Peroxi +
Emericella pluriseminata	LP lac ++ HP lac +++ Peroxi +	HP lac +++
Emericellopsis minima	HP lac +++	HP lac +++
Gaeumannomyces graminis	HP lac + Peroxi +++	-
Massarina sp.	LP lac +++ HP lac+++	LP lac ++
Microascus sp.	LP lac ++ HP lac +++ Peroxi ++	LP lac + HP lac +++ Peroxi++
Neocosmospora solani	HP lac +++	-
Parasarocladium radiatum	HP lac + Peroxi +	-
Penicillium antarcticum	Peroxi ++	-
Penicillium fellutanum	HP lac +	HP lac +
Pholiota gummosa	LP lac +++ HP lac +++ Peroxi +++	-
Pyrenochaetopsis tabarestanensis	HP lac +++	HP lac +++
Stachybotrys chlorohalonata	LP lac + HP lacc +++ Peroxi+++	-
Talaromyces flavus	HP lac +++	HP lac +
Trichoderma harzianum	Peroxi+	Peroxi +
Wardomycopsis humicola	HP lac +++ Peroxi+	HP lac +
Westerdykella dispersa	LP lac +++ HP lac +++ Peroxi ++	LP lac ++ HP lac ++ Peroxi +

of deeper investigation. *W. dispersa* is a known source of interesting new secondary metabolites [29] (e.g. alkaloids), but low or none LMEs activity has been reported by Da Silva *et al*. [30] against PAHs.

This result was confirmed by de la Cruz-Izquierdo *et al*. [31] that reported only low LiP production by a soilborn *Westerdykella* sp. isolate. As stated for *S. chlorohalonata*, probably the origin of *W. dispersa* has been a determinant factor on its LMEs production. As *W. dispersa*, the genus *Microascus* has been studied for its metabolites and LMEs production [32]. Raybarman *et al*. [33] detected LMEs activity of a strain of *Microascus* sp. on coir fibres, with production of laccases, Mn and LiP. Although this report did not manage to identify the strain at species level, the genus *Microascus* remains consistent with the cited work and should be studied more carefully for its biodegradative performances. Although marine *A. luteoalbus* LMEs production is not yet reported in literature, many papers deal with its production of unusual metabolites [34]. This paper instead outlines the production of many lignin-modifying enzymes (peroxydases, LP and HP laccases) both with and without Sea Salts, indicating its biodegradative potential. Finally, *Pholiota gummosa* is the only Basidiomycota of the eight most performing fungal strains assessed. The genus *Pholiota* is known for producing LMEs [35]; the ability of this particular species to produce the three classes of enzymes investigated, has been reported here for the first time.

Conclusion

The fungal community of the Livorno's harbour sediments has shown strong oxidative abilities on model chemicals, indicating an adaptation to the polluting conditions present in the port area. Indeed, this screening shows that 26 out of 74 tested fungi can produce enzymes that modify lignin and that could degrade organopollutants (PAHs and PCB). Eighteen strains produced LME in high salinity conditions, meaning that i) they were fully adapted to the marine environment, and ii) they have the enzymatic potential to degrade most of the aromatic pollutants which characterise the harbour sediments. These LME producing strains potentially represent the starting point to create microbial consortia suitable for bioremediation approaches. Moreover, these fungi are a source of new extremozymes that can find application in future research and in several industrial fields.

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THE NATIONAL MONITORING PROGRAM OF ISRAEL'S MEDITERRANEAN WATERS – SCIENTIFIC PERSPECTIVES

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Abstract – The Levantine Basin (LB) is considered an impoverished and sensitive ecosystem in the Mediterranean Sea. Since the beginning of the industrial revolution this sea has been influenced by increasing global, regional and local anthropogenic pressures. The LB is at the eastern most terminus of the Mediterranean Sea with relatively long residence time of water subject to warming, salinization and acidification. The opening of the Suez Canal in 1864 linking the Red Sea with the Mediterranean has facilitated the migration and settling of hundreds of Eritrean species along the Levantine coasts at the expense of native species and irreversibly altering the ecosystem. The damming of the Nile at Aswan in the mid 1960's reduced freshwater, nutrients and sediment fluxes into the LB resulting in probably reduced primary productivity, increased salinity and shore erosion along the Mediterranean coast of Israel. Locally, intense human activity including ports expansion, development of desalination plants, gas drilling, power plants, increase in maritime transportation (and more) impose heavy pressure on the coastal and deep-water ecosystems.
The National Monitoring Program of Israel's Mediterranean Waters (NMPIL) show significant signals of changes in the marine ecosystem off the shore of Israel, corresponding to the above pressures. In December 2018, a government decision on expanding the NMPIL was adopted in line with the United Nations Environmental Program's (UNEP) Integrated Monitoring and Assessment Program (IMAP) under the Barcelona Convention, considering also climate change perspectives. This communication shows the NMPIL structure and scientific rationale, and present three representative case studies of the monitoring results.

Introduction

The NMPIL is implemented based on the Ecosystem Approach (EcAp) for Good Environmental Status (GES) of the Mediterranean Sea by Ecological Objectives and indicators (in line with the Marine Strategy Framework Directive, MSFD) and on Climate Change indicators. The program covers large spatial (up to ~24 000 km^2) and temporal scales (several orders of magnitude) (Figure 1) and implement diverse monitoring methodologies and infrastructures (from molecular to ROVs) and complex logistics. These include molecular tools, barcoding and meta-barcoding, imaging using AI, radioisotopes (rates measurements), diverse sampling (rossette/CTD, box and piston corers; nets; diving; etc.), autonomous vehicles/measurements (mooring, gliders), remote sensing, operational/ecological models.

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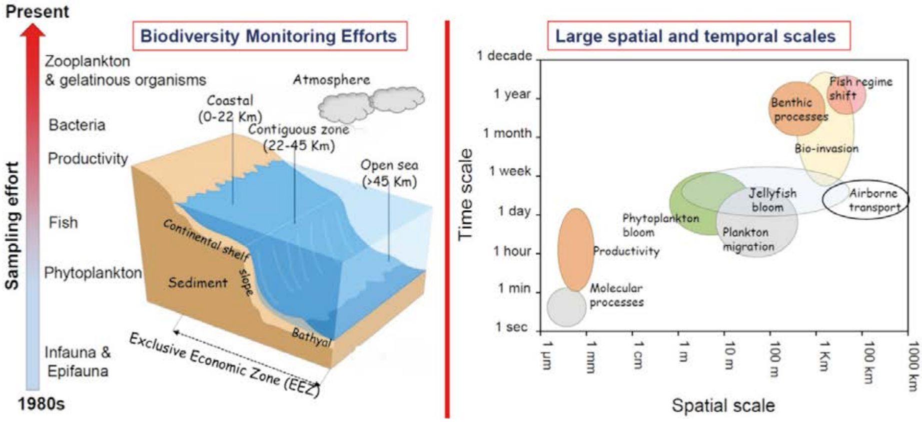

Figure 1 – The scales of spatial and temporal trends and the evolution of biodiversity monitoring efforts in the National Monitoring Program of Israel's Mediterranean Waters.

The annual monitoring and long-term results are reported via 5 main scientific reports:

- **Monitoring Climate Change and Hydrography** [1] (sections: thermohaline changes and continuous measurements; sea-level changes; Acidification and the carbonate system; changes in dissolved nutrients and oxygen in the open sea; Israel Marine Data Centre).
- **Monitoring Marine Pollution** [4] (sections: heavy metal in marine and estuary sediments; heavy metals and organic pollutants in ports and marinas; pollutants in marine biota; heavy metals and nutrients in atmospheric precipitates; nutrients and chlorophyll in estuaries and the continental shelf).
- **Monitoring Marine Litter** (litter and microplastic: beaches; marine sediments; surface seawater).
- **Monitoring Marine Biodiversity** [3] (sections: biology and ecology of phytoplankton in seawater; biology and ecology of bacteria in seawater and sediments; biology and ecology of zooplankton; biology and ecology of infauna; biology and ecology of epifauna; ecology of populations in rocky shores and hard substrates; barcoding and genetic resources).
- **Monitoring Sea-floor integrity and Sedimentology.**

In addition, part of the marine pollution and eutrophication annual results are submitted to the UNEP/MAP Secretariat/MED POL Programme database as agreed upon the Barcelona Convention parties. The implementation of the Integrated Monitoring and Assessment Cluster is still under discussion and probably soon will be adopted in order to contribute to the delivery of the MED QSR (quality status report) 2023.

Materials and Methods

The monitoring sites were designed to cover different bio-types or habitats – littoral, continental shelf, slope, bathyal, atmosphere, rivers and estuaries, benthic and pelagic; and the potential impacts of land base sources or marine infrastructures (Figure 2).

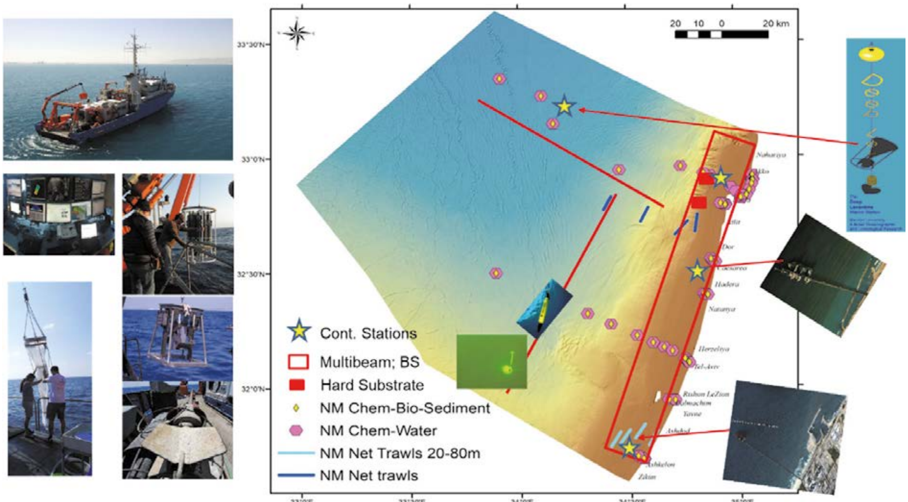

Figure 2 – Location of monitoring stations or transects in frame of the National Monitoring Program of Israel's Mediterranean Waters. Pictures includes the R.V. Bat Galim operated by IOLR and different sampling devices and continous measurement stations.

A summary of the different ecological objectives (EO), as defined by MAP-ECAP, which are implemented within the NMPIL, and monitored matrices, are presented in Table2.

Table 2 – Ecological objectives (EO) and monitored matrices as implemented within the National Monitoring Program of Israel's Mediterranean Waters.

Ecological Objective (EO)	**NMPIL**	**Matrices**
Biodiversity	√	Water, soft and hard sea-floor
Non-indigenous species	√	Water, soft and hard sea-floor
Harvest of commercially exploited fish	√	Benthic/pelagic
Marine food webs	√	Complex/in process
Eutrophication	√	Water
Sea-floor integrity	√	Soft and hard sea-floor
Hydrography	√	Water
Coastal ecosystems	√	complex
Pollution	√	Water, sediment, biota
Marine litter	√	Water, sediment, beach
Energy incl. underwater noise		Not yet
Climate Change	√	Temp, Sal, Acidity, Sea-level, Bio-invasive, hydro-meteorology

Results and Discussion

Here, we present three representative case studies of results from the long-term record of the NMPIL attributed to climate change and to marine pollution.

Climate Change case study 1 - Over the past ~32 years the Levantine Surface Water (LSW) and Levantine Intermediate Water (LIW) masses displayed positive long-term trends in salinity of +0.008±0.006 and +0.005±0.003 year^{-1}, respectively, and temperature of +0.13±0.05°C year^{-1} and +0.03±0.01°C year^{-1}, respectively (Figure 3). Inter-annual variations in salinity, temperature and nutrients were superimposed on all long-term trends [1,5,6]. The thermohaline variability in the LB coastal waters during 2011-2021 showed a statistically significant long-term warming and salinification trends with yearly rates of 0.048°C and 0.006, respectively [6], similar to the LIW rates.

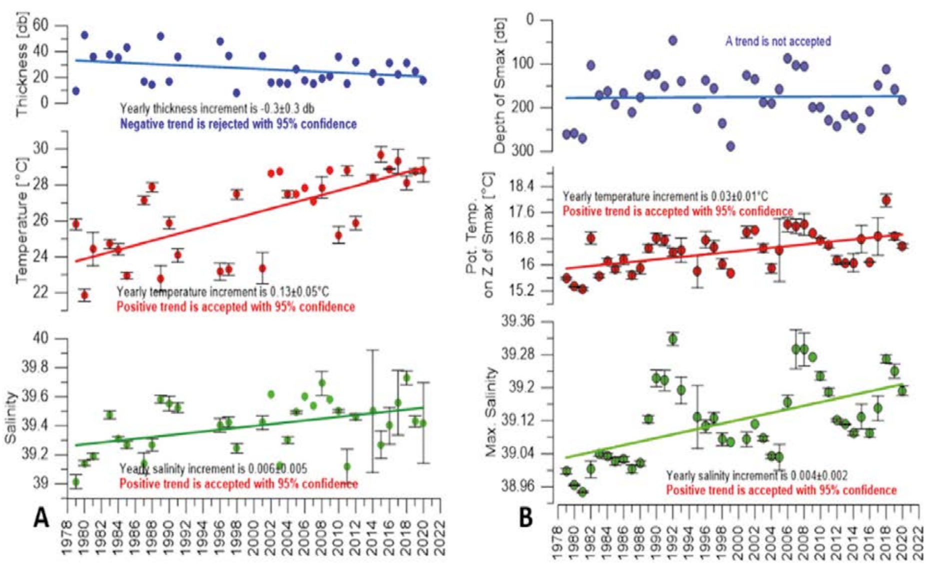

Figure 3 – Inter-annual and long-term changes of temperature and salinity in the Levantine Surface Water (LSW) and Levantine Intermediate Water (LIW), derived from 32 years of CTD profile measurements [5,6]. For the LSW only observations performed during the warm period (July-October) presented.

Climate Change case study 2 - Sea level variations are monitored by the Hadera Gloss #80 station (Figure 1) since 1992, at the LB coastal waters. During 1992 – 2020 an average sea level rise of 4.7 mm per year was observed (Figure 4) [1], higher than the global average of 3.2 mm per year. The sea level annual maximal and minimal levels (Figure 4) represent the seasonal summer and winter temperature variability, respectively.

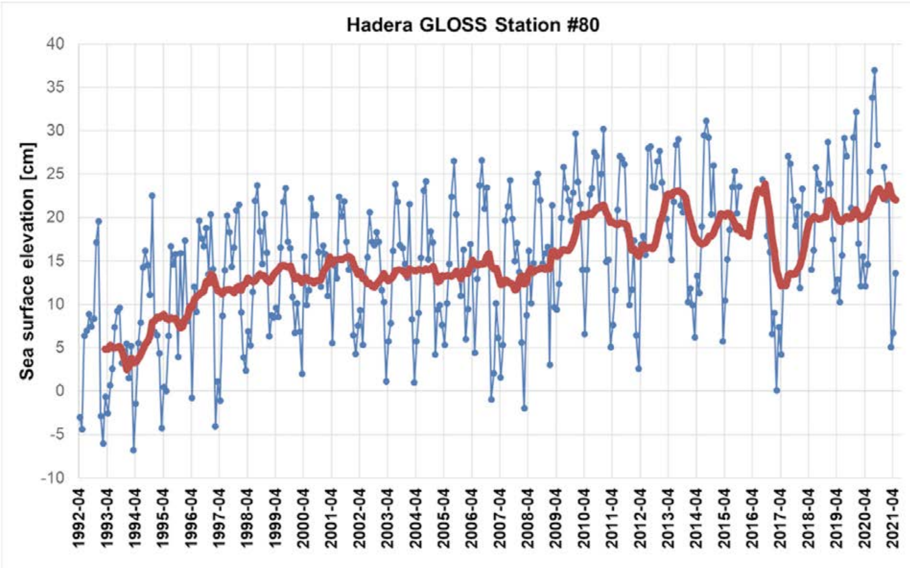

Figure 4 – Long-term changes of sea surface elevation as recorded at Hadera Gloss #80 Station [1; Ayah Lazar].

Marine Pollution case study 3 - Haifa bay (HB), located at the northern Israeli Mediterranean shoreline, was contaminated in the past by mercury through a point source of effluents discharge of a chlor-alkali plant (Electo-Chemical Industries) located at the northern part of the bay, which operated until 2004 [4]. The sediments and biota in HB have been monitored annually since 1978, as part of the NMPIL [3]. The long-term variations of total Hg (THg) concentration in surface sediments is monitored at 2 stations (8 and 9), off the former location of the chloro-alkali plant, and by sediment cores colected at station 9 between 1985 and 2021 [3,4]. The total amount of anthropogenic THg in the top 23 cm of each core is represented by the area integrated under each curve, corrected for the naturally-occurring THg. A general systematic decrease in the mercury surface sediment concentrations and total amounts is evident over the years (Figure 5).

Despite the long-term exponential decrease in the concentrations of THg in sediments and in the marine biota, an unexpected increase in the levels of mercury in coastal fish was observed after the closure of the chloro-alkali plant during 2006-2014 (Figure 6). To determine the cause of this increase, THg and methyl Hg (MeHg) were measured in seawater, coastal groundwater, suspended particulate matter, plankton, macroalgae, benthic fauna, and in marine and beach sediments. Extremely high concentrations were found in groundwater and sediments from the vicinity of chloro-alkali plant. This finding suggested a discharge of polluted groundwater into the northern part of HB after stopping groundwater pumping for internal use of the plant and ceasing the consequent seawater intrusion. Thus, the intrusion of anthropogenic Hg via the groundwater marine discharge enabled the assimilation of Hg by plankton or adsorb onto inorganic particles, which are further ingested by benthic and pelagic consumers [7]. These findings were used by the Ministry of Environmental Protection to instruct for the restoration of the polluted area.

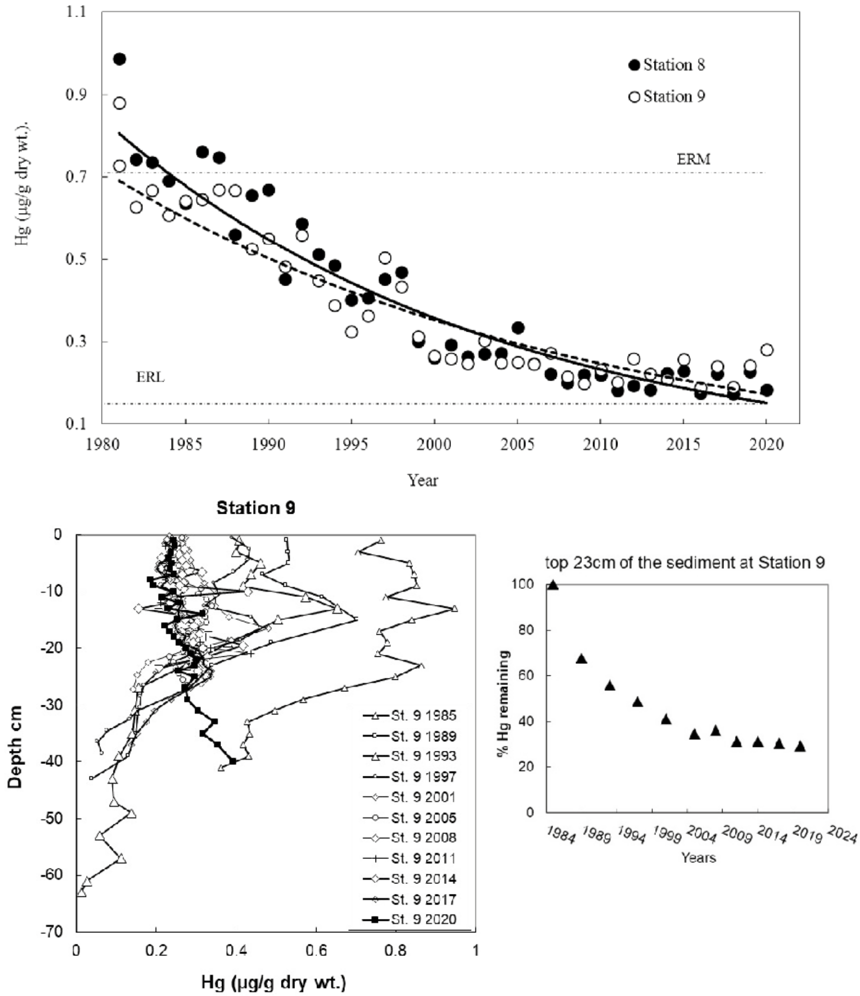

Figure 5 – Total Hg concentrations in surface sediments (top) and in sedimentary depth-profiles (lower left) at station 9 at the northern part of Haifa bay. A decrease of total Hg in the top 23 cm of sediments at station 9 between 1985 till 2020 is presented as percentage of the total Hg content in the 1985 core [3,4].

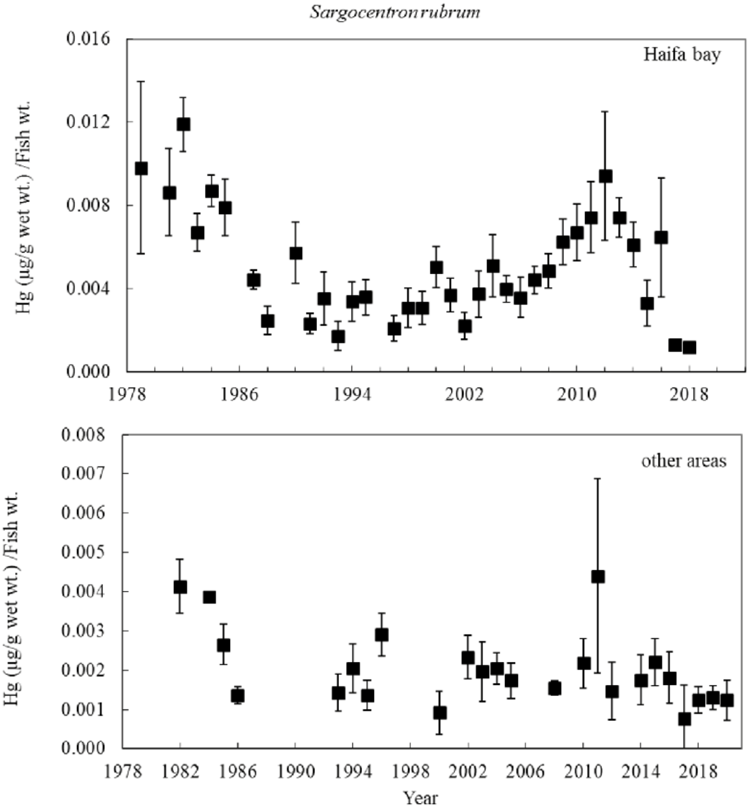

Figure 6 – Levels of Hg in the fish *Sargocentrum rubrum* (concentration normalized to fish weight) at Haifa bay (upper panel) and in other areas along the Mediterranean coast of Israel (lower panel) during 1980 till 2020.

Conclusion

The NMPIL has been developed over time in terms of its monitoring tools, methodologies, sampling efforts, spatial coverage and food web scales. While during the 80s of the former millennium the program was focused solely on marine pollution aspects at the coastal belt it has been expanded to include different habitats entering into the deep sea (littoral, continental shelf, slope, bathyal, atmosphere, rivers and estuaries, benthic and pelagic) and across the food web populations: bacteria, phytoplankton, zooplankton, mollusca, echinodermata, crustacea, polychaeta and fish. While Israel's national practice brings its NMPIL to the forefront of IMAP implementation, more monitoring efforts are needed to better address all the ecological objectives (or descriptors as defined in the MSFD). In addition, more knowledge is needed to better assess IMAP ecological objectives and indicators and the implementation of the Ecosystem Approach (EcAp) for Good Environmental Status (GES) of the Mediterranean Sea.

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IN SITU RARE LONG TERM OBSERVATIONS OF THE DOGTOOTH GROUPER *EPINEPHELUS CANINUS* IN ARTIFICIAL REEFS RECENTLY IMMERSED IN THE NATIONAL PARK OF THE CALANQUES (NORTH-WESTERN MEDITERRANEAN SEA, FRANCE)

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Abstract – In winter 2017, biomimetic designs of porous concrete artificial reefs (Ragues® modules of 3 m in height for 12 tons in weight) targeting different high-value and apex rocky species such as groupers were immersed between -19 and – 22m in the National Park of the Calanques (French Mediterranean coast - 43° 12.679' N / 5° 23.485' E) as part of an experimental ecological restoration project called REXCOR. Still ongoing, the main objective of the REXCOR project is to evaluate the capacity of innovative designs of artificial reefs to restore altered ecological functions of the rocky coastline (shelter, breeding, feeding, nursery grounds) historically impacted by the sewage outflow of the city of Marseilles (second largest town in France). During the first summer after their deployment, one specimen of the Dogtooth Grouper, *Epinephelus caninus*, (Valenciennes, 1843) estimated to 65 cm was observed by scubadivers during three consecutive months (June, July and August 2018) and then in December 2018 inside the artificial reefs. Thanks to photoidentification and to the analysis of the different morphologic characteristics, it was determined as a unique individual. The specimen was a gravid female estimated between four to more than eight years old. To our knowledge, this is the first documented record of high site-fidelity (at least 7 months) for *E. caninus* found in North-western Mediterranean coastal habitats. This could represent a first positive cue to undertake a larger project of ecological restoration. It is also the first record in the National Park of the Calanques since its creation in 2012 and the first record in artificial reefs in France, especially at such a low depth despite the presence of others important artificial reefs sites in this area.

1. Introduction

Groupers (Perciformes: Serranidae) represent one of the most emblematic Mediterranean fish. Due a high market value both for recreational and commercial fisheries, grouper populations are declining and some species such as *Epinephelus marginatus* are now considered as locally threatened [1]. As a keystone species, the study and the protection of groupers directly benefits associated coastal ecosystems. The long-term presence of such high trophic level species is considered as a good indicator to evaluate the health of a

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Mediterranean reef and the efficiency of management measures such as the creation of Marine Protected Areas [2]. Consequently, important efforts are undertaken in order to improve the scientific knowledge and the management of groupers populations. Seven species are found in the Mediterranean sea but some of them are still poorly described in terms of biology, ecology, stock structure, distribution, conservation and management plan. Among the 163 grouper species evaluated trough the global IUCN Red List assessment, 50 species were classified as Data Deficient (DD) and this reflect the lack of accurate information [3,4].

Available published data on the Dogtooth Grouper, *Epinephelus caninus* (Valenciennes, 1843) in the Western Mediterranean sea is particularly scarce (5, 6, 7). The intrinsic vulnerability index calculated by Fishbase (http://www.fishbase.org) according to the species life history associated to fishing vulnerability is particularly high (87/100), with 100 being the most vulnerable score). Widely distributed in the Eastern Atlantic from Portugal to Angola, this sub-tropical species is uncommon in the Mediterranean Sea especially in its north-western shore. It is mostly found in deep areas from 30 to 300-400 m occurring on both sandy mud and hard substrates [5, 6, 7, 8, 9]. As most of the groupers, *E. caninus* is a protogynous hermaphrodites and it is expected to be bottom-dwelling lie-in-wait predators that ambush their prey as it passes nearby [5, 10]. These predatory fish mostly feed on small fishes and crustaceans [5,9,10,11]. Morales-Nin et al. [12] described a specimen of 164 cm of total length and weighed 57 kg. Examinations of the otoliths of this fish reveal that *E. caninus* could reach 55 years old, a similar longevity observed in other grouper species such as *E. marginatus* [5]. Reproductive biology and behavior are still unclear for the Dogtooth Grouper. Some coastal lagoons of the southern shore of the Mediterranean Sea are described as potential nursery grounds for *E. caninus* [13]. Known to occur in French Mediterranean waters [14], only few published deep records (two ROV observations between -183 m and – 189 m [9]) and unpublished data [6] are available.

Table 1 – Summary of informations for the Dogtooth Grouper *Epinephelus caninus* extracted by Fishbase (http://www.fishbase.org).

IUCN Status (Mediterranean)	Depth range (m)	Maximum size (cm)	Trophic level	Intrinsic Vulnerability Index
EN	30 - 400	164	3.8 ±0.55	87/100

2. Materials and Methods

With 873 716 inhabitants in 2021 the city of Marseilles is the second largest in France. Until 50 years ago, effluents were discharged directly into the sea without treatment. Various investments to improve the quality of wastewater treatment have been made between 1987 and 2008 so as to become one of the most efficient wastewater treatment plants in the Mediterranean (Geolide – 1 860 000 Population Equivalent) which drastically improve the water quality as 90 % to 95 % dissolved and suspended solids are removed (Boissery com. pers.).

After almost ten years, this decrease in anthropogenic pressure was not associated to the restoration of different historical biogenic habitats such as rocky reefs and *Posidonia* *oceanica* seagrass beds. Thus, the study of the resilience, here the capacity of this degraded area to host again the associated biocenosis, especially the high trophic level rocky species, and the description of the ongoing restoration trajectory, was not possible. This motivated local authorities, national agencies and the Marine Protected Area to intend an experimental artificial reefs restoration program.

On winter 2017, four replicated villages of artificial reefs were immersed between -19 and – 22 m in the French National Park of the Calanques (French Mediterranean coast - 43° 12.679'N / 5° 23.485'E) as part of an experimental ecological restoration project called REXCOR. Still ongoing, the main objective of the project is to study the capacity of innovative designs of artificial reefs to study the restoration of the main altered ecological functions of the rocky coastline (shelter, breeding, feeding, nursery grounds) historically impacted. The four 4 villages (A, B, C, D) were settled at a different distance of the discharge from the wastewater treatment plant at respectively 170 m, 700 m, 1000 m and 1500 m.

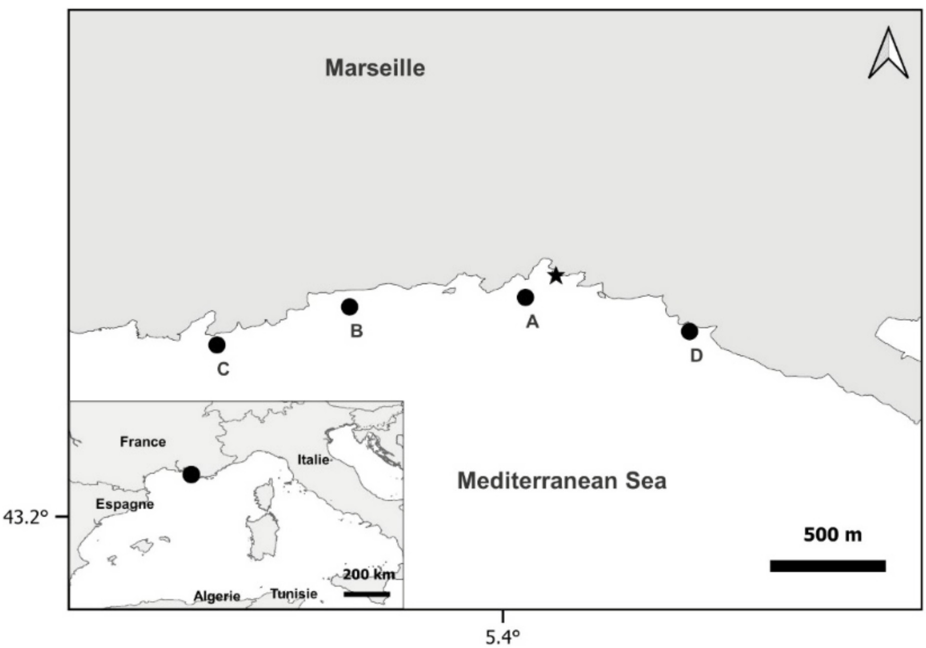

Figure 1 – Study area of the experimental ecological project REXCOR project (National Park of the Calanques). A, B, C and D represent the four artificial reefs villages. The star represents the discharge of the wastewater treatment plant.

Biomimetic designs of concrete artificial reefs 3 m high and weighing 12 tons (Ragues ®) were specifically developed to create new hard substrata and narrow cavities of different dimensions and shape targeting different high-value and rare rocky species such as lobsters, seabreams and groupers but also sessile species such as gorgons and corals.

Different monitoring programs were launched and are still ongoing including scubadiving surveys to study the mobile fauna (summer and autumn), photoquadrats studies to study sessile communities successions (summer and autumn), acoustic surveys (spring, summer and winter) to study the wildlife noise by night and technical surveys (summer and autumn) to study the integrity of innovative artificial reefs designs.

Figure 2 – The REXCOR project host different monitoring programs in order to study the resilience of the local rocky ecosystem inside an around the artificial reef villages in the impacted area of the National Park of the Calanques (left: Ragues ® module monitoring, center: acoustic surveys, right photoquadrats studies).

3. Results and discussion

In 2018, during the first year after the deployment of the villages, nine scuba diving campaigns were led by different scientific teams in order to realize the monitoring programs. On four occasions, one specimen of *Epinephelus caninus* was observed inside the cavities newly created by the artificial reefs immersed at around 1 km west of the discharge area. To our knowledge, this is the first record ever of *E. caninus* in the National Park of the Calanques since its creation in 2012 and the first record in French waters at such a low depth (< 25 m) by scubadivers. Interestingly, 400 other artificial reefs were immersed in 2008 in a nearby (but deeper) area from 25 to 31 m at less than 10 km away [15, 16]. Thoroughly monitored for ten years, no *E. caninus* were observed in the artificial reefs of the Prado (Le Direach, com. pers.). The design and/or the site selection could have played a major role in the efficiency of artificial reefs to shelter high trophic level species [17].

Thanks to photoidentication and video analysis, the different characteristic dark bands of the dog tooth grouper radiating posteriorly from the eye and associated cephalic blotches were studied as previously suggested [18]. We determined that the same individual (approximatively 65 cm) was sheltered inside the artificial reefs for at least 7 months. Strong site fidelity has already been described in other grouper species such as *E. marginatus* [19,20] but not for *E. caninus*. Site fidelity is a good indicator of the production effect of artificial and natural reefs [21, 22, 23]. This suggests that local food resources and habitat provided by artificial reefs and natural surrounding areas probably allowed to meet the different ecological needs (shelter, feeding) of such a high trophic level species. If an "*attraction vs production*" debate still exists, many studies are now available to clearly describe the interest of artificial reefs for some benthic species to shelter a whole ecosystem from primary producers to high trophic level species [24,25]. Moreover, the abdominal cavity of this potential sexually mature female (estimated between four to eight years old according to different authors [12,26]) seemed to be full of eggs during the summer and very close to spawn. Artificial reefs could have played a key function during the last days before the reproduction of this individual.

Our preliminary results suggest that the historical degraded area studied in 2018 in the national park of the Calanques could now support again important ecological functions for rocky species such as groupers. The water quality does not seem to limit at least the long-term presence of this high trophic bentho-demersal fish species and potentially the associated food web.

Using biomimetic artificial reefs to create new hard substrates in degraded coastal areas targeting benthic fish species seems to be efficient at least to study the potential of restoring a degraded area and to evaluate the local policies and stakeholders new policies and actions. Some design of artificial reefs could also play an important role for endangered and unknown species such as the Dogtooth Grouper supporting ecological functions including reproduction, shelter and food resources for such species.

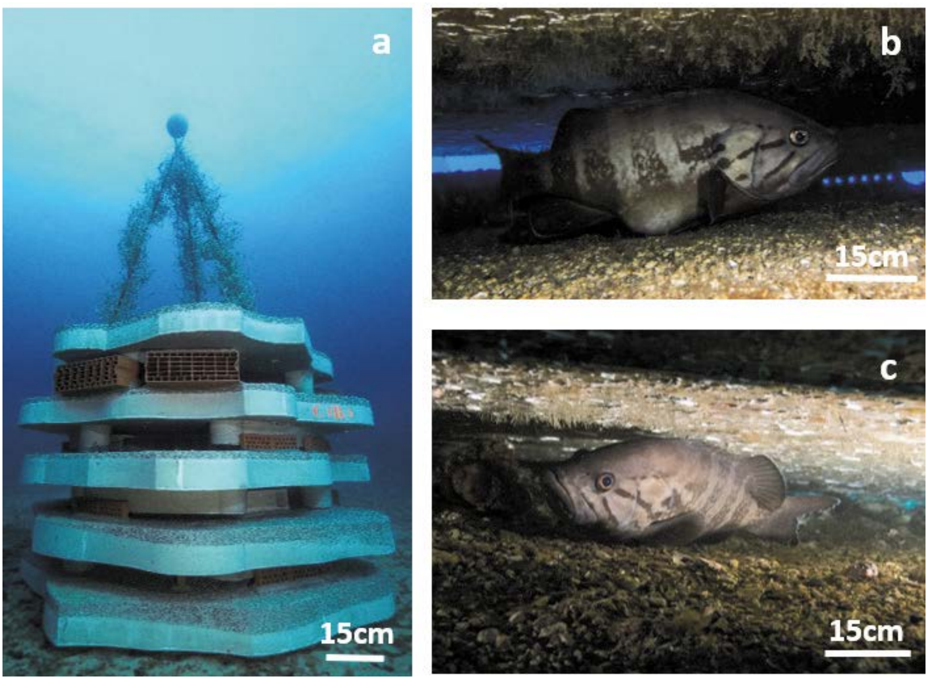

Figure 3 – Illustrations of the Ragues artificial reef (a) and the individual of the dogtooth grouper *Epinephelus caninus* observed inside of these modules in 2018.

4. Conclusion

The settlement of biomimetic artificial reefs showed that after one year in an historically degraded urban area, a rapid colonization and a high residency for at least one individual of the Dogtooth Grouper was possible. This suggest that this high trophic level species was able to reside on the area of the newly settled artificial reefs and that the water quality is not anymore an ecological filter to support important ecological functions (shelter, feeding, breeding…), but maybe the availability of healthy hard substrate is still missing locally. Further studies are needed to better quantify the long-term movements of resident species between natural and artificial reefs and how spatial and temporal patterns could differ between species. The interest of artificial reefs as a tool of the potential of recovery and restoration of an historical degraded area to recover its trophic structure trough habitat restoration still need more considerations in prevention of larger scale restoration projects.

5. Acknowledgements

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EFFECTS OF PETROLEUM HYDROCARBONS ON *SALICORNIA PERENNANS* GERMINATION AND GROWTH UNDER SALINE CONDITIONS

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Abstract – The research aimed at studying the effects of petroleum hydrocarbons (PHs) on *Salicornia perennans* Willd. growth at different saline concentrations. The study investigated 1) germination and seedling growth and 2) plant growth and photosynthetic performance in hydroponics conditions. Results show that PHs, together with salinity, strongly affected the germination. In freshwater, final germination did not differ between control and PHs treated plants. Under saline conditions, PHs generally stimulated germination, especially at the highest concentration (6000 ppm). Germination did not occur at 50 and 70 NaCl g/l. PHs and salinity strongly affected radicle growth: at 0 up to 15 NaCl g/l germination was reduced by both PHs treatments, while at higher salinity, no statistically significant differences were observed. Plant growth was significantly affected at 0 g/l of salt and with 6000 ppm PHs addition. The photosynthetic performance, evaluated through the maximum quantum yield of photosystem II (F_v/F_m), was slightly affected by the treatments, showing only a transient decrease in the plants treated with PHs in the absence of NaCl. On the contrary, plants grown in saline conditions maintained optimal values of F_v/F_m throughout the treatment period, highlighting a good tolerance of photosynthetic apparatus towards PHs.

Introduction

Petroleum hydrocarbons (PHs) are among the most concerning pollutants, especially for wetlands. Besides entailing the modification of some physical and chemical properties of water and soils, PHs are toxic for the environment: plants, animals and microbes (1). Coastal wetlands are unique and fragile environments that have relatively limited distribution and are inhabited by several specialized species. Moreover, they often encompass habitats of conservation interest, such as those of the Natura 2000 network. Halophytes are specialized plants adapted to thrive in salty habitats and represent interesting candidates to restore contaminated sites where salt content deeply impacts the environment. To test the possible use of halophytes as plants to employ in the remediation of PHs contaminated areas, *Salicornia perennans* Willd. (Chenopodiaceae), an annual succulent halophyte inhabiting brackish and saline environments, was chosen. The annual species belonging to the genus *Salicornia*, commonly known as glasswort, are reported to tolerate a broad range of saline conditions. They can produce a very high number of seeds

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which can easily germinate in vitro. Moreover, their cultivation is easy both in-soil and off-soil, possibly yielding relatively high biomass in a short time. Thus, this species can be considered a good candidate to test their capacity to tolerate and remediate petroleum hydrocarbons-contaminated saline waters.

In order to evaluate *S. perennans* resistance to salinity and to petroleum hydrocarbon stress, we investigated the germination capability and plant growth under different combination of salt and PHs concentrations.

Materials and Methods

Germinations trials

Fifty fruits of *S. perennans* (collected at Calambrone on the coastal area of Tuscany, Italy) were placed in each Petri dish, and germination was monitored daily. Salt treatments were: 0; 7,5 g/l (0,13 M); 15 g/l (0,26 M); 30 g/l (0,51 M); 50 g/l (0,86 M); 70 g/l NaCl (1,20 M). PHs treatments: A) 600 ppm B) 6000 ppm. When germination did not occur anymore, non-germinated seeds were washed and transferred in Petri dishes containing distilled water for the recovery experiment and then germination was monitored. In order to evaluate the effects of PHs on seedling growth, 30 seedlings were grown in the same conditions of salinity and PHs, after germination in distilled water. After 10 days, radicle, hypocotyl and cotyledons were measured using a stereomicroscope. Finally, the dry weight ratio was calculated on the same seedlings Germination was monitored daily until no germinating seeds were observed. The final germination rate has been statistically analysed through two-way ANOVA tests with the PAST software. Differences among means and the interaction among factors have been evaluated using Tukey's post hoc test.

Plant growth trials

After 30 days from germination plants were transferred in 500 ml flask in hydroponic solution and salt was gradually added with different concentration of NaCl: 0 g/l; 7,5 g/l (0,13 M); 15 g/l (0,26 M); 30 g/l (0,51 M); 50 g/l (0,86 M); 70 g/l (1,20 M). PHs addition was performed after 30 days from plants adaptation to salt treatment at two increasing concentrations: 600 ppm and 6000 ppm.

After 30 days from PHs addition, plants were collected and separated into aerial and root parts. Plant organs were gently washed, oven-dried at 60 °C and weighted.

During the experiment, the photosystem II (PSII) functionality was evaluated by chlorophyll fluorescence measurements conducted on leaves of the *S. perennans* grown under different NaCl treatments (0 and 30 g/l NaCl) and PHs (600 and 6000 ppm).

Chlorophyll fluorescence was measured using a portable miniaturized pulse-amplitude- modulated fluorimeter (Mini-PAM; Heinz WalzGmbH, Effeltrich, Germany). Measurements were conducted in vivo on the green leaves after 1 week and 3 weeks from the beginning of the treatments. Plants were pre-darkened for 30 min, and the maximum quantum yield of photosystem II was evaluated as $F_v/F_m=(F_m - F_o)/F_m$, where F_o and F_m are the minimum and the maximum fluorescence yield emitted by the leaves in the dark-adapted state, respectively. The F_v/F_m values have been statistically analysed through three-way ANOVA to test main and interactive effects of NaCl concentration (0 and 30 g/l NaCl), PHs concentration (600 and 6000 ppm) and treatment time (1 and 3 weeks). Differences among means and the interaction among factors have been evaluated using Tukey's post hoc test.

Results

Salt and PHs effects on germination

Salicornia perennans showed a great germination capability when growing without salt (100 % seeds germinated). Salinity remarkably affected germination of *S. perennans* as just 7,5 g/l of NaCl were enough to lower the maximum germination to 68 %, while under 15 g/l germination was reduced to 27,3 % and with 30 g/l, it was barely detectable (just one seed germinated in the three replicates). With 50 and 70 g/l of NaCl, no germination has been observed (data not shown).

PHs, in general, accelerated and increased germination percentages (Fig.1). As regards in the case of no salt added, conditions of 6000 ppm PHs allowed *S. perennans* seeds to germinate faster than in control conditions and with 600 ppm of hydrocarbons. Similarly, plants grown with 7,5 g/l or 15 g/l of NaCl and 600 ppm of hydrocarbons reached final germination rates almost equal to those observed without salinity. Finally, for the highest NaCl treatment that allowed a certain number of seeds to germinate, only in the case with 6000 ppm of hydrocarbons germination occurred not at a barely detectable level (mean final germination 22 %).

The three tested salinity concentrations exerted statistically significant effects on germination. On the other hand, only the highest PHs treatment exerted statistically significant effects on germination.

PHs exerted important effects on the morphology of the germinated seedlings since, under the highest treatment, roots did not develop (Fig. 2 A, B).

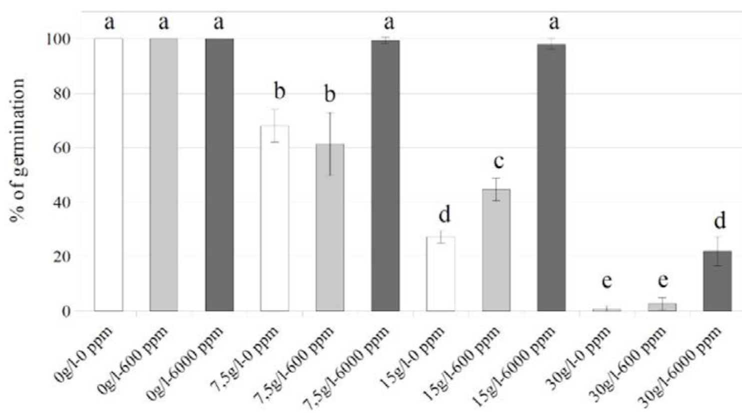

Figure 1 – Final germination rates of *S. perennans* under salinity and PHs treatments. White bars, no PHs; grey bars, 600 ppm PHs; black bars, 6000 ppm PHs. Different letters show statistically different means among treatments.

A  B 

Figure 2 – A) Different germination stages of *S. perennans* grown in control conditions (no salt, no PHs); B) Morphological Effects on roots of 6000 ppm hydrocarbons-treated *S. perennans* seedlings.

Salt and PHs effects on plants

Salicornia perennans showed to tolerate the highest doses of salt (50-70g/l) even if anticipating the blooming phase. Hence, the PHs addictions were performed only at the salt rate of 0 and 30 g/l. In figure 3, biomass data registered at the end of the trials are shown. The aerial biomass was reduced under the treatment of 0 g/l NaCl combined with the highest rate of PHs (6000 ppm); in the root biomass, a reduction was observed at 30 g/l compared to 0 g/l, while the PHs addition seemed to not alter the root biomass (data not shown).

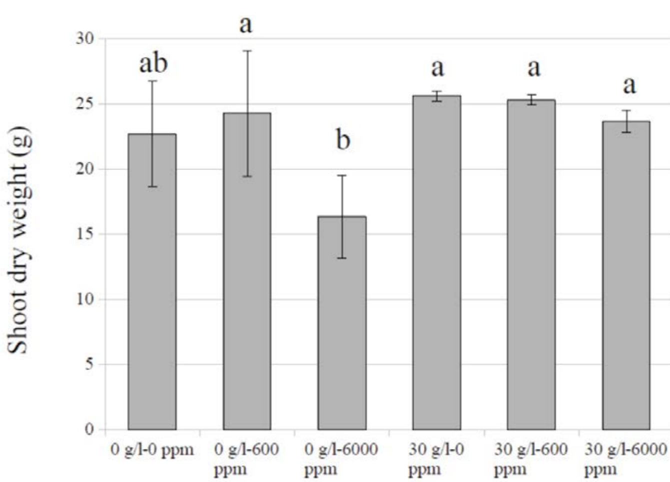

Figure 3 – Shoot dry weight of *S. perennans* plants treated with and without PHs at 0 and 30 g/l of NaCl. Different letters show statistically different means among treatments.

The effects of salt and PHs treatments on the physiological performance of plants were evaluated through the analysis of Fv/Fm on leaves (Fig. 4). Indeed, the presence of a stress factor generally results in a lowering of Fv/Fm, indicating an inactivation or damage of PSII functionality (2). Our results indicate that at 0 g/l NaCl, plants showed a slight reduction of Fv/Fm at increasing PHs concentration after one week of treatment, although they recovered the optimal values after three weeks. On the contrary, plants treated with 30 g/l NaCl maintained optimal values of Fv/Fm (close to 0.8) throughout the treatment period, highlighting their higher stress tolerance (Fig. 4).

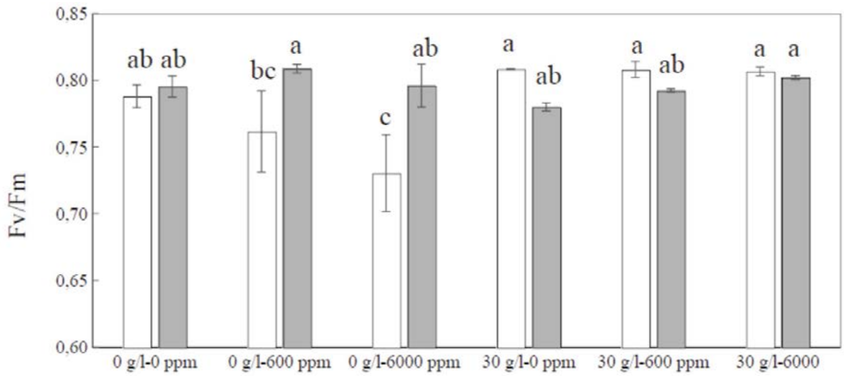

Figure 4 – Effects of salinity and PHs on Fv/Fm value after one week (white) and after three weeks (grey). Different letters show statistically different means among treatments.

Discussion

There is little literature data concerning the effects of PHs on seed germination under saline conditions concerning the genus *Salicornia*; thus, studies are needed to clarify this important aspect. Salinity is well-known to deeply affect the germination of halophytes, and studies on *Salicornia* have shown that this factor, even at low concentrations, determines a significant reduction of final germination rate in the close congener *S. europaea* L. In this light, the tested *S. perenanns* appears to be more a halotolerant than a true halophyte. In fact, the natural process of germination occurs in the wet season, when the salt concentration lowers thanks to the rainfall.

Generally, the treatment with PHs on seed germination in soil has turned out to be detrimental to the final germination rate (1, 3). The low PHs treatment (600 ppm) generally slowed down the *S. perennans* germination but determined a lower final germination rate only in plants grown with 7,5 g/l of salt. On the other hand, the highest treatment with PHs (6000 ppm) caused unexpected effects. Indeed, the latter treatment accelerated the germination also for seeds grown without salinity, while in mild saline conditions (7,5-15 g/l), it succeeded in counterbalancing the inhibiting effect of salt on the final germination. Differently, the effects of the highest PHs treatment on seedling radicle are somehow consistent with what was reported for other species in which a significantly reduced root growth has been observed.

Despite the positive action exerted by PHs on germination at certain saline concentrations, in consideration of the important effects on the development of the radicle in germinated seedlings, it is obvious that the overall action of PHs cannot be regarded as beneficial.

The obtained results show that PHs can enhance germination in *S. perennans* seedlings under saline conditions. This is in contrast with what was reported for a different species of the same genus: *Salicaria persica* grown in soil (3). The recovery experiment shows that PHs can exert their effects even after their removal, suggesting that hydrocarbons can possibly penetrate fruit teguments and directly affect the embryo. The measurements on germinated seedlings show that PHs, despite enhancing germination under saline conditions, at the same time exert important detrimental effects on radicle growth. This latter result can be only partially explained by the water stress, while the toxicity of PHs should be accounted for by the reduction of the radicle growth. Taken together, our results show that PHs are toxic for the seedlings of *S. perennans* and that this species reacts with an increase in germination. On the contrary, adult plants have turned out to be much more resistant and only slightly affected by PHs, depending on the saline conditions. In particular, PHs treatment exerted a transient reduction in photosynthetic potential and a slight decrease of aerial plant biomass in plants grown without salt, highlighting that saline conditions are necessary for this halophyte to enable the resistance to the PHs stress.

Conclusion

The outcomes of the present study represent the first data available in the evaluation of the salt and PHs stress on *S. perennans.*

Salicornia perennans showed to be more susceptible to the toxic effects of PHs under saline conditions at the stage of seedling than at the adult stage. In conclusion, petroleum pollution may be particularly critical at the early stages of the development of *S. perennans* seedlings, while the saline conditions are necessary for this halophyte to enable the resistance to the PHs stress. Further studies are necessary to elucidate the mechanism involved in germination and seedling radicle development and to investigate the *S. perennans* efficiency in degrading PHs in salty ponds at a field scale. Also, long-term observations are needed, and more information on other possible sources of impact should be gathered to obtain more reliable conclusions.

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THE PROTECTION OF *POSIDONIA OCEANICA (L.) DELILE* AND THE MANAGEMENT OF ITS BEACH-CAST LEAVES. THE ITALIAN JURIDICAL FRAMEWORK

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Abstract – This work aims at reconstructing the complex network of rules that, also due to the implementation of obligations accepted at the international and european level, our legal system sets up for the protection of *Posidonia oceanica (L.) Delile* in the sea and for the management of the beach-cast leaves ashore, highlighting the many unsolved, highly problematic knots. For what concerns the protection in the sea, the laws protecting *Posidonia* as a species and as a habitat can only apply to clearly defined areas, outside of which the protection needs must be weighed against the other interests at stake – chiefly those related to the economic and social development.
As for the management of beach-cast *Posidonia*, the few interventions of the state legislator have left over the years a fragmentary and lacking legislative framework, the lacunae of which have been filled by ministerial circulars and guidelines, in a substitute operation that, however valuable, has made even more evident the need of a specific discipline.
The Regions as well have intervened on the subject matter, not only by means of circulars, guidelines and alike, but also through laws. It is the case of the Region of Sardinia, which, with regional law no.1/2020, has tried to introduce some rules aiming at giving priority to on-site preservation or recovery. However, many of these rules did not overcome the scrutiny of the Constitutional Court (Judgment no.86 of 2021).
The latest addition to this framework is Article 5 of Law no.60/2022, the so-called *Legge Salvamare* (*Sea-saving Law*), which, once again, appears still far from providing the long-coveted, well-structured rules.

1. *The protection of* Posidonia oceanica (L.) Delile

1.1 The ecological relevance of *Posidonia oceanica*

The endemic *Posidonia oceanica (L.) Delile* is the dominant seagrass in the Mediterranean Sea[1], where it forms extensive meadows that, *inter alia,* provide the main carbon sink in the Mediterranean, sustain coastal ecosystems, play a key role in preventing coastal erosion, and have a buffering effect against water acidification[2].

[1] According to article 1 (d) of the *SPA/BD Protocol* (cf. *infra* in the text) *endemic species* means «any species whose range is restricted to a limited geographical area».
[2] *Ex aliis*, Rotini A., Chiesa S., Manfra L., Borrello P., Piermarini R., Silvestri C., Cappucci S., Parlagreco L., Devoti S., Pisapia M., Creo C., Mezzetti T., Scarpato A., and Migliore L., *Effectiveness of the "Ecological Beach" Model: Beneficial Management of Posidonia Beach Casts and* banquette, *Water* 12(11):3238, with further bibliographical indications.

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Nevertheless, in addition to natural stress factors, *Posidonia* is quite frequently subjected to pressures deriving from anthropic activities based both on sea and land[3],the harmful effects of which are amplified due to its being a very slow-growing plant, so that its destruction or regression have long-term consequences.

And in fact, due to being very sensitive to anthropic pressures and to environmental changes, *Posidonia oceanica* is used as a general indicator in the assessment of the environmental status of marine and coastal waters, and its preservation is usually related to the quality goals (e.g. maintaining or achieving a good «ecological» or «environmental» status) required by the *Water Framework Directive (WFD*, 2000/60/EC) and the *Marine Strategy Framework Directive* (*MSFD,* 2008/56/EC), implemented by Lg.D. no.152/2006 and Lg.D. no.190/2010, respectively[4].

Its relevance being undeniable, *Posidonia oceanica* therefore enjoys special protection at international, European and national level, sometimes as an endangered species, in other cases as a habitat.

1.2 The protection of *Posidonia oceanica* at the international and the European level

As a species, *Posidonia oceanica* has been included among the *Strictly protected flora species* (cf. Appendix I, as amended in 1996) of the *Bern Convention on the conservation of European wildlife and natural habitats* (1979), signed under the aegis of the Council of Europe[5], ratified and implemented by Italy with Law no.503/1981. And it is worth noting that, due to its inclusion in Appendix I of the Convention, the protection of *Posidonia* as a species, according to Article 5[6], requires, according to Article 4, the protection of its habitats, as well.

Posidonia also features, once again as a species, in the *List of the endangered or threatened species* (cf. Annex II) of the *Protocol concerning specially protected areas and biological diversity in the Mediterranean* (the so-called *SPA/BD Protocol*), adopted in 1995 in the context of the *Barcelona Convention* (1976), ratified and implemented by Italy with Law no.175/1999[7].

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[3] As a mere example, it could be useful to mention the impacts deriving from fisheries, from maritime traffic, from *offshore* activities, e.g. for the extraction of hydrocarbons, from cable and pipe laying, from the realization of coastal infrastructures, from dredging activities, from the release of waste waters, etc., which could result in effects – again, just to mention a few – such as the release of contaminants and/or of substances which can increase turbidity or eutrophication, the destruction of *habitats,* the change of sediment fluxes, the spread of invasive species due to climate change.

[4] Cf. Tab A.2.4 of Annex 1 to Part III of Lg.D. no.152/2006, which refers to Angiospermae (and macro-algae as well) as quality elements for the assessment of coastal waters, and Tab.1 of Annex III to Lg.D. 190/2010, which recalls Decision (UE) 2017/848, that includes the assessment of *Posidonia oceanica* habitats among the criteria for the assessment of human-induced eutrophication of marine waters.

[5] It may be useful to remember that, as to the Mediterranean Sea and in addition to member States of the Council of Europe, the Convention has been signed and ratified by Morocco and Tunisia, too.

[6] According to Article 5, each Party should «take appropriate and necessary legislative and administrative measures to ensure the special protection of the wild flora species specified in Appendix I» In any case, «[d]eliberate picking, collecting, cutting or uprooting of such plants shall be prohibited.».

[7] The *Barcelona Convention (Convention for the protection of the Mediterranean Sea against pollution)* had been ratified with Law no.30/1979. The *SPA7BD Protocol* has replaced the previous *Protocol concerning Mediterranean specially protected areas* (1982) adopted for the implementation of the *Barcelona Convention* and ratified and implemented by Italy with Law no.127/1985.

According to Article 3 (1) (b) of the *SPA/BD Protocol,* the Parties must take the necessary measures to, *inter alia,* «protect, preserve and manage threatened or endangered species of flora and fauna»; *Posidonia* included*,* as said.

In particular (cf. Article 4 et seq.), each State Party may set up Specially Protected Areas (SPAs) in the marine and coastal zones subject to its sovereignty or jurisdiction and may regulate and, if necessary, prohibit any activity likely to harm the species or to endanger the ecosystems and to adopt protection measures aimed at safeguarding ecological and biological processes[8].

Moreover, and that takes on particular relevance, Article 8 et seq. regulate the procedure to create a *List of Specially Protected Areas of Mediterranean Importance* (SPAMI list) to, among others, promote the protection of threatened species and their habitats. And it should be noted that SPAMIs may be established not only in the coastal and marine areas subject to the sovereignty or jurisdiction of the State, but also in zones situated, partly or wholly, on the high sea (cf. Article 9). For this purpose, the *SPA/BD Protocol* provides both the criteria for the choice of protected marine and coastal areas that might be included in the SPAMI list (cf. Annex I) and the procedure to be followed for the establishment of a SPAMI (cf. Article 9).

Posidonia enjoys special protection, in this case as a habitat, at the European level, too. *Posidonia* beds (*1120) are, namely, included (cf. Annex I) among natural habitat types protected under the so-called *Habitats Directive* (92/43/EEC), whose protection requires the designation of special areas of conservation[9].

Moreover, due to their being indicated by the asterisk, *Posidonia* beds are classified as *priority natural habitats*, that is natural habitats «in danger of disappearance», whose conservation, according to article 1 (1) (d), represents, for EU and Member States, a «particular responsibility in view of the proportion of their natural range which falls within the [European territory]».

1.3 The protection of *Posidonia oceanica* in the Italian legal system: a complex balancing of interests

As mentioned above, Italy has ratified and implemented both the *Bern Convention* and the *Barcelona Convention* and its protocols.

In the meantime, with particular regard to protected areas, Law no. 979/1982 had regulated the establishment of «marine nature reserves» («riserve naturali marine») in the marine environments (waters, seabeds and parts of the coast facing the sea) (cf. Article 25 et seq.).

[8] According to Article 6, the protection measures might consist, for example, in the prohibition of dumping or discharge of wastes, the regulation of the passage of ships and any stopping or anchorage, the regulation of the introduction of not indigenous species (in this regard see also Article 13), the regulation or prohibition of activities involving the exploration or modification of the soil or the exploitation of the seabed and its subsoil, the regulation or prohibition of fishing and harvesting of plants. In addition, according to Article 11, the State Parties could regulate or prohibit all forms of destruction and disturbance, including, for example, the picking, collecting, cutting, uprooting of the species and should adopt measures and plans with regard to *ex situ* reproduction.

[9] It is worth remembering that the protected areas established in accordance with the *Habitats Directive* and the *Birds Directive* (Directive 2009/17/EC, which has replaced Directive 79/409/EEC) as well, make up the *Natura 2000* network.

The matter is now regulated by Law no.394/1991, the so-called *Legge quadro sulle aree protette* (*Framework Law on protected areas*), of which Article 2 (4) regarding the classification of natural protected areas, specifies that, for what concerns the marine environment, these ones include both the specially protected areas and the marine reserves set up under Law no.127/1985 (that is, nowadays, Law no.175/1999[10]) and Law no.979/1982, respectively. And it is worth noting that some of the areas have also been recognised as SPAMIs[11].

With d.P.R. no.357/1997, Italy has also implemented the *Habitats directive,* introducing, in accordance with Article 4 of the Directive, the procedure for the establishment of the so-called Special Conservation Zones (SCZs), that is the areas requiring special measures of protection and management (cf. Article 3)[12], as well as the so-called *Valutazione di incidenza* (*Impact Evaluation*) for plans and projects likely to have a significant effect on these zones (cf. Article 5)[13].

Regarding the legislation on protected areas (as said, marine protected areas included) in particular, the law of 1991, although far from any 'museological' conception, undoubtedly aims at providing the protection-preservation of the natural heritage, albeit with a decreasing intensity depending on the zoning[14]. It follows that, at least for areas subject to enhanced protection – zone A (*Integral reserve*) and zone B (*General Reserve*) – the protection of *Posidonia,* as guaranteed by the tools provided by the Framework law[15], should prevail over any other interests involved, including those connected with the social and economic development of the country.

Likewise, also the protection requirements of habitats according to d.P.R. no.357/1997 should prevail over any other conflicting interests; so that, in the case of a proven and significant impairment of the conservation status of the habitat, preservation needs ought to be preferred. This implies that if no acceptable alternatives are found, the implementation or the carrying out of any conflicting projects and activities will be forbidden.

Such a conclusion is nevertheless mitigated by the provisions of Article 5 of d.P.R. no.357/1997, which allows to overcome a negative *Impact Evaluation*[16]. This possibility, provided for as a general rule by paragraph 9, is in fact permitted – albeit under a more stringent screening – also when the site concerned hosts a priority natural habitat type and/or a priority species, due to the occurrence of requirements related to human health and public safety or to requirements of primary importance for the environment or, further to an opinion from the European Commission, for other imperative reasons of overriding public interest[17].

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[10] Cf. *supra* note 7.
[11] Cf. http://www.rac-spa.org/spami.
[12] According to Article 4 of the Directive, on proposal of each Member State, which identifies the so-called proposed Sites of Community Importance (pSCIs), the European Commission establishes a list of Sites of Community Importance (SCIs). Once a site of Community importance has been adopted, the Member State concerned designates that site as a special area of conservation (SCZ for Italy), as soon as possible and within six years at most.
[13] It should be noted that the Impact Evaluation is required not only for SCZs, but also for pSCIs and SCIs.
[14] Cf. Article 12 (2) of Law no.394/1991.
[15] That is: Park regulations (Article 11), Park plan (Article 12), authorization measures (Article 13).
[16] The provision reproduces Article 6 of the *Habitats Directive.*
[17] In the case of sites which do not host priority habitats or species, the less restrictive provision of paragraph 9 allows to overcome a negative *Impact Evaluation* «for imperative reasons of overriding public interest, including those of a social or economic nature».

That said, in any case these provisions seem still plainly inadequate in offering effective protection for *Posidonia*, if only because they can at most ensure the preservation of spatially delimited areas.

We must indeed reach a completely different conclusion in the case of interventions carried out in the areas which are not subject to specific protection. In this hypothesis, in fact, the protection is (or should be) ensured, for example, by the legislation on the exploitation of natural resources, living and non-living, of marine waters and of the seabed and its subsoil or on land-based activities and through the enforcement of mechanisms such as environmental assessments and authorizations.

But in this case, in the balancing between competing interests, it cannot be ruled out that the protection of *Posidonia* might undertake a recessive character and turn out to be defeated.

1.4 Towards the new «ecosystem-based approach» of *Marine Strategy Framework Directive* and *Marine Spatial Planning Directive*

According to Article 1 of the *Marine Strategy Framework Directive* (*MSFD*, 2008) mentioned above, implemented, as said, by Lg.D. no.190/2010, to achieve or maintain good environmental status in the marine environment, Member States should have developed and implemented marine strategies applying «an ecosystem-based approach to the management of human activities», so to ensure that «the collective pressure of such activities is kept within levels compatible with the achievement of good environmental status and that the capacity of marine ecosystems to respond to human-induced changes is not compromised, while enabling the sustainable use of marine goods and services by present and future generations».

Following up on the *MSFD,* the *Marine Spatial Planning Directive (MSPD,* 2014)[18] has established a framework for maritime spatial planning, aimed at «promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources» (cf. Article 1). In particular, by applying «an ecosystem-based approach» (again), the maritime spatial plans should «promote the coexistence of relevant activities and uses», so as to «contribute to the sustainable development of energy sectors at sea, of maritime transport, and of the fisheries and aquaculture sectors, and to the preservation, protection and improvement of the environment, including resilience to climate change impacts» (cf. Article 5).

Implementing the *MSPD*, Lg.D. no.201/2016 has regulated the procedure that, by 31 March 2021[19], should have led to the adoption of «management plans» («piani di gestione») (Article 5), aimed at identifying «the spatial and temporal distribution» of existing and future activities and uses in marine waters[20], in order to «promote and guarantee their coexistence» in

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[18] Directive 2014/89/EU.

[19] The original deadline of 31 December 2020 had been extended by Decree-Law no.162/2019, conv. into Law no.8/2020.

[20] In the broad sense of Article 3 of Lg.D. no.190/2010, comprehensive, therefore, of waters, the seabed and subsoil on the seaward side of the baseline from which the extent of territorial waters is measured extending to the outmost reach where the State has or exercises jurisdictional rights (territorial sea, continental shelf, EEZs, ecological protection zones, fishing protected areas). Coastal waters are excluded in case they fall under urban and country planning, as long as this is mentioned in managements plans, in order to ensure the consistency of the provisions of each (cf. Article 2 of Lg.D. no.201/2016).

the light of the principle of sustainable development (Article 4)[21].

The overall aim is to use a holistic approach to draft comprehensive plans – in fact, sectoral plannings is, by nature, unable to consider all the variables – to encompass and/or harmonize all the other plans and programs concerning marine waters, their protection and the use of their resources, as well as relevant terrestrial activities due to land-sea interactions.

In short, plans should be built up like strategic and guide plans both for sectoral planning and for the granting of authorizations. And plans corroborated in their choices by their being subject to Strategic Environmental Assessment (SEA) and, possibly, Impact Evaluation (Article 5).

DPCM 1 December 2017 has approved the Guidelines aiming, in compliance with Lg.D. no.201/2016, at defining the 'stakes' for the drafting of management plans – one for each of the three identified marine regions[22] – relative to what is referred to by the Guidelines (see the Preface to the Annex) as the «Sea System» («Sistema Mare»), that is the organic governance of demands and needs, according to a sustainable development perspective, deriving from the multiple human activities that affects sea spaces.

Ambitious goals, as can be seen. But, unlike the sad destiny encountered by the Plan for the sea which had been introduced by Law no.979/1982 many years ago[23], this time the plans, albeit behind schedule (the deadline for adoption was, as said, 31 March 2021) are being drafted and the environmental assessment procedures have been started[24]. Time will tell.

2. *The management of beach-cast* Posidonia

2.1 Defining premises. Or even: on the difficult dialogue between science and law

As we shall see, the rules on the management of beached *Posidonia* refer in turn – as to their spatial scope – to different terms such as «spiaggia», «lido del mare», «arenile», «battigia» «litorale», but they never provide rigorous definitions.

Aside, for the moment, from the definitions used in scientific literature (on the point, see below), to give legal content to these terms it is necessary to look for laws or court rulings, if existing.

[21] Hence, the (non-exhaustive) list of the typology of areas or activities that could be subject to plan provisions (fishing and aquaculture areas, installations and infrastructures for the exploitation of fossil energy sources or for the extraction of minerals and raw materials or for the production of energy from renewable sources, maritime transport routes, military training areas, nature and species conservation sites and protected areas, underwater cultural heritage, submarine cable and pipeline routes, scientific research, tourism) (Article 5 again).

[22] Three marine regions have been identified. They correspond to the three subregions referred to in Article 4 of *MSFD* (and subsequently in art.3 of Lg.D. no.190/2010), that is the Western Mediterranean Sea, the Adriatic Sea, the Ionian Sea and the Central Mediterranean Sea.

[23] According to Article 1, the Minister of the Merchant Marine (later, the Minister of the Environment) in agreement with the Regions, should have adopt a Masterplan for the defence of the sea and its coasts from pollution and for the protection of marine environment. As is known, the plan did not overcome the draft stage.

[24] In February 2022 a *scoping* procedure was initiated for the submission to Strategic Environmental Assessment and Impact Evaluation of the Plans for the three marine regions (divided into sub-regions). The documents are available on the site www.mite.gov.it.

As known, Article 822 of the Civil Code and Article 28 of the Maritime Code include in the so-called maritime domain both the «lido del mare» and the «spiaggia», however without defining them; the terms «arenile», «battigia», «litorale» are not even mentioned.

We have indeed a legal definition (or, better, two different definitions) for:

a) «battigia», which, as to its etymology, is the *line* (that is, *linea*) along which the wave beats on the beach[25]. And, actually, Article 142 of Lg.D. no.42/2004, on the protection of natural landscape, puts on the list of the areas protected by law, among the others, coastal territories included into a swath of land with a width of 300 meters «from the *linea di battigia*» (but without defining it). In other provisions, however, «battigia» is not a line but an *area*. It is the case, for example, of the provisions regulating the domain of the State[26], which define the «battigia» as the *area* situated in front of the zones subject to domain concessions and to which free and open access and transit must be guaranteed[27].

As for the other terms, in the absence of legal definitions, a contribution in giving content to, at least, some of them has been provided by jurisprudence. In particular, it is established case-law that:

b) «lido del mare» is the portion of the «riva» (no definition is provided[28]) in direct contact with marine waters, which normally cover it during ordinary storms, so that the only possible use is the maritime one[29];

c) «spiaggia» encompasses both the stretch of the inland close to the sea which is covered by water only during storms of exceptional severity and the so called «arenile»[30];

d) «arenile», in turn, is the stretch of inland resulting from the natural receding of the waters and remaining fit to the public uses –even if only potential and not current – of the sea[31].

Lastly, no juridical definition seems to exist as to:

e) «litorale»; in this regard, according to dictionaries, the term seems not to have a unique definition: in fact, it refers both to «lido del mare» and to «costa, zona costiera» (that is, «coast, coastal zone») generally of great extension[32].

The aforementioned definitions (and the partitions of the coast to which they relate) do not seem to match those in use in scientific literature This also includes English-language

[25] See www.treccani.it/vocabolario/ (*ad vocem*).
[26] Cf. Article 03 (1) (e) of Decree-Law no.400/1993, conv. into Law no.494/1993 and Article 11 (2) (d) of Law no.217/2011.
[27] It is worth noting, however, that this area is always identified by municipalities (which are competent on the point) as a strip, mostly 5 meters wide (reduced to 3 for beaches less than 20 meters wide) measured *from* the «battigia». See, for instance, the *Regolamento per l'uso del demanio marittimo* (*Regulation on the use of the maritime domain*) of the Città di Venezia (resolution of the City Council no. 65/2010).
[28] In dictionaries, *riva* is the land area delimiting a stretch of water, notably when the terminal zone is low and flat. See www.treccani.it/vocabolario/ (*ad vocem*).
[29] Supreme Court of Cassation, Joint Chambers, no.849/1962; more recently, V civil section, no.4769/2004; III civil section, no.10304/2004; I civil section, no.17737/2009, I civil section, no.6619/2015; II civil section, no.29592/2021 (ord.).
[30] Supreme Court of Cassation, III civil section, no.10304/2004; I civil section, no.17737/2009; I civil section, no.6619/2015.
[31] Supreme Court of Cassation, III civil section, no.6349/1991; II civil section, no.10817/2009; I civil section, no.17737/2009.
[32] See www.treccani.it/vocabolario/ (*ad vocem*).

publications, in which the terms are not always used univocally[33]. In general, anyway, the coastal zone is usually featured and defined according to figure 1 (see below).

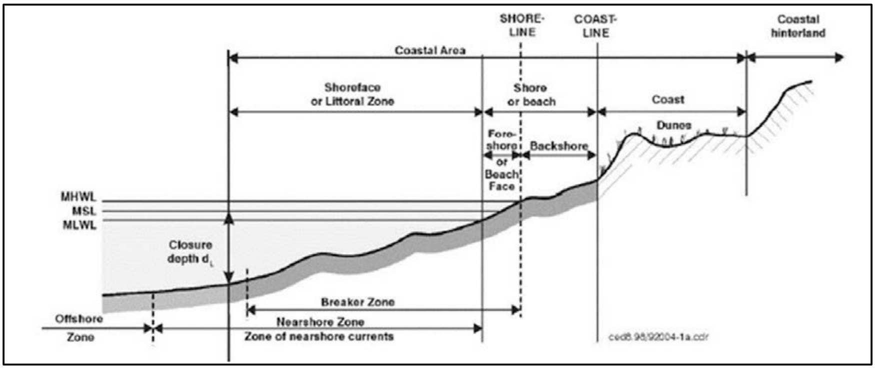

Figure 1 – *Definition of coastal terms,* in Mangor K., Drønen, N. K., Kærgaard, K.H. and Kristensen, S.E. (2017), *Shoreline management guidelines,* DHI, Hørsholm, Denmark, p.7

Glossaries offer a series of definitions, among which[34]:

beach or *shore:* the zone of unconsolidated material that extends from the Mean Low Water (MLW) line to the place with a marked change in material or physiografic form, or to the line of permanent vegetation (the effective limit of storm waves and storm surge), i.e. to the coastline[35]. It can be divided in the *foreshore* and the *backshore*;

foreshore or *beach face:* the zone between MLW and the seaward berm, which corresponds to the upper limit of wave uprush at high tide; it is the part of the shore which is wet due to the varying tide and wave run-up under normal conditions, i.e. excluding the impact of extreme storm waves and storm surge;

backshore: the part of the beach lying between the foreshore and the coastline; it is dry under normal conditions and is acted upon by waves only under extreme events with high tide and storm surge;

shoreline: the intersection between the MHW line and the shore; it is not easy to identify in natural settings (and definitions differ[36]);

land: the area located landward the *shoreline,* therefore consisting of the backshore, the coast and the coastal hinterland;

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[33] Cf., among the others, Mangor K., Drønen, N. K., Kærgaard, K.H. and Kristensen, S.E. (2017), *Shoreline management guidelines,* DHI, Hørsholm, Denmark, p.7 et seq.; USACE (2002), *Coastal Engineering Manual - Appendix A Glossary of Coastal Terminology***,** EM 1110-2-1100, *ad vocem.*

[34] See in particular the above mentioned *Shoreline management guidelines*, p.7 et seq.

[35] According to USACE (2002), *Coastal Engineering Manual,* cit, *beach* is used for shores of unconsolidated material only.

[36] For example, according to USACE (2002), *Coastal Engineering Manual,* cit., the *shoreline* is the intersection of a specified plane of water with the shore or beach. On charts, anyway, the shoreline approximates the MHW line.

littoral: the zone off the low water line, extending seaward from the foreshore, in which the littoral processes take place; but also another term for *shore,* or also «of or pertaining to a shore»[37].

Albeit obviously incomplete, this overview shows clearly that the terms and the definitions used by the Italian legislator and the nomenclature in use in the scientific field are not always perfectly equivalent.

Sometimes, they seem to match.

For instance, once it is clear (as we shall see) that, as regards beach-cast *Posidonia,* when the legislator refers to *battigia,* this cannot be but an area and not a line, it seems quite easy to use *foreshore*; it is anyway worth noting that not all problems are solved, given that the question remains as to whether the area is to be delimited according to a naturalistic criterion or according to the legal criterion, that is 'measuring tape in hand'.

Sometimes, on the contrary, they do not.

For instance, it proves to be much more problematic to find an adequate match for *spiaggia*, which does not seem to be *tout court* identifiable with *shore* or *beach,* given the fact that it encompasses not only the *backshore,* but also the *arenile*, that is an area the juridical definition of which does not seem to find a specific correspondence and which, in any case, might seem to fall within the notion of *land*[38].

Also for *lido del mare* the definition coined by the jurisprudence does not seem to find a correspondence in the terms in use in scientific literature.

Finally, as to *litorale,* the fundamental issue is probably the lacking of a juridical definition; so that it turns out to be impossible to decide if the term may find a correspondence in the definition, ambivalent indeed, offered by scientific literature.

That said, to avoid arbitrary and misleading translations, it seemed in any case more appropriate to maintain the terms used by the Italian legislator. With the hope that a dialogue between the legislator and the scientific community finally takes place…

2.2 The non-virtuous approach: the disposal as waste

That said, if the protection of the meadows of *Posidonia* in the marine environment still presents, as seen, some problematic knots, the protection is even less effective for beach-cast leaves of *Posidonia*, which can be found in coastal areas where extensive seagrass meadows occur, sometimes assuming the characteristics of permanent structures called *banquettes.*

In spite of being recognised as an important resource for coastal ecosystems and whilst its removal could negatively affect the sediment budget of the beach, beached *Posidonia* is often removed, primarily because it is believed to reduce the touristic appeal of the site, and subsequently managed as waste. Local authorities, often under the intense pressure from public maritime domain concessionaires, tend indeed to consider beach-cast *Posidonia* as a Municipal Waste, according to Article 183 (1) (b-ter) (4) of Lg.D. no.152/2006[39], not only removing it but, moreover, sending it to disposal sites (mostly landfills).

[37] In this sense, for instance, USACE (2002), *Coastal Engineering Manual,* cit.

[38] So that *sandy inland* or *land* (and not *sandy shore*) could be the correct translation, consistent with the origin of the term: *arenile* from *arena,* that is *sand* (www.treccani.it/vocabolario/).

[39] According to cit. Article 183 (1) (b-ter) (4), Municipal Waste includes, among the others, «waste of every nature and origin, lying on […] sea beaches». Article 183 (1) (b-ter) (4) been introduced by Lg.D. no.116/2020. But a similar provision was also present in the previous legislation (Article 184 Lg.D. no.152/2006 and Article 7 of Lg.D. no.22/1997).

In this regard, it is worth recalling that, in addition to the provision of the above mentioned Article 183 (1) (b-ter) (4) about the management of beached *Posidonia* as Urban Waste, as seen, Article 183 (1) (n) of the same Lg.D. no.152/2006, as amended by Article 14 (8) (b-bis) of Decree-Law no.91/2014, conv. into Law no.116/2014, specifies that operations *in situ* (that is, gathering, mixing, preliminary sorting and preliminary storage for the purposes of collection) concerning natural materials deriving, among the others, from coastal storms, even if mixed with materials of anthropic origin, do not fall, for the strictly necessary technical time, under the purview of waste management activities.

Treating beach-cast *Posidonia* as waste to be disposed of is an approach absolutely not in line with the criteria of waste management under a circular economy, that is: prevention, recovery and finally, but only as a last option, disposal (the well-known «waste management hierarchy»)[40]. And it is in any case worth remembering that this approach is destined to be abandoned soon, considering that, starting from 2030, the waste suitable for recovery, notably urban waste, will no longer be allowed to be disposed of in landfills (cf. Article 5 (4-bis) of Lg.D. 36/2003, introduced by Article 1 (1) (d) of Lg.D. no.121/2020).

2.3 The unsatisfying answer of the legislator and the 'substitute' role of ministerial circulars and Guidelines.

In May 2022 the Parliament has approved the so-called *Legge Salvamare* (*Sea-saving Law*), Article 5 of which, as we shall see, deals with the legal regime of beached *Posidonia.*

The provision fits into a juridical framework characterized by a patchwork of sectorial and fragmentary provisions, and therefore devoid of any overarching order. At the time of its entry into force, in fact, there were currently in force, along with the aforementioned Article 183 (1) (b-ter) (4) and Article 183 (1) (n) of Lg.D. no.152/2006, just a few provisions which, listed in a mere chronological order (the sole applicable criterion, actually), testify, as a matter of fact, about the lawmaker's scant attention to the issue in the past.

And it is a quite singular and symptomatic thing that the first intervention of the legislator is a very sectorial one, concerning the reuse of beached *Posidonia* in agriculture. Lg.D. no.75/2010, regulating fertilizers, includes it, namely, among the organic matrices that can be used, up to 20 % in weight of the initial mixture, in the production of soil conditioners and organo-mineral fertilizers, after separation of the organic fraction from the sand that might be present (cf. Annex 2 and Annex 5, respectively)[41].

The slightly later Article 39 (11) of Lg.D. no.205/2010, in turn, lays down that, in any case without prejudice to the rules concerning both the protection of the marine environment and by-products, *Posidonia* (and jellyfish, as well) can be buried on site on the conditions that their presence on the «battigia» – and the «battigia» alone – can be unequivocally ascribed to storms and that no transport or treatment occur.

As a derogation from waste regulations, it follows that, as specified by the Supreme Court of Cassation: a) «transport» means the typical waste management activity according to Article 183 (1) (n) of Lg.D. no.152/2006, while «treatment» means recovery or disposal

[40] Cf., in this respect, Article 179 et seq. of Lg.D. 152/2006.

[41] Indeed, similar provisions were already present in the previous legislation: cf. Annex 2 and Annex 5 of Lg.D. 217/2006, as amended by M.D. 22 January 2009 of the Ministry of Agricultural Food and Forestry Policies (MIPAAF).

operations, including prior preparation for them, as referred to in Article 183 (1) (s), so that merely preparatory operations to on-site burial should be reasonably allowable; b) the burden of proving the fulfilment of the conditions set out by the law for the application of the derogation lies with the one who invokes it; c) the non-compliance with these conditions should result in the application of waste regulations, rules for the repression of the offences included[42].

One last point, concerning the reference to the rules on by-products. It is quite clear that, for what concerns beach-cast *Posidonia,* the conditions for the applicability of Article 184-*bis* of Lg.D. no.152/2006 (and of its implementing Decree, M.D. no.264/2016) are lacking[43]. And it is difficult to imagine an *ope legis* extension of the rule of Article 184-*bis* similar to the one provided by the same Article 39 of Lg.D. no205/2010, at paragraph 13, according to which, as a matter of fact, the provisions of Article 184-*bis* also apply to the material removed, for hydraulic safety reasons only, from the beds of rivers, lakes and streams. That said, the reference to Article 184-*bis* should probably be interpreted as meaning that – in compliance with the other conditions laid down by the provision – the on-site burial is certain and that it will not lead to overall adverse environmental or human health impacts.

Lastly, Article 185 (1) (f) of Lg.D. no.152/2006, as modified by Article 39-*quater* (1) of Decree-Law no.41/2021 (conv. into Law no.69/2021) and by Article 35 (1) (b) (2-*bis*) of Decree-Law no.77/2021 (conv. into Law no.108/2021), specifies that beach-cast posidonia, whenever released into the same marine environment or re-used for agronomic purposes or in substitution of raw materials in productive cycles, through processes or methods which do not harm the environment or endanger human health is excluded from the application field of waste management rules[44].

In this regard, some further remarks can be made.

One the one hand, it is worth noting that the provision encompasses two different hypotheses.

The first one, concerning the release of beach-cast *Posidonia* into the marine environment, ultimately allows the closing of the natural cycle of the plant, without this resulting as a waste disposal operation (it should be remembered that, according to Annex B to Part IV of Lg.D. no.152/2006, the «release to seas» integrates a case of waste disposal).

As to the second hypothesis (re-use for agronomic purposes or in productive cycles),

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[42] Cf. Supreme Court of Cassation, III penal section, decision no.3943/2015. The Court has held the existence of the crime of illegal waste disposal in a case in which some vegetal material had been moved from the foreshore, mixed with construction waste and deposited onto a nearby site (in the case in point it had not been clarified if they were algae or plants of *Posidonia*, but according to the Court the distinction was, at that point, irrelevant).

[43] According to Article 184-*bis,* by-products are substances or objects resulting from a production process the primary aim of which is not their production and that they shall be used in the same or in a different production cycle.

[44] When Decree-Law no.41/2021 (the so-called *Decreto Sostegni, Decree Subsidies*) was being converted, the Presidency of the Senate had imposed as a condition of proposability of Article 39-*quater* that the effectiveness of the provision should end on 31 December 2022 (cf. session n.324 of 6 May 2021). This was due to the fact that the Decree-Law concerned the introduction of temporary measures to cope with the Covid emergency. The reference to the date of 31 December 2022 has been repealed by Decree-Law no.77/2021, which instead bore a series of measures regarding the *governance* of the so-called *PNRR, Piano nazionale di Ripresa e Resilienza* (*National Recovery and Resilience Plan*) and specifically, as said, by Article 35, entitled «Misure di semplificazione per la promozione dell'economia circolare» («Simplification measures for the promoting of circular economy»).

it recognises that beached *Posidonia* may not be considered as a waste to dispose of, but as a resource that, despite no longer being able to play any ecological roles, can still offer ecosystem services. In this regard, it might be useful to remember that Article 3 of M.D. no.264/2016[45] expressly excludes from its scope substances and materials to which Article 185 of Lg.D. no.152/2006 does not apply.

On the other hand, given that the regulation refers to «beach-cast posidonia», both the release into the marine environment and the utilization in agriculture or in productive cycles will need to be preceded by the sieving of the sand and the removal of anthropic materials. And in any case, the above mentioned Article 183 (1) (n) regarding on-site operations will have to be applied[46].

Lastly, it must be highlighted how, once again, the legislator has simply added another piece to a puzzle still far away from being completed.

In the face of such an unclear and dismally lacking regulatory framework, with an operation which cannot be defined as anything other than actual 'substitution', a series of documents – Circolari ministeriali (Ministerial Circulars) of the then Minister of the Environment (MATTM) and Linee guida (Guidelines) of ISPRA – have been issued, in order to determine, in the light of the above mentioned priority criteria in matters of waste management, the correct approach to the management of beached *Posidonia.*

Going into detail, the following documents have been issued over the years, sometimes on the basis of field studies:

a) the MATTM Circular no.8123/2006 (*Gestione della posidonia spiaggiata*), addressed to coastal municipalities;
b) the ISPRA Guidelines no.55/*2010 (Formazione e gestione delle banquettes di Posidonia oceanica sugli arenili)*;
c) the MATTM Circular no.8838/2019 (*Gestione degli accumuli di Posidonia oceanica spiaggiati*), addressed to Regions and autonomous Provinces;
d) the ISPRA Guidelines no.192/2020 (*La Spiaggia Ecologica: gestione sostenibile della* banquette *di* Posidonia oceanica *sugli arenili del Lazio*).

In implementing the above mentioned principles of circular economy, all the documents provided a series of recommendations – also technical – for the management of both beached *Posidonia* and the so-called «anthropic accumulations» (on these latter, see below).

With reference in particular to beach-cast *Posidonia,* both the MATTM Circular no.8838/2019 and the ISPRA Guidelines no.192/2020 (the latest published documents and the 'ripest', indeed) listed, according to a descending order of priority, a series of possible options, that is:

[45] It is the decree introducing indicative criteria to facilitate the demonstration of the compliance with the requirements for the application of the rules concerning by-products. It also provides some specific provisions concerning the use of residual biomass for biogas production and for energy production through combustion.

[46] According to G. Amendola (2021), *Ultime notizie sulla posidonia: il «decreto sostegni»,* in osservatorioagromafie.it, by including beach-cast *Posidonia* in Article 185, the Italian legislator has gone beyond Article 2 of the *Waste Framework Directive* (Directive 2008/98/EC). It is worth noting that, as to the other materials regulated by both the Directive and Article 185 (i.e. straw and other natural agricultural or forestry materials), the exclusion applies on the condition that they are non-hazardous (hence the necessity of their characterization); according to the wording of Article 185, this is not necessary for beached *Posidonia*.

a) on-site preservation;
b) temporary displacement on the same beach or onto neighbouring beaches and repositioning on the foreshore of the beach of origin for the winter season;
c) on-site burial;
d) transfer to waste recovery plants;
e) transfer to landfills;
f) re-introduction into the marine environment (still considered, at the time of the emanation of the Circular and of the Guidelines, as a waste disposal activity, given that the above mentioned provision of Article 185 (1) (f) of Lg.D. no.152/2006, as modified in 2021, had not yet entered into force).

All the documents underlined however that the selection of the type of intervention should have been carried out on a case-by-case basis, taking into account both the specificities of the landmarks and the socio-economic conditions of the sites.

The issuing of these documents aimed, as said, at filling in the many 'gaps' left by the legislator. Nevertheless, it must be stressed that – in the absence of an appropriate primary or secondary discipline – this should not have been and should not be the solution, not least for the many issues related to their enforceability and perhaps, and even before, their own unlawfulness.

Referring to circulars, due to their assuming, in this case, an «inter-subjective dimension»[47], regardless of their nature – be it interpretative («interpretativa») or regulatory («normativa»)[48] – it is quite clear that these are acts the binding nature of which is fundamentally non-existent, given that they represent nothing more than a guidance, however authoritative[49]. The question would even shift to the level of their own admissibility and lawfulness if it should be assumed that the laws in force at the time of their adoption were not sufficient to uphold them (in this case, we would probably be dealing with actual circular-regulations, that is «circolari-regolamento», as they are defined by commentators[50]).

All the more reason, due to their not being contemplated or recalled by a legal provision, no effects should be ascribed to Guidelines, except, perhaps, those consisting in that *moral suasion* which is a distinctive trait of *soft law* instruments, also in this case correlated to the authoritativeness of the source.

In both cases, these are issues that, due to their complexity, should deserve a much deeper analysis and, therefore, can only be mentioned herein.

Instead, it must pointed out that, as this concise reconstruction would highlight, the lawmaker's initiatives up to 2022 have been circumscribed to some specific and sectoral

[47] That is, circulars addressed to public entities or subjects external to the administration that has adopted them. On this point and on the forthcoming considerations about circulars and guidelines cf. M. Clarich (2022), *Manuale di diritto amministrativo,* Il Mulino, p.89 et seq.
[48] The former aiming at harmonizing the implementation of rules by public administrations, the latter issued for the purpose of orienting the exercise of the functions within the margin of discretion left by the law.
[49] Basically, in this case, there would not even be the limited efficacy that circulars acquire towards those belonging to the administrations which issued them, the non-compliance with which – although they are not binding and therefore may be waived – implies at least a duty to provide adequate reasons, which can be assessed by the judge under the profile of the excess of power.
[50] Intended as atypical acts, containing general and abstract rules the addressees of which do not belong to the public administration that issued the act.

hypotheses only, neglecting – unlike it was supposed to do – to outline which actions ought to have been primarily undertaken and without providing an adequate and coherent set of rules (including technical ones). Leaving to ministerial circulars and guidelines the task to effectively regulate the issue; thus generating, in consequence, the above mentioned perplexities.

2.4 The undertakings of the Regions about the management of beached *Posidonia* and the 'restraints' of the Constitutional Court (judgment no.86 of 2021)

Given the lack, as seen, of a comprehensive discipline set out by the state lawmaker, the 'substitute' work carried on by ministerial circulars and guidelines has been joined by a conspicuous regulatory activity by the Regions in exercising their competences in regards of, for example, waste management, protection against coastal erosion, and tourism. This by means of a congeries of different acts, from Council resolutions to guidelines, to plans or programmes, etc.; such acts, in some cases, recall the ministerial circulars, thus contributing to give them, *de facto,* a sort of efficacy by virtue of the principle of effectiveness[51].

In an attempt to balance the needs of protecting beach-cast *Posidonia* and the demands related to the tourist use of the beaches and, alternatively, to promote the recovery of the detached leaves rather than their disposal, the Region of Sardinia had recently tried to regulate the matter in a more comprehensive manner than until then the statal lawmaker had done.

Recognising the importance of beach-cast *Posidonia* in contrasting coastal erosion and as a reusable resource (Article 1, par.1), regional law no.1/2020 had in fact provided that:

a) on-site preservation had to be considered the preferable solution (Article 1, par.1);
b) should the deposits of beached *Posidonia* impede the normal fruition of the beaches during the summer season (and only in that case), it was allowed to temporarily relocate the accumulations to suitable areas of the same «arenile» or, where not available, to specifically selected suitable areas within the municipal territory (Article 1, par.1); the removal should have been possibile within the month of April and the relocation – in the beach of origin or, should it not be possible due to new deposits, in a nearby beach – had to take place, with due regard to dunes and dune vegetation, within the month of November (Article 1, par.2);
c) should municipalities deem it necessary to opt for the permanent removal of the deposits of beached *Posidonia,* these would have to be delivered preferentially to installations for recovery, in particular to composting plants (Article 1, par.3); and, to promote recovery and re-use, the law made provisions for dedicated grants (Article 1, par.9 and Article 2);
d) landfill disposal was in any case prohibited (Article 1, par.4);

[51] So, as a mere example, we can mention, among the latest, the *Linee guida per la gestione del materiale spiaggiato* (*Guidelines for the management of beached material)*, issued by the Region of Friuli Venezia Giulia to regulate the fruition of State-owned areas for tourism purposes and the conservation of natural habitats and of biodiversity (cf. Council resolution no.1066/2017); the Executive note no.42595/2021 of the Region of Sicily concerning the cleaning of beaches, including those hosting beach-cast *Posidonia;* the *Linee guida per la gestione delle biomasse vegetali spiaggiate* (*Guidelines for the management of beached vegetal biomass*) issued by the Region of Puglia (adopted in 2015 and recently updated with Council resolution no.822/2022).

e) the Region should have to set up a Plan for the management of *Posidonia,* containing general information about «spiagge» and «litorali», detailed sheets on individual sites, and guidelines for management and maintenance (Article 1, par.11).

According to the law, all the operations of collection, removal and relocation were to be carried out after separation of the organic material from the sand – which should have been used for beach nourishment in the site of origin or in the site of new destination – and from man-made waste (Article 1, pars.5 and 6); the screening operations could have been carried out both in the site of origin and in the site of new destination (Article 1, par.5).

The law also regulated the operating methods for the carrying out of the activities on the beaches, with a series of prescriptions and limitations related, for example, to the use of machinery (Article 1, par.6).

Finally, the law introduced some *ad hoc* provisions for the management of both the so called «anthropic accumulations» (Article 1, par.1) and the vegetable matter from agriculture or forestry naturally laid down, among others, on the «battigia» (Article 1, par.8); two hypotheses which, as we shall see in brief, have also been regulated by Article 5 of the so-called *Sea-saving Law* (see *infra*).

Not few provisions of the regional law, however, have failed the scrutiny of the Constitutional Court, which has declared their unconstitutionality with a very articulated decision (the no.86 of 2021) which undoubtedly, for the many points of reflection that offers, would deserve far more space. That said, it might be worth retracing, albeit in extreme synthesis, the line of argumentation followed by the Court, with specific regard to the issues related to the management of beached *Posidonia.*

First of all, the Court acknowledges that, while the protection of *Posidonia* as a marine plant is entrusted to a substantial legislation, both national and supranational, the same cannot be said for its beach-cast remains, which, however, play a key role in the conservation of coastal areas and of their ecosystems (point 4 of the *considerato in diritto*).

In the face of an effectively inadequate national legislation – so much so that the important role in the protection of the environment has been played, as the Court underlines, by the Ministerial circulars – the regional law has intervened with «the highly commendable purpose» («il ben meritevole fine») to draw up a set of norms aiming at balancing the demands to make beaches more usable in the summertime – in the context of the exclusive regional competence over «tourism» – and the needs related to the protection of the environment and of the possible recovery of the *Posidonia* (point 4 and point 5 of the *considerato in diritto*).

But, for the Court, the «highly commendable purpose» is not good enough.

In fact, both disciplines – the one relating to the protection of *Posidonia* as a marine plant and the other concerning the remains deposited on the shoreline by the wave motion – fall within the exclusive competence of the state legislator over the subject-matter «protection of the environment [and] the ecosystem» according to Article 117 (2) (s) of the Constitution. Namely, it is up to the state legislator to decide whether or not beach-cast *Posidonia* must be subject to the rules on waste management; which, indeed, in the Court's opinion, should not come to have a negative connotation, given that it only expresses the legal qualification, from which it is possible to determine which rules apply (point 4, point 8 and point 10 of the *considerato in diritto*).

Recalling its own case law, the Court points out that the Regions are allowed to exercise their competencies for the fulfilment of interests which are functionally related to the strictly environmental ones, on the condition that the regional law provides higher and stricter levels of protection than those laid down by the State (point 8 of the *considerato in diritto*).

Thus, ultimately, a regional law will have to be declared unconstitutional should it turn out that it has overlapped and contrasted the discipline laid down by the State on the subject-matter of the protection of the environment, not widening but reducing the scope of the latter (or, in other words, derogating *in pejus* to it) (point 10 of the *considerato in diritto*).

And it is in the light of this criterion that, as said, many regional provisions have been deemed unconstitutional, and particularly:

a) Article 1, par.1, with regard to the *ex-situ* temporary displacement (that is, in areas within the municipal territory), because it introduces an *in pejus* derogation from the national rules regulating waste management (collection, temporary storage, transport);
b) Article 1, par.4, as regards to the absolute prohibition of the disposal in landfills, because in contrast with the national discipline, for which it is allowed should recovery turn out to be technically or economically infeasible (Article 182 Lg.D. no.152/2006) [52];
c) Article 1, par.5, in the part where it stated that the screening operations could be carried out also in the site of the new destination (again, an *in pejus* derogation from the national discipline).

So, as a result of the decision of the Court, the provisions of the regional law concerning the management of beach-cast *Posidonia* which are still in force are those which:

a) indicate the on-site preservation as the preferable solution;
b) allow, for the summer season, the temporary relocation of the accumulations, as long as this is done in suitable areas of the same «arenile»;
c) introduce a specific discipline regulating the activities of collection, transport, and repositioning, when allowed;
d) promote and encourage, also through incentives, the recovery of beach-cast *Posidonia*;
e) introduce an obligation, for the Region, to set up a Plan for the management of *Posidonia*.

In conclusion, it seems to me that the considerations and the evaluations of the Court can be fully subscribed[53]. Anyway, what it really stands out – and that seems to shine through the words of the Court itself – is that the Italian legislator could not delay anymore to regulate appropriately the management of beach-cast *Posidonia.* However, the long-awaited answer seems not to have arrived with the *Sea-saving Law.*

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[52] In this case, however, it seems to me that the derogation introduced by the regional law should be actually regarded as *in melius,* so that, by referring to the national rules which allow landfilling also in case of economic infeasibility (assessed through a cost-benefit analysis and an evaluation of possible advantages), the Court, though not saying it openly, may have rather tried, as sometimes in the past, to balance all of the interests (cf. Judgements no. 214 of 2008; no.246 of 2006; no.307 of 2003). The question cannot but be mentioned, given that the issue of the inderogability, even *in melius*, of the national rules in the light of the Constitutional Court's case law – oscillating, actually – is too broad to be discussed here. In any case, it is worth recalling what said about Article 5 (4-*bis*) of Lg.D. 36/2003 about the prohibition of landfilling for urban waste starting from 2030.

[53] With the possible exception for the considerations concerning the unconstitutionality of the provision regarding the prohibition of landfilling (see above note 52).

2.5 The management of beach-cast *Posidonia* according to Article 5 of Law 17 May 2022, no.60. *Parturient montes …*

After a very long gestation (the draft law had been presented on 25 October 2019), in May 2022, as mentioned above, the Parliament has definitively approved the so-called *Legge Salvamare* (*Sea-saving Law*) which, at Article 5, bears, among the others, a series of measures aimed at the management of beached *Posidonia*[54].

First of all, it must be underlined that the provision, ultimately resuming the content of the MATTM Circulars and the Guidelines of ISPRA, appropriately makes a distinction between:

a) the management of vegetable biomass, deriving from sea plants or algae, naturally laid down on the «lido del mare» and the «arenile» (paragraph 1) (on this, see below);
b) the management of «anthropic accumulations» consisting of fully mineralized vegetable biomass of marine origin, sand and further inert material mixed with man-made material, resulting from the relocation and subsequent accumulation in given areas (paragraph 2)[55];
c) and finally – as a residual hypothesis, whereas paragraph 1 and paragraph 2 should not be applicable – the management of products consisting of vegetable matter from agriculture or forestry naturally laid down on the «battigia», deriving from the operations referred to in Article 183 (1) (n), that is, waste management operations, and specifically all the operations aiming at separating man-made waste from the vegetable matter (paragraph 3)[56].

As to vegetable biomass deriving from sea plants or algae (not only beach-cast *Posidonia*, in fact), Article 5, paragraph 1, states that, without prejudice to the possibility of on-site preservation or removal to waste management facilities, they can be repositioned in the natural environment, also by reimmersion in the sea itself or by relocation in retrodunal areas or in other zones in any case belonging to the same physiographic unit (in the latter case, after sieving the sand and removing anthropic waste from the organic material, with recovered sand being potentially reused for beach nourishment). In case of reimmersion in the sea, this operation should be carried out, on a trial basis, in sites deemed suitable by the competent authority.

That said, it is certainly to be positively welcomed that, for the first time, a primary source of law has intervened in the subject matter, trying to summarize in a single rule the possible destinations of beach-cast vegetable biomass, *Posidonia* included. At least, this is what should be expected reading the heading of Article 5, that is: *Norme in materia di*

[54] It must be underlined, however, that the macroscopical delay was actually due to the controversial approval of the other rules of the law, regulating the recovery of waste at sea and inland waters; the text of Article 5 went unchanged through the many passages from one Chamber to the other.
[55] According to Article 5 (2), the sandy material resulting from the sieving of anthropic accumulations may: a) be excluded from the application of the rules on waste management in accordance with Article 185 of Lg.D. no.152/2006; b) recovered (and specifically, according to Annex C to Lg.D.152/2006, code R10, subjected to land treatment resulting in benefit to agriculture or ecological improvement); c) considered as a by-product according to Article 184-*bis* of the same Decree. The decision on the applicable regime is up to the «competent authority» (presumably, the authority which should grant the authorization for recovery operations).
[56] According to Article 5 (3), in this case Article 185 (1) (f) should apply.

gestione delle biomasse vegetali spiaggiate (*Provisions on the management of beach-cast vegetable biomass*).

However, it is evident that the final result did not meet the expectations and that much more could be done (see, purely by way of example, bill S 1822 − introduced on 20 May 2020 and put aside following the approval of Article 5 − which consisted of 7 articles and contained a much more exhaustive discipline).

In my opinion, in fact, the provision of the abovementioned Article 5 (1) leaves several unresolved knots.

The first thing that clearly emerges is that the list of possible destinations appears to be actually far away from taking a clear stance, that is to say that it seems to have been drawn up in total disregard of the aforementioned «waste management hierarchy» and of its priority criteria on the basis of which, it is worth remembering, ministerial circulars and guidelines had been issued. This becomes patently obvious from the fact that in Article 5 the on-site preservation is followed by the removal to waste management facilities, with no distinction between recovery and disposal activities.

Furthermore, it would have been preferable for the legislator to precisely state under what conditions vegetable biomass (and, specifically, *Posidonia*) can be removed from the beach, even if for recovery. In this regard, in fact, it is definitely correct that recovery should be given priority, compared to disposal; however, the moment beach-cast *Posidonia* is considered a resource, and as such something susceptible of acquiring economic value (also thanks, possibly, to subsidies, as in the case of the law of Sardinia), it is also clear that the law should have provided for a set of strict requirements to prevent arbitrary removal (with ministerial circulars being too 'weak' for the purpose).

But there is more. With specific regard to beach-cast *Posidonia,* the list of the possible destinations of vegetable biomass referred to in Article 5 does not include some of the hypotheses regulated by the rules which were in place at the moment of the entry into force of the *Legge Salvamare*. So that it should be questioned whether the previous rules should have to be considered implicitly repealed or whether they keep being applicated; the latter option is, in my opinion, to be preferred, so as to avoid the formation of lacunae.

Embracing this second interpretation, the overall picture of the management options of beach-cast *Posidonia,* as resulting from the combined provisions of Article 5 of the *Legge Salvamare* and the pre-existing rules in the subject matter, reorganized in the light of the waste management hierarchy (prevention, recovery, disposal), should be recomposed as follows:

a) on-site preservation; this hypothesis should include the burial on site under the conditions of Article 39 (11) of Lg.D. no.205/2010;
b) repositioning in the natural environment, including reimmersion in the sea or relocation in retrodunal areas or in other zones belonging to the same physiographic unit, under the conditions of Article 5 (and, for reimmersion in the sea, Article 185 (1) (f) of Lg.D. no.152/2006, too);
c) re-use for agronomic purposes or in substitution of raw materials in productive cycles (see Article 185 (1) (f) of Lg.D. no.152/2006); this hypothesis should include the production of fertilizers according to Lg.D. no.75/2010;
d) removal to waste management facilities for recovery (Article 5) and consequent application of Article 184-*ter* of Lg.D. no.152/2006, according to which, in lack of specific European rules (and that is the case), end-of-waste criteria (for example,

processes and treatments permitted, identification of the specific purposes and of the technical requirements of the end-product) should be identified on a case-by-case basis with a ministerial decree of the Ministry of the Ecological Transition or, failing this, with the authorization issued to each recovery facility;

e) removal to waste management facilities for disposal (Article 5).

In conclusion, Article 5 of the *Legge Salvamare* leaves, as the saying goes, a bitter taste. Once again, in fact, the legislator seems to have made no more than a mere recognition – not only extremely succinct, but even lacunose – of the management procedures of beach-cast *Posidonia*, without providing any guidance on their priority order and without establishing a coherent system of rules (including technical ones) for their implementation.

So much for any (unrealistic) aspirations towards a comprehensive and systematic regulation of the subject matter…

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COLONIZATION OF TRANSPLANTED *POSIDONIA OCEANICA*: UNDERSTANDING THE SPATIAL DYNAMICS THROUGH HIGH-SPATIAL RESOLUTION UNDERWATER PHOTOMOSAICS

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Abstract – Following the restoration of a *Posidonia oceanica* meadow impacted by the Concordia shipwreck, we investigated the spatial dynamic of the most important and protected Mediterranean endemic seagrass over a two-year period applying three spatial metrics: number of patches, mean patch size and total cover. By means of underwater photomosaics, we noticed a diminution in the number of patches in favour of the mean size and total cover. The outcomes showed that, under suitable environmental conditions, *P. oceanica* colonizes rapidly the dead *matte* substrate. This study underlines the importance of considering the spatial dynamic of transplanted seagrasses in monitoring programmes and gives new insights on the progression rate of transplanted *P. oceanica*.

Introduction

The coastal zone constitutes an interface ecosystem between the land and sea and represents one of the most important contexts in which human activity, economy, ecology, and geomorphology interact. Seagrasses are a mixed group of flowering plants living in shallow coastal marine and estuarine environments worldwide, thriving both on soft and rocky bottoms [1].

P. oceanica is the most important and widespread endemic seagrass in the Mediterranean Sea capable of forming extensive meadows from the sea surface up to 45 meters depth. Due to its sensitivity to human-induced alterations and thanks to its ecological, physical, economic, and bio-indicator roles [2], is protected at both species and habitat level by national and international directives and legislations. Despite the legal framework and protection measures, since the end of last century *P. oceanica* meadows are rapidly declining mainly due to human activities and climate changes [3].

Due to the slow growth rate and the rare sexual reproduction, the damaged *P. oceanica* meadows are unlikely to recolonize naturally. Hence, when the regression factors are removed, and the pre-disturbance environmental features are re-established, active transplantation represents an appropriate intervention to restore the seagrass beds and speed up the recovery process.

Monitoring of transplanted *P. oceanica* has been so far relying on the structural and functional features of the phanerogam, whereas to date the spatial dynamic is not considered.

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Indeed, despite the spatial dynamic of natural *P. oceanica* meadows are well described [4], the expansion rate of the transplants is still lacking.

High-resolution underwater photomosaics have been increasingly employed in marine research programmes and monitoring activities thanks to the imagery's quality, low operational costs, fast application, and repeatability. Photomosaics have been used to track the spatial dynamic of natural meadows [5-6] and coralligerous reefs [7-8], to map and classify ecologically sensitive habitats [9-11], nowadays, they are frequently applied in studying the restored seagrass beds [12-15]. Hence, photomosaics represents an important monitoring tool that can be rapidly and frequently applied for sequential surveys over vast areas of restored seagrass to study the spatial dynamic of the transplants and to detect at fine scale both increases and declines in the seagrass cover.

The present study reports the spatial dynamic of *P. oceanica* transplanted during a large-scale seagrass restoration in a previously disturbed area of the Tyrrhenian Sea. This area is located on the site of the Concordia shipwreck and has been subjected to multiple disturbances resulting from the 2012 shipwreck and its removal, which have led to the loss of a well-preserved *P. oceanica* meadow [16-18].

After the wreck removal and three years of remediation activities, any disturbances that caused *P. oceanica* loss were removed, and the phanerogam regression ceased. Since the regression factors were removed and the environmental features were re-established, a pilot study focused on a *P. oceanica* experimental transplantation was carried out in 2016 for designing a specific protocol to be applied at a broader scale [19]. This study laid the basis for a large-scale *P. oceanica* transplantation planned to speed up the recovery of the meadow impacted by the Concordia shipwreck and its removal [20].

Hence, following the large-scale transplantation, we evaluated over 1149 m^2 and during a 2-year period, by means of high-spatial resolution underwater photomosaics, the spatial dynamic of transplanted *P. oceanica* assessing the number of patches, mean patch size and total cover.

Materials and Methods

Study area:

Fieldwork was carried out on the east side of Giglio Island (central Tyrrhenian Sea, Italy), inside the restricted area interested by the Concordia shipwreck (upper panel of Figure 1). The *P. oceanica* meadow settled within the area was mechanically and physically affected by the shipwreck and its removal, leading to the disappearance of 8427 m^2 of *P. oceanica,* and leaving on the seabed a dead *matte* substratum from 5 to 35 meters depth (olive green tone in the upper panel of Figure 1) [16-18].

Since the regression factors were removed and the physico-chemical parameters of the water column were re-established, a transplantation area of 2048 m^2 was selected within the 8427 m^2 of dead matte, extended from 10 to 23 meters depth and previously colonized by *P. oceanica,* to perform a large-scale restoration [20] with the methods proposed in [19].

Within the 2048 m^2, three transplantation areas (red polygons and labels A1 – A3 in the lower panel of Figure 1) were selected, for a total extension of 1149 m^2, where performing the investigation.

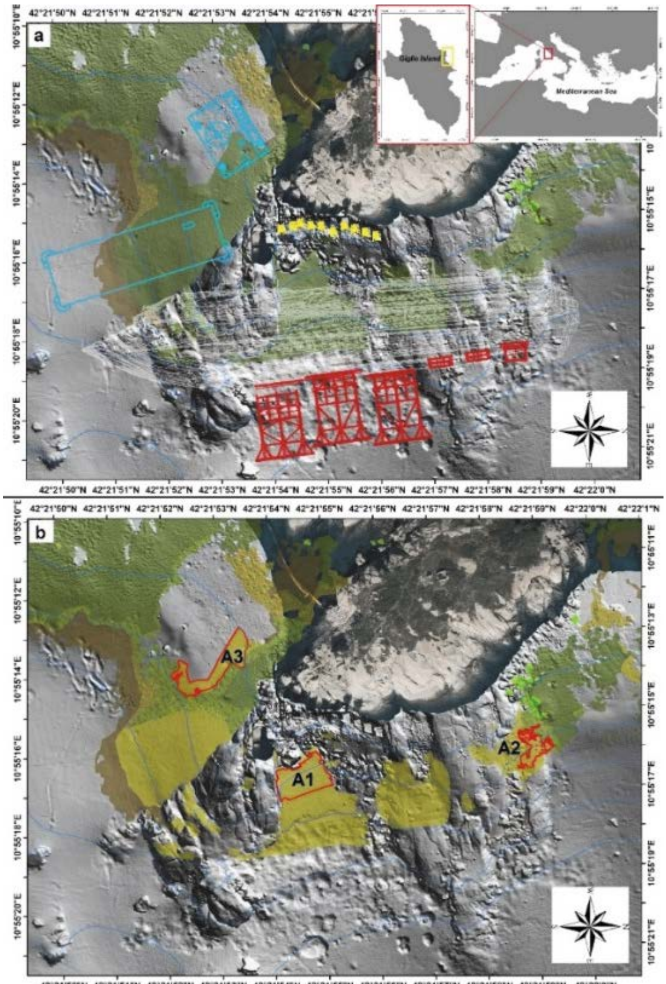

Figure 1 – Study area where the investigation was carried out. Panel **a**) Transplantation was performed within the Concordia shipwreck area. Both the 2012 shipwreck (grey outline) and its removal operations (supporting vessels in light blue, platforms in red, anchor blocks in yellow) led to the loss of a well preserved *P. oceanica* meadow (green hues). Panel **b**) The aforesaid events left on the seabed a dead *matte* substratum (olive-green colour). Three transplantation areas (red polygons and labels A1 – A3) were selected to carry out the investigation.

Photogrammetric surveys and spatial dynamic:

High resolutions (centimeter scale) underwater photomosaics were performed to assess the spatial dynamic of the newly transplanted *P. oceanica*. Photomosaics were performed in 2019, 2020, 2021 every June and October, respectively before and after the beginning of the transplantation activities, according to [14-15].

Next, the high resolution photomosaics were imported and analysed through Geographical Information System (GIS) software. The transplanted *P. oceanica* patches, represented by a single cutting if separated at least 5 cm from the surrounding fragments or aggregation of cuttings instead, were manually outlined by the freehand drawing tool in ArcGIS10.2.2 and the spatial metrics i) number of patches (NumP), ii) mean patch size (MPS) and iii) total cover (TC) were calculated in ESRI ArcMap 10.2.2 by using the Attribute Table and the Calculate area tool included in the Spatial statistic toolbox. NumP and MPS represented respectively the amount of *P. oceanica* patches and their average size (expressed in m^2), TC is defined as the sum of all the patches size (in m^2). The spatial metrics were calculated every year in all the areas from the photomosaic performed in October.

Data analysis:

MPS spatial metric, calculated separately for each transplanted area, was tested for the time effect (3 levels for area 1: 2019, 2020, 2021; 2 levels for areas 2 and 3: 2020, 2021) with Generalized Linear Models (GLM) selecting a gaussian distribution. The best models were selected according to the Akaike Information Criterion (AIC) value, and a significance level of 0.05 (P-value < 0.05) was chosen within each regression model. Data were analyzed in the R platform version 4.0.2.

Results

The three spatial metrics showed similar patterns during the study period, that is a diminution in the number of patches (NumP) in favour of their mean patch size (MPS) and total cover (TC) (Figures 2-3).

At the end of the transplantation, in October 2019, the area 1 was characterized by 2347 NumP of *P. oceanica* with a MPS ± SD of 0.0176 ± 0.0169 m^2 and a TC of 41.36 m^2. Over the study period, the NumP decreased whereas both the TC and MPS significantly increased (Table 1) showing in October 2021, after 2 years from the transplantation, 1719 NumP with a MPS of 0.0309 ± 0.0316 m^2 and a TC of 53.20 m^2 (Figure 2, panel a). Considering the ratio between TC of patches and transplanted surface, from 2019 to 2020 and from 2020 to 2021 the area 1 showed an increase respectively of +0.6 % and +1.6 % (Figure 2, panel a).

At the end of the transplanting activities, in 2020, the areas 2 and 3 were respectively characterized by 799 and 1883 NumP, 0.0263 ± 0.0185 m^2 and 0.0158 ± 0.0109 m^2 MPS, 21.06 m^2 and 29.76 m^2 of TC (Figure 2, panels b and c). After one year from the transplantation, the area 2 reduced both the NumP (695) and the total area (19.56 m^2) whereas the MPS did not significantly increase its value (0.0281 ± 0.0225 m^2) (Figure 2, panel b) (Table 1). Considering the ratio between TC of patches and transplanted surface, from 2020 to 2021 area 2 showed a diminution of -0.7 % (Figure 2, panel b).

The area 3 reduced the NumP (1717) while significantly increased both the MPS (0.0237 ± 0.0206 m^2) and the TC (40.69 m^2) (Figure 2, panel c) (Table 1). Considering the ratio between TC of patches and transplanted surface, from 2020 to 2021, area 3 showed an increase of +2.5 % (Figure 2, panel c).

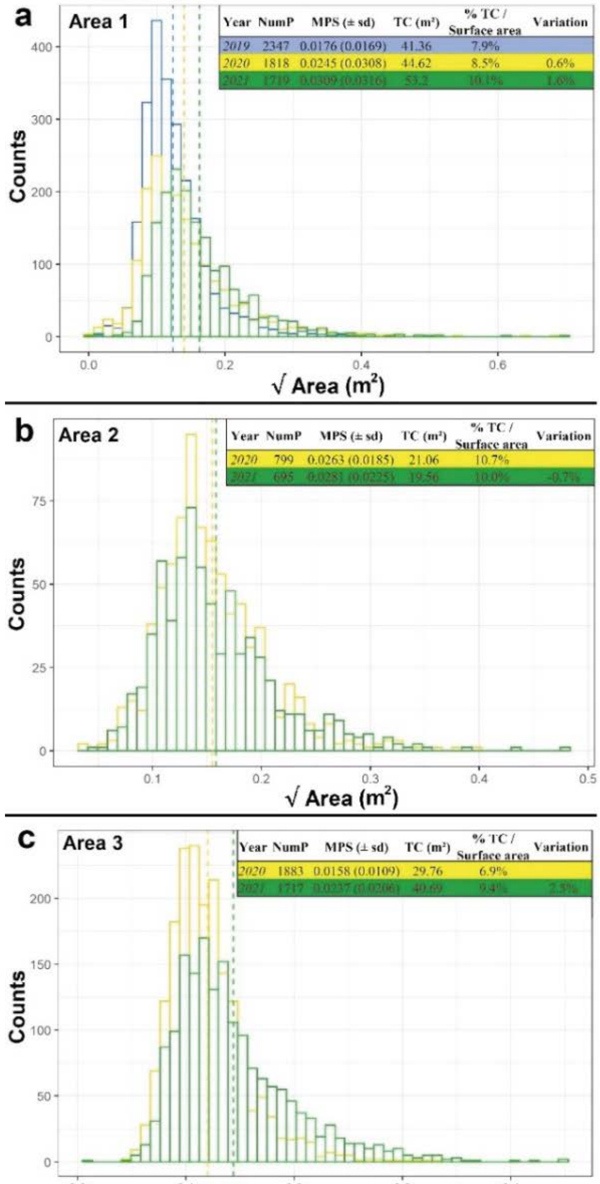

Figure 2 – Size frequency distribution for transplanted *P. oceanica* patches within the 3 areas. Spatial metrics of area 1 are reported in panel **a** (2019 in blue, 2020 yellow, 2021 green), area 2 in **b** (2020 yellow, 2021 green) and area 3 in **c** (2020 yellow, 2021 green). NumP refers to the number of patches, MPS to their mean size, TC to total cover.

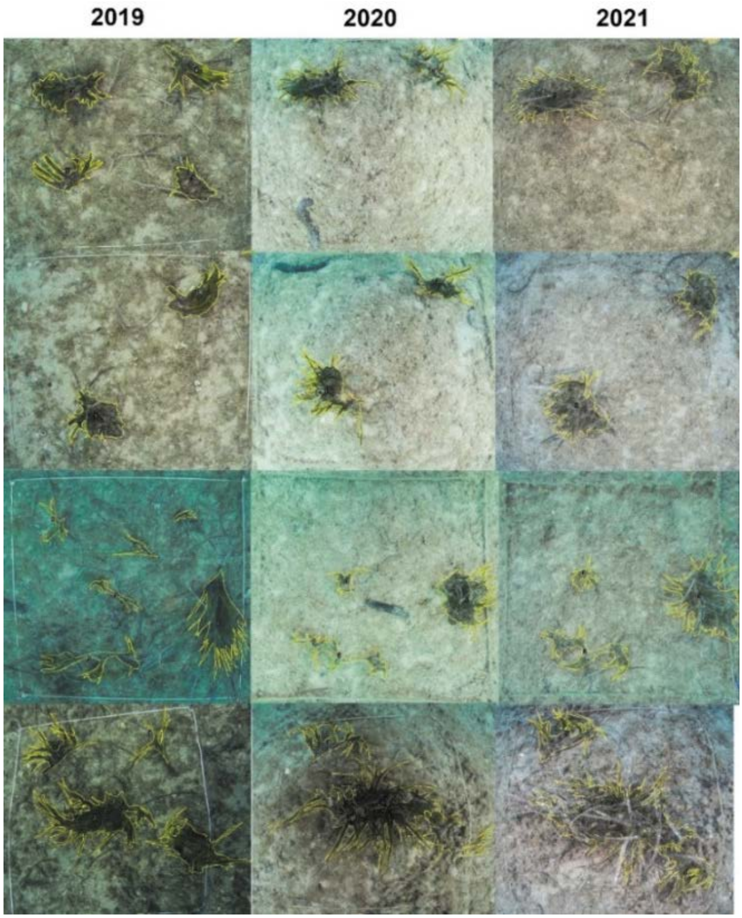

Figure 3 – Temporal evolution of transplanted *P. oceanica* patches within four fixed monitoring squares.

Table 1 – Results from the best GLM fit for mean patch size (MPS) within the 3 areas. The coefficients of effects are reported with Standard Error (SE) in the bracket. The intercept coefficient represents the estimated value in 2019 for area 1 and in 2020 for areas 2 and 3.

Mean Patch Size (MPS)

Formula: Patch size (m²) ~ Time								
AREA 1			**AREA 2**			**AREA 3**		
Effect	**Coefficient**	**P**	**Effect**	**Coefficient**	**P**	**Effect**	**Coefficient**	**P**
Intercept	0.0176 (0.0005)	***	Intercept	0.0264 (0.0007)	***	Intercept	0.0158 (0.0004)	***
Year (2020)	0.0069 (0.0008)	***	Year (2021)	0.0018 (0.0011)	n.s.	Year (2021)	0.0079 (0.0005)	***
Year (2021)	0.0133 (0.0008)	***						
AIC: -26025			**AIC**: -7369.5			**AIC**: -19414		

*Significant codes: ***P < 0.001; **P < 0.01; *P < 0.05; n.s. P > 0.05*

Discussion

The Costa Concordia shipwreck and its salvaging traumatically affected the *P. oceanica* meadow established within the wreck area, leading to its regression [16-18]. After the wreck removal and the cleaning operations, any source of disturbance linked to the phanerogam disappearance was eliminated and the regression ceased. Thus, once re-established the natural environmental features required for the seagrass's survival and growth, an experimental investigation was carried out focused on a *P. oceanica* transplantation and aimed at designing new strategies concerning seagrass restoration. The experimental outcomes proved that the impacted area was suitable for a larger scale restoration and highlighted the feasibility in using planting material produced by boat anchoring or storms (not requiring a donor site and the consequent damage) fixed with chemo-degradable iron stakes [19]. This evidence laid the basis for a restoration upscaling to speed up the recovery of the *P. oceanica* meadow lost after the Concordia shipwrecking [20]. The outcomes confirmed that our protocol could be efficiently applied at larger scales, showing diminutions in cuttings' survival and shoot density over the first year, followed by stability in the number of living cuttings and increases of leaf bundles.

Despite the expansion rates of several transplanted seagrasses are known, such as *Posidonia australis* [21], *Halodule wrigthii* [22-23], *Zoostera marina, Z. noltii* and *Cymodocea nodosa* [24], quantitative data regarding *P. oceanica* are still lacking.

The present study, although performed over a short-term period, gave new insights on the dynamic of transplanted *P. oceanica*. Despite *P. oceanica* is a slow-growth species, in our study we observed an expansion process occurring in the transplanted patches in the first year. During the study period, the number of patches diminished (especially the smallest ones) in favour of their mean size and total cover. During the first year, we observed an expansion rate ranging from +0.6 % (within area 1) to +2.5 % (in area 3), although a reduction of -0.7 % was also highlighted (in area 2). The natural progression rate of a *P. oceanica* meadow margin owing to plagiotropic rhizomes is estimated to be +2.5 % each year [4]. Hence, the progression rates highlighted in our study were in line with those observed for the re-colonization of natural *P. oceanica*. Under suitable environmental conditions for the survival and growth, especially on dead *matte*, *P. oceanica* (both natural and transplanted) can re-colonize all the bare substratum by the progression of its plagiotropic rhizomes. The colonization-predisposition of transplanted *P. oceanica* was also highlighted by [12] and [19] through the higher primary production and leaves growth of the transplanted plants if compared with the data coming from the natural plants.

Despite this first evidence, a longer monitoring period, at least 5 years, could give more robust and concrete outcomes, also considering the slow rhizome elongation rates of *P. oceanica*. A longer time period may also allow detection of potential scenarios of seagrass dynamics not highlighted in shorter-term studies such as increase or decrease in the transplanted seagrass cover [22]. Furthermore, data on spatial patterns of expansion deriving from lengthened surveys may also be used for developing statistical models useful for predictions of longer-term growth patterns [22].

Regarding the application of non-destructive monitoring methods, the use of high-spatial-resolution underwater photomosaics let the scientist study the structural dynamics of the transplanted *P. oceanica* over vast areas. Applying this rapid, efficient, and low-cost technique to seagrass restoration management could assist during the transplantation activities and could give, over time, new insights into both the colonization processes and the spatial dynamics of transplants. Hence, considering the knowledge gaps in transplanted seagrass dynamic and that the restoration efforts are growing worldwide, the transplants spatial dynamic merits inclusion in metrics of newly created habitat to be investigated and monitored over time.

Lastly, this study adds a further contribution to seagrass restoration techniques as expected for the “UN Decade on Ecosystem Restoration” and the EU biodiversity Strategy for 2030, aiming at restoring ecosystems across land and sea, especially those with considerable value in terms of goods and services such as seagrasses [25].

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FIRST INVESTIGATION OF PER-AND POLY FLUOROALKYLSUBSTANCES (PFAS) IN STRIPED DOLPHIN *STENELLA COERULEOALBA* STRANDED ALONG TUSCANY COAST (NORTH WESTERN MEDITERRANEAN SEA)

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Abstract – Per- and poly fluoroalkylsubstances (PFAS) were measured in liver, muscle, blood and brain of 26 striped dolphins *Stenella coeruleoalba* stranded along Tuscany coasts (Italy, North Western Mediterranean Sea) from 2020 to 2022. Dolphins were collected thank to the Regional networking group. Morphometric parameters total length, weight, sex, age were collected when possible and also the condition of the stranded specimens and exact localization of stranding. Using high performance liquid chromatography coupled with high resolution mass spectrometry 18 target PFAS, including perfluoroalkyl-carboxylates (PFCA), -sulfonates (PFSA) and –sulfonamides (FASA), were quantified in each sample. Moreover, a suspect screening on the full scan analysis was carried out for identification of non-target PFAS. PFOS, PFHxS and FOSA were found in all samples with PFOS blood concentration level ranging from some tens to hundreds ppbs. The concentrations follow the trend PFOS>FOSA>PFHxS and the PFOS concentration appears to be inversely proportional to the weight of the animals, as reported in the most recent literature. No significant differences between sexes were registered.

The PFOS/FOSA blood concentration ratio has a threshold at about 20 kg, with two distinct numerical intervals related to the age of the animals (younger or older than 1 yr). PFNA, PFDA and PFUnDA are the PFCA with the highest concentrations in analysed samples, reaching with maximum concentrations of tens of µg/kg.

The presence of these high concern substances in striped dolphins underlines a remarkable impact of anthropic activities on wildlife, and prompts further researches about the impact of PFAS on marine mammal conservation and health.

Introduction

The striped dolphin (*Stenella coeruleoalba*) is the most common cetacean in the Mediterranean Sea and the most representative species of the continental slope of this semi-closed basin. For this reason there is a high frequency of strandings of this species along Italian coasts [14]. Sampling stranded specimens it has been possible to investigate levels of contaminants of different types and to carry out studies to assess health status of Mediterranean striped dolphin [10].

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Per- and poly fluoroalkylsubstances (PFAS) are a group of organic molecules synthetically produced and used in a wide range of commercial and industrial applications. Two well-studied groups include the perfluoroalkyl sulfonates (PFSA) and perfluoroalkyl carboxylates (PFCA). Perfluorooctanesulfonic acid (PFOS) is the most known PFAS. Due to its toxicity and bioaccumulability, in May 2009, PFOS and its related compounds were added to the Annex B "Restriction" of the Stockholm Convention on Persistent Organic Pollutants and they were also included in the list of priority hazardous substances which must be monitored in EU water bodies, including transitional and coastal waters, according to EQS Directive (2013/39/EU).

Global distribution of PFAS in waters [12] and in aquatic organisms [7,6], have been documented in many studies, demonstrating their persistence in the environment and their bioaccumulation and biomagnification. According to the scenario reported above, PFAS represent emerging chemicals that are of environmental concern for marine mammals [3]. At the same time, marine mammals share the coastal environment with humans and consume similar food, thus they may also serve as indicators for environmental change and ecosystem health [13]. Moreover, factors controlling the bioaccumulation and tissue distribution of different PFASs are not fully understood. Two mechanisms for PFAS accumulation have been proposed: partitioning to phospholipids and binding to specific proteins. The study of the bioaccumulation in multiple organ tissues characterised by different phospholipid and protein content can help to better understand factors affecting PFAS accumulation and partitioning among tissues [5].

In this study, we investigated the PFAS occurrence in 4 tissues (liver, blood, muscle and brain) of striped dolphins (*Stenella coeruleoalba*, Meyen 1833) of different ages stranded along Tuscany coast between 2020 and 2022.

Materials and Methods

Tissue samples (blood, liver, brain, and muscle) were sampled from stranded striped dolphins along Tuscany coasts during 2020 and 2022.

For each specimen, date, exact localization of stranding, status of conservation of the dolphin and, when possible, total length, weight and sex were recorded. Stranded animals were classified into 5 categories on the degree of post-mortem autolysis: 1. live stranded and subsequently died on the beach; 2. fresh carcass, no external signs of decomposition; 3. early signs of decomposition (skin decolouration, sloughing); 4. strong decomposition; 5. mummification. No animals beyond code 4 were analysed. Tissue sampling was conducted during the pathological examination. If not registered, weight was estimated according to exponential curve specifically created for this species ($W=2.1839 \exp 0.0175 L$; $R^2=0.95$) with data recorded in Tuscany. Age was assigned according to Marsili et al. [10]. Individuals below 16 months and less than 20 kg weight were considered unweaned. All the sample were stored frozen at -20 °C until the chemical analysis.

Samples of striped dolphin's tissue were extracted by QuEChERS protocol, and the extracts were analysed by ultra-high performance liquid chromatography coupled with high resolution mass spectrometry (UHPLC-HRMS Thermo Fisher Scientific Orbitrap, Waltham, MS, USA).

The whole method used in ARPAT-AVL Laboratory is accredited according to UNI EN ISO 17025 [11] for analysis of PFOS in whole fish. 2 g test portion of frozen tissue was put in a 50 ml glass tube with a glass stopper and spiked with a 100 µl solution of PFAC-ILS at 200 ng/ml. The tubes were allowed to stand overnight at -18 °C. The next day, one ceramic homogenizer was introduced and, subsequently, 10.0 mL of water and 10.0 mL of acetonitrile were added in two separate steps. Then a QuEChERS pouche was added and the tube was stirring again in the same mode and centrifuged at 3500 rpm for 10 minutes. Surnatant was transferred in a polypropylene tube and stored overnight at -20 ºC. The frozen mixture was centrifuged at 10000 rpm for 5 minutes at -10 ºC (SL Plus series Centrifuge, Thermo Fisher, Waltham, MS, USA) and, finally, 1 ml of the surnatant was put in a polypropylene vial suitable for direct injection in LC-MS analysis. 18 target PFAS (perfluorobutanoate PFBA, perfluoropentanoate PFPeA, perfluorohexanoate PFHxA, perfluoroheptanoate PFHpA, perfluorooctanoate PFOA, perfluorononanoate PFNA, perfluorodecanoate PFDA, perfluoroundecanoate PFUnDA, perfluorododecanoate PFDoDA, perfluorotridecanoate PFTrDA, perfluorotetradecanoate PFTeDA, perfluorobutansulfonate PFBS, perfluoro-pentanesulfonate PFPeS, perfluorohexanesulfonate PFHxS, perfluoropentanesulfonate PFHpS, PFOS, perfluorohexanesulfonate PFDS, perfluorooctane sulfonamide FOSA) were quantified.

Data acquisition and analysis was performed by Xcalibur software platform (Thermo Fisher, Waltham, MS, USA). The PFAS compounds were identified by full scan mode (FS) and retention time matching with the calibration standards. A further confirmation was performed by parallel reaction monitoring (PRM). The concentration of each PFAS was determined using the response ratio of the PFAS quantitation ion to that of the relevant labelled. Analytes lacking an analogous labelled standard were quantified using the internal standard with the closest retention time. HRMS raw files were also processed using Compound Discoverer 3.1 (Thermo Scientific, USA) in order to identify the presence of non-target PFAS by comparison with the PFAS lists submitted to the NORMAN Suspect List Exchange Database.

Results & Discussion

Twenty-six striped dolphins (16 females, 9 males and 1 not identified) stranded along Tuscany coasts during the period 2020-2022 were dissected to analyse PFAS content in the different tissues (Tab. 1). Total lengths ranged from 91.5 to 216 cm, registered weight from 9 to 89 kg, and age of specimens from 6 months to 22 years. The stomach content was scrutinized for 23 dolphin specimens in order to classify the unweaned (RT144, 158, 159, 162, 170) because their stomach was completely empty.

PFAS concentrations and profiles in the tissues of stranded striped dolphins are summarized in Figures 2 and 3. Among the 18 target PFAS analysed in the present work and the 2 confirmed suspects, PFBA, PFPeA, PFHxA, PFBS, PFPeS and PFDS were always below detection limits and are excluded by any further discussion, while PFNA, PFDA, PFUnDA, PFHxS, PFOS, perfluorobutane sulfonamide FBSA, perfluorohexane sulfonamide FHxSA and FOSA were found in all samples.

Table 1 – Specimen detail of the stranded striped dolphins analysed in this study; ID= code of the animal, TL=total length cm, W=weight kg, F=female, M=male. *weight estimation.

ID	Year	Stranding site	TL	W	Sex	Age
RT144Sc	2020	Forte dei Marmi (LU)	114	14.8	F	1
RT149Sc	2020	M. del Boccale (LI)	195	70	F	12
RT150Sc	2020	M. del Boccale (LI)	120	25	F	1
RT151Sc	2020	Calambrone (PI)	210	86*	F	18
RT152Sc	2020	Rio Marina (LI)	199	62	F	13
RT154Sc	2020	M.Grosseto (GR)	192	74	F	11
RT156Sc	2020	Capoliveri (LI)	200	84	M	14
RT157Sc	2020	Rosignano (LI)	216	89	M	22
RT158Sc	2020	Porto Azzurro	100	9.5	F	8 months
RT159Sc	2020	Porto Azzurro	91.5	9	F	6 months
RT160Sc	2020	Capoliveri (LI)	191	65.2	F	11
RT161Sc	2020	Piombino (LI)	205	72	F	16
RT162Sc	2020	Camaiore (LU)	103	13	M	9 months
RT164Sc	2020	Campo nell'Elba	197	54	M	13
RT165Sc	2020	Capalbio (GR)	190	60*		10
RT166SC	2021	Lacona (LI)	204	77*	F	15
RT167Sc	2021	Portoferraio (LI)	149	32.2	F	14
RT169Sc	2021	Bibbona (LI)	163	47.6	M	14
RT170Sc	2021	Castag. Carducci (LI)	112	18	M	3
RT171Sc	2021	Pisa (PI)	193	62.3	M	9
RT175Sc	2021	Pisa (PI)	204	67	F	4
RT177Sc	2021	Forte dei Marmi (LU)	200	71.9	F	n/a
RT178Sc	2021	Piombino (LI)	200	68.5	M	n/a
RT181Sc	2021	Capoliveri (LI)	148	29*	M	n/a
RT187Sc	2021	Roccamare (GR)	183	68.3	F	n/a
RT188Sc	2022	Rocchette (GR)	152	30.6	F	n/a

The PFAS profile in liver, blood and muscle showed a similar pattern (Figure 3) and was generally composed of the same six dominant PFAS: PFOS>FOSA>PFNA>PFUnDA>PFTrDA>PFDA. Otherwise, PFTrDA was detected at higher concentrations than PFOS in brain with a different PFAS profile: PFTrDA>PFOS>PFTeDA>PFUnDA>FOSA>PFDoDA. PFCA in blood and muscle tissue showed a clear pattern with higher concentrations of the odd-chained PFCA than either the next and the previous even-chained PFCA supporting the hypothesis that the degradation of atmospheric polyfluorinated precursors is a relevant source for PFCA in the marine environment [8]. Suspect screening analysis allowed identifying 2 novel FBSA and FHxSA) in all the analysed tissues. Only few studies reported these compounds in biota. FBSA has previously been detected in fish tissues [4,1], FBSA and FHxSA in the blood serum of turtles [2] and to our knowledge, this is the first study to report FBSA and FHxSA in cetacean tissues. FOSA was the most abundant perfluorosulfonamide followed by FHxSA and FBSA in all the tissues.

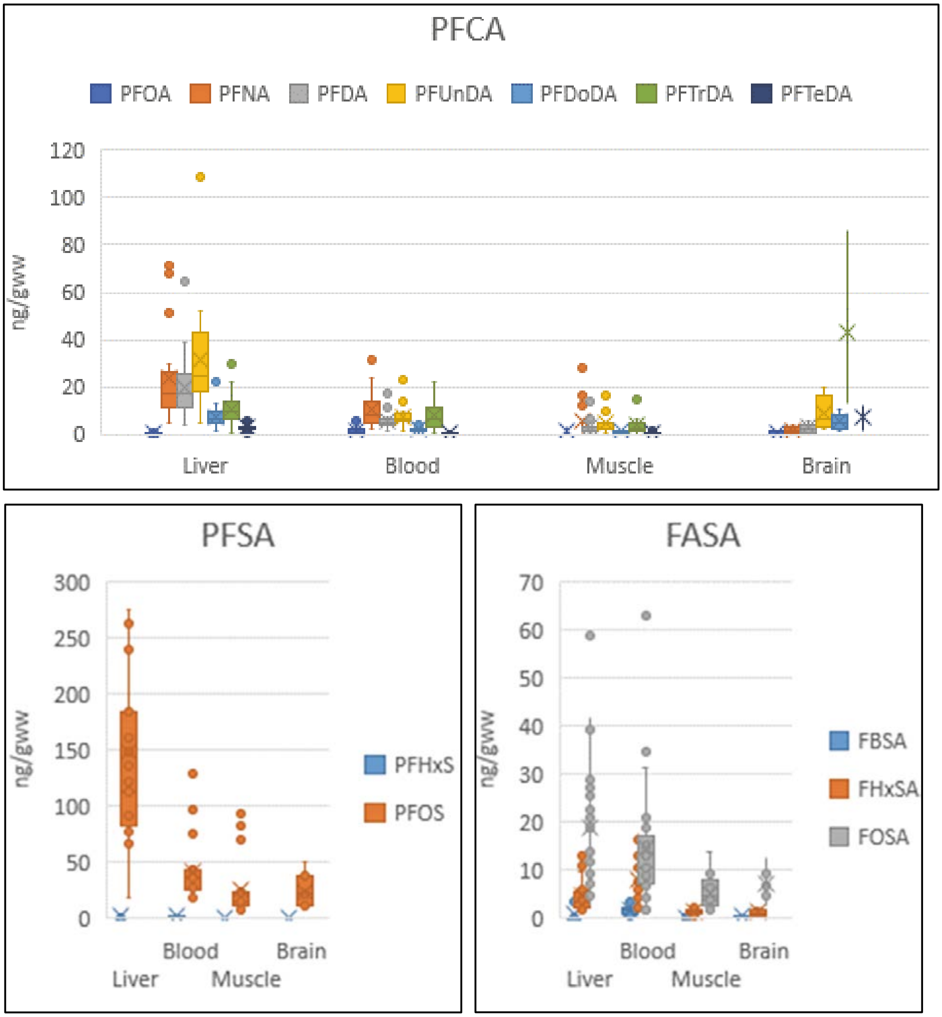

Figure 2 – Concentration of the PFAS detected above LOQ in the tissue of stranded striped dolphins.

ΣFASA concentrations were slightly lower than corresponding-tissue ΣPFCA and ΣPFSA ranging from 1.8 to 77 ng/g wet weight (ww). PFOS concentration level ranged from 4.2 ng/g ww in a muscle sample to 501 ng/g ww in a liver sample. PFTrDA ranged from 13 to 87 ng/g ww in the brain of the analysed striped dolphins.

No differences between sexes for all the investigated compounds and the total PFAS concentrations were evidenced.

Few studies have investigated the contamination by PFAS in cetacean specimens of the Mediterranean Sea. Kannan et al. [8] measured PFOS levels in livers of striped dolphins stranded in North Tyrrhenian Sea and South Adriatic Sea in 1991 and Lopez-Berenguer et al. [9] measured the content of PFCA and PFSA in liver and muscle samples of stranded striped dolphins in the south-eastern coast of Spain during the period 2009-2018. The median of PFOS concentrations measured in liver tissue collected from stranded dead animals along the coasts of Tuscany in this study (37 ng/g ww, N=23) was similar to the level measured in 1991 (22 ng/g ww, N=1) [8] and 3.5 times lower than the median value measured in the western Mediterranean sea in 2009-2018 (118 ng/g ww, N=29) [5]. However, currently a clear geographical comparison is difficult since other PFAS in the liver of the stranded dolphins in the coastline of Spain [9] confirm higher contamination of the Spanish specimens than the Italian ones but the PFAS levels in muscle tissue of the Italian and Spanish striped dolphins were very similar.

Though there are only few data and have to be confirmed with further monitoring data, however we might conclude that no decreasing trend in PFOS or PFOS-precursor occurrence has happened since 1990s, but a difference between the Western and the Eastern basins of the Mediterranean sea in PFAS sources and occurrence is likely present.

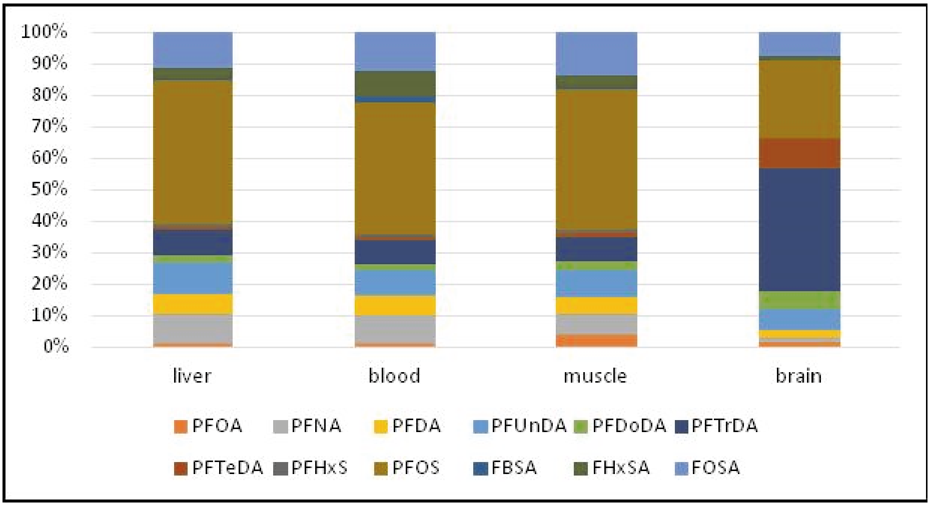

Figure 3 – Percentage distribution pattern of the median concentration of the PFAS detected above LOQ in the tissue of stranded striped dolphins.

The PFSA and PFCA concentrations in calves were significantly higher than in older individuals. This pattern, already detected in other cetacean monitoring study [13], can be explained by multiple processes: the maternal transfer of PFAS from the mother to the offspring or a marked difference in diet composition between the calves and adults. Calves with less than 16 months mainly feed on their mothers' milk [9], so the maternal transfer by lactation can cause a higher PFAS body burden in calves while, as they grow, they feed on various preys of different trophic levels. Furthermore, an increasing ability of metabolism and elimination of PFAS in juvenile and adult dolphins or a grow dilution effect cannot be excluded. Otherwise, no significant differences were found between adults and calves for perfluorosulfonamides but sulfonamides are the only neutral compounds considered in the present study which are known to have different distribution mechanisms in the organism respect to the ionic PFAS.

Unlike most legacy POPs, PFAS do not follow lipophilic pathways. They bind to blood proteins and through the bloodstream they displace to different tissues according to their affinity for the tissue constituents (phospholipids or/and specific proteins) and their capacity to pass the blood/tissue barriers. Both the functional group and carbon-chain length can affect the PFAS distribution. Moreover, structural proteins and storage lipids could also act as significant sorption compartments for neutral or semi-neutral PFAS. The propensity of the various PFAS in distributing in the different tissues can be assessed by calculating tissue/blood ratios (Figure 4).

The muscle-blood ratios (Figure 4, left) were generally below one for most of the dolphin indicating a low affinity of all the PFAS for the muscle tissue. Part of the PFAS detected in muscle can be due to the blood embedded into the muscle fibres. However, there is a weak but significant correlation ($y = 0.05x - 0.13$; $R^2 = 0.81$) between the median of the muscle-blood ratios and the number of fluorinated carbon atoms for all the PFAS homologues and groups, except PFOA. This indicates a slightly higher muscle accumulation of the long-chain PFAS than of the short-chain ones, probably due to the affinity of the fluorinated tail with the membrane phospholipid bilayer.

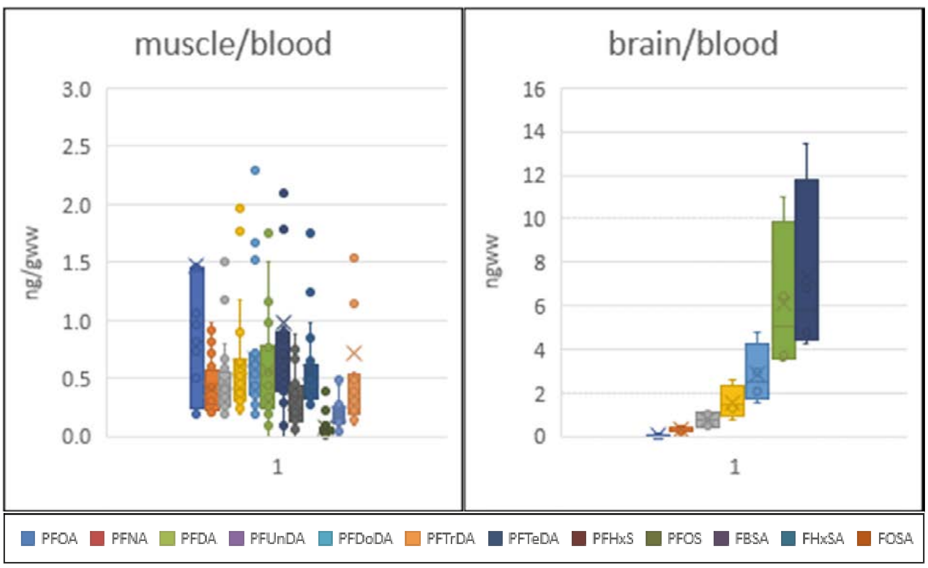

Figure 4 – Muscle-blood and brain-blood ratios of the concentration of PFAS detected above LOQ in the stranded striped dolphins.

The calculated PFAS brain-blood ratios increased with chain length (Figure 4, right), and PFCA (>C9) showed brain-blood ratios higher than one and up to 13 for PFTeDA, the longest congener. This trend is consistent with most of the published data for wildlife species. The long-chain PFAS may cross cerebral barriers more effectively than short-chain PFAS and in addition they have stronger association with phospholipids that can enhance the bioaccumulation in phospholipids rich tissue such as the brain [2].

The liver contains high concentrations of fatty acid-binding protein that may also bind PFAS; moreover, the liver is the primary site of metabolism, and elevated levels of PFCA and PFCA in this tissue may represent a high level of exposure to precursor compounds. Unlike muscle and brain, the liver-blood ratios were extremely variable depending on the specific compound. The liver-blood ratio was always above one for PFCA except for PFOA. PFHxS and FOSA have ratios around the value of one and sulfonamides showed a clear increase of the liver-blood ratio according to the chain length. It has been hypothesized that cetaceans may lack totally or partially the ability of transforming PFAS precursors such as FOSA to PFOS within their tissues because generally they have the FOSA levels of the same order or even higher than those of PFOS [9]. On the contrary, the FOSA/PFOS ratios calculated in the present study were generally around 0.25, indicating lower concentrations of FOSA than PFOS for all tissues and suggesting a biological degradation within the liver followed by a redistribution of the PFOS into the other tissues. An opposite behaviour is instead detected for FHxSA: the FHxSA/PFHxS ratios were above the value of one with median values >4.5 for all the tissue, and FHxSA reached the highest concentrations in blood tissue. This finding suggests for this semi-neutral precursor a slow rate of metabolic transformation, and accumulation into bloodstream of the striped dolphin.

Conclusions

The study of the accumulation of hazardous substances in stranded mammals can help to understand the health status of individuals and their behaviour. It is evident from the present study that longer PFAS accumulate in the different tissues, with a similar distribution pattern in liver, blood and muscle, but different from that found in brain, where the longest perfluoroalkylcarboxylates prevail. The highest concentrations have been determined in liver, where the precursors partially undergo oxidation to perfluoroalkylacids.

The PFSA and PFCA concentrations in calves were significantly higher than in the older individuals. This behaviour is in contrast to what is only due to bioaccumulation and biomagnification through preys but it might be attributed to the maternal transfer of PFAS during the pregnancy period or the following lactation, showing that younger and more vulnerable individuals are subject to a higher pressure by these very persistent compounds.

The presence of these high concern substances in striped dolphins underlines a remarkable impact of anthropic activities on wildlife, and prompts further researches about the impact of PFAS on marine mammal conservation and health.

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STOMACH CONTENTS OF BOTTLENOSE DOLPHIN *TURSIOPS TRUNCATUS* (MONTAGU, 1821): FIRST RESULTS FROM SPECIMENS STRANDED IN THE TUSCAN ARCHIPELAGO IN THE PERIOD 1990–2021

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Abstract – Bottlenose dolphin is one of the most frequently observed cetaceans in the Mediterranean. The diet of *Tursiops truncatus* (Cetacea: Odontoceti) consists on a variety of prey, including fishes, cephalopods, and occasionally crustaceans. The first data of stomachs contents of thirty-five *T. truncatus* stranded in Tuscany coasts, north-western Mediterranean, between 1990 and August 2021, are presented. The results show an abundant and frequent presence of Osteichthyes, compared to cephalopods. European hake, conger eel, Sparidae and Octopodidae results to be important prey not only for bottlenose dolphins but also species of commercial interest.

Introduction

Bottlenose dolphin *Tursiops truncatus* (Montagu, 1821) is a cosmopolitan species; it is found in all tropical and temperate coastal waters of the world [7]. The bottlenose dolphins in the Mediterranean Sea mainly shows coastal habits [6,9], which often lead it to interact with fishing activities, such as opportunistic feeding from set nets. The diet of *T. truncatus* consists on a variety of prey, including fishes, cephalopods, and occasionally crustaceans [1]. The trophic spectrum of bottlenose dolphin in the Mediterranean Sea is mainly composed on a great variety of demersal and pelagic preys [3,8,10,13,16] including species of commercial value, such as *Merluccius merluccius* (Linnaeus, 1758) and octopus species. The most widely used technique for evaluating cetacean diet is the stomach content analysis [11] of stranded animals.

In this study, first data on the diet of specimens of *T. truncatus* stranded in Tuscany, north-western Mediterranean, are provided.

Stranding of bottlenose is a rather common event along Tuscany coasts: a total of 207 bottlenose dolphins were found stranded in Tuscany between February 1990 and August 2021, showing and increasing trend with a peak mortality in summer months (ARPAT, unpublished data). This temporal trend is not referred probably to a real increase in mortality for this species but to the increasing monitoring, thanks to the efforts and coordination by

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Regional Agency for Environmental Protection (ARPAT) as stated by Regional Regulation LR 30/2015[1] and the consequent establishment of the Observatory for Biodiversity in Tuscany.

Therefore, the stranded individuals are a unique opportunity to collect data aimed at increasing the biology and ecology of this species, including is dietary habits and trophic spectrum.

Materials and Methods

The bottlenose dolphins examined come from a stomachs collection of forty-seven individuals (20 males and 27 females) stranded along the Tuscany coasts between 1990 and August 2021 and collected by the Regional Agency for Environmental Protection of Tuscany (ARPAT, Livorno, Italy).

After dissection, the collected stomachs were frozen at -20 °C. They were successively de-frozen and their content, after being washed in a sieve with 0.3 mm of mesh, was preserved in a solution of 75 % ethanol. The stomach content analysis was performed under stereoscope. The identification of preys was carried out using specific guides [4,15] and comparing the undigested remains, e.g. otoliths for bony fishes and beaks for mollusk cephalopods, with collections of original samples; the preys were identified at the lowest possible taxonomic level.

The contribution of each prey item (e.g. species of higher Taxa) to the food spectrum was assessed as percentage of abundance (%N, e.g. its contribution to the total number of preys) and percentage of frequency (%F), that is the percentage of stomachs in which at least one individual of a given prey item was found.

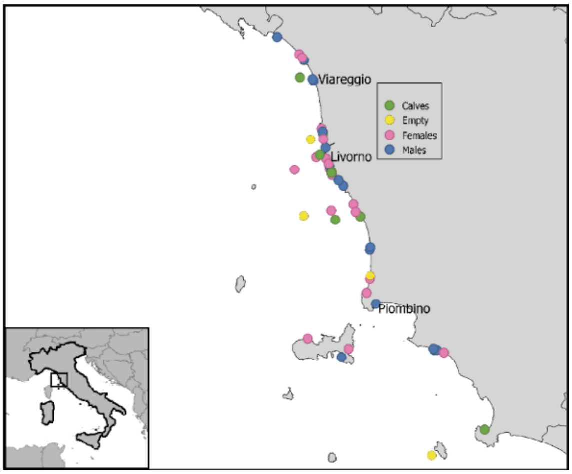

Figure 1 – Locations of the sites of *T. truncatus* strandings.

[1] *Legge regionale 19 marzo 2015, n. 30. Norme per la conservazione e la valorizzazione del patrimonio naturalistico-ambientale regionale. Modifiche alla l.r. 24/1994, alla l.r. 65/1997, alla l.r. 24/2000 ed alla l.r. 10/2010.*

Results

After the analysis of stomach contents of 47 collected samples, thirty-five *T. truncatus* stomachs (17 males and 18 females) showed some food remain, while the other stomachs were empty or belonged to calves nursed by the mother (Figure 1).

Table 1 shows the list of preys found in the stomachs analysed, with the relative data of abundance and frequency. Overall, a total of 2792 prey items (belonging to 76 taxa) were identified as 2358 fishes (58 taxa) and 434 cephalopods (18 taxa). Osteichthyes resulted the most abundant and frequent preys with a numerical abundance percentage (%N) of 84.5 % and a percentage frequency (%F) of 97.1 %. Cephalopods were less abundant than fishes (%N=15.5), while their frequency was high (%F=74.3). The results obtained show that European hake, *M. merluccius* (%N=21.9), and the conger eel, *C. conger* (12.4 %), were the most abundant species, while the snake blenny, *O. barbatum* (6.8 %), the annular sea bream. *D. annularis* (5.1 %), and the common Pandora, *P. erythrinus* (3.9 %), were fishes of secondary importance, in terms of numerical abundance (Table 1). The most abundant cephalopods were the broadtail shortfin squid, *I. coindetii* (4.7 %), followed by the horned octopus, *E. cirrhosa* (3.2 %), and the common octopus, *O. vulgaris* (2.3 %). As shown in Table 1, *C. conger* was the most frequent prey (80.0 %), while *M. merluccius* was present in half of the dolphins examined (48.6 %); other species, e.g. *D. annularis, P. erythrinus* and *I. coindetii* have a frequency of occurrence of 45.7 % each one. At level of Families, Congridae (%N=13.1; %F=82.9), Merlucciidae (%N=21.9; %F=48.6) and Sparidae (%N=11.0; %F=65.7) were the most important for bony fishes, while Octopodidae (%N=7.0; %F=42.9) and Ommastrephidae (%N=4.7; %F=45.7) were the most important for cephalopods (Figure 2).

Table 1 – List of preys found in *T. truncatus* from the Tuscany area (western Mediterranean Sea). For each prey item: N, number of preys; %N, percentage in number (* = < 0.1); F, number of occurrence; %F, frequency of occurrence in percentage.

	N	%N	F	%F
OSTEICHTHYES				
Argentinidae	2	0.1	1	2.9
Argentina sphyraena Linnaeus, 1758	2	0.1	1	2.9
Atherinidae	2	0.1	1	2.9
Atherina boyeri Risso, 1810	2	0.1	1	2.9
Bothidae	5	0.2	3	8.6
Arnoglossus sp. Bleeker, 1862	4	0.1	2	5.7
Bothus podas (Delaroche, 1809)	1	*	1	2.9
Callionymidae	4	0.1	2	5.7
Callionymus risso Lesueur, 1814	1	*	1	2.9
Callionymus sp. Linnaeus, 1758	3	0.1	1	2.9
Carangidae	119	4.3	11	31.4
Trachurus mediterraneus (Steindachner, 1868)	64	2.3	8	22.9
Trachurus sp. Rafinesque, 1810	55	2.0	4	11.4
Carapidae	4	0.1	1	2.9
Carapidae unidentified	4	0.1	1	2.9

	N	%N	F	%F
Centracanthidae	44	1.6	11	31.4
Spicara flexuosa Rafinesque, 1810	26	0.9	8	22.9
Spicara maena (Linnaeus, 1758)	2	0.1	1	2.9
Spicara smaris (Linnaeus, 1758)	16	0.6	4	11.4
Cepolidae	1	*	1	2.9
Cepola macrophthalma (Linnaeus, 1758)	1	*	1	2.9
Citharidae	6	0.2	3	8.6
Citharus linguatula (Linnaeus, 1758)	6	0.2	3	8.6
Clupeidae	102	3.7	11	31.4
Sardina pilchardus (Walbaum, 1792)	87	3.1	4	11.4
Sardinella aurita Valenciennes, 1847	3	0.1	2	5.7
Clupeidae unidentified	12	0.4	6	17.1
Congridae	366	13.1	29	82.9
Ariosoma balearicum (Delaroche, 1809)	11	0.4	6	17.1
Conger conger (Linnaeus, 1758)	345	12.4	28	80.0
Gnathophis mystax (Delaroche, 1809)	10	0.4	3	8.6
Engraulidae	47	1.7	10	28.6
Engraulis encrasicolus (Linnaeus, 1758)	47	1.7	10	28.6
Gadidae	87	3.1	10	28.6
Micromesistius poutassou (Risso, 1827)	1	*	1	2.9
Trisopterus capelanus (Lacepède, 1800)	86	3.1	10	28.6
Gobiidae	164	5.9	20	57.1
Lesueurigobius sp. Whitley, 1950	32	1.1	11	31.4
Gobius niger Linnaeus, 1758	92	3.3	11	31.4
Gobius spp. Linnaeus, 1758	8	0.3	3	8.6
Gobiidae unidentified	32	1.1	1	2.9
Haemulidae	1	*	1	2.9
Pomadasys incisus (Bowdich, 1825)	1	*	1	2.9
Merlucciidae	612	21.9	17	48.6
Merluccius merluccius (Linnaeus, 1758)	612	21.9	17	48.6
Moronidae	1	*	1	2.9
Dicentrarchus labrax (Linnaeus, 1758)	1	*	1	2.9
Mugilidae	36	1.3	11	31.4
Chelon ramada (Risso, 1827)	15	0.5	4	11.4
Mugilidae unidentified	21	0.8	7	20.0
Mullidae	66	2.4	8	22.9
Mullus barbatus Linnaeus, 1758	1	*	1	2.9
Mullus sp. Linnaeus, 1758	65	2.3	7	20.0
Ophidiidae	191	6.8	13	37.1
Ophidion barbatum Linnaeus, 1758	191	6.8	13	37.1
Phycidae	12	0.4	1	2.9
Phycis sp. Walbaum, 1792	12	0.4	1	2.9
Sciaenidae	12	0.4	2	5.7
Umbrina cirrosa (Linnaeus, 1758)	12	0.4	2	5.7

	N	%N	F	%F
Scombridae	2	0.1	1	2.9
Scomber sp. Linnaeus, 1758	2	0.1	1	2.9
Serranidae	13	0.5	5	14.3
Serranus cabrilla (Linnaeus, 1758)	1	*	1	2.9
Serranus sp. Cuvier, 1816	12	0.4	4	11.4
Soleidae	3	0.1	3	8.6
Solea solea (Linnaeus, 1758)	1	*	1	2.9
Solea sp. Quensel, 1806	1	*	1	2.9
Soleidae unidentified	1	*	1	2.9
Sparidae	308	11.0	23	65.7
Boops boops (Linnaeus, 1758)	23	0.8	6	17.1
Dentex dentex (Linnaeus, 1758)	1	*	1	2.9
Diplodus annularis (Linnaeus, 1758)	143	5.1	16	45.7
Diplodus vulgaris (Geoffroy Saint-Hilaire, 1817)	5	0.2	2	5.7
Lithognathus mormyrus (Linnaeus, 1758)	16	0.6	1	2.9
Pagellus acarne (Risso, 1827)	1	*	1	2.9
Pagellus erythrinus (Linnaeus, 1758)	110	3.9	16	45.7
Sparus aurata Linnaeus, 1758	8	0.3	2	5.7
Spondyliosoma cantharus (Linnaeus, 1758)	1	*	1	2.9
Sphyraenidae	9	0.3	3	8.6
Sphyraena sphyraena (Linnaeus, 1758)	9	0.3	3	8.6
Synodontidae	1	*	1	2.9
Synodus saurus (Linnaeus, 1758)	1	*	1	2.9
Triglidae	32	1.1	13	37.1
Chelidonichthys cuculus (Linnaeus, 1758)	8	0.3	3	8.6
Chelidonichthys lucerna (Linnaeus, 1758)	2	0.1	2	5.7
Triglidae unidentified	22	0.8	9	25.7
Osteichthyes unidentified	106	3.8	21	60.0
Total Osteichthyes	2358	84.5	34	97.1
CEPHALOPODA				
Argonautidae	1	*	1	2.9
Argonauta argo Linnaeus, 1758	1	*	1	2.9
Enoploteuthidae	1	*	1	2.9
Abralia veranyi (Rüppell, 1844)	1	*	1	2.9
Histioteuthidae	7	0.3	1	2.9
Histioteuthis reversa (Verrill, 1880)	7	0.3	1	2.9
Loliginidae	65	2.3	12	34.3
Alloteuthis spp. Wülker, 1920	12	0.4	5	14.3
Loligo vulgaris Lamarck, 1798	51	1.8	9	25.7
Loligo sp. Lamarck, 1798	2	0.1	1	2.9
Octopodidae	195	7.0	15	42.9
Eledone cirrhosa (Lamarck, 1798)	90	3.2	9	25.7
Eledone moschata (Lamarck, 1798)	40	1.4	7	20.0
Octopus vulgaris Cuvier, 1797	64	2.3	9	25.7
Octopodidae unidentified	1	*	1	2.9

	N	%N	F	%F
Ommastrephidae	130	4.7	16	45.7
Illex coindetii (Vérany, 1839)	130	4.7	16	45.7
Onychoteuthidae	11	0.4	2	5.7
Ancistroteuthis lichtensteinii (Férussac [in Férussac & d'Orbigny], 1835)	7	0.3	2	5.7
Onychoteuthis banksii (Leach, 1817)	4	0.1	1	2.9
Sepiidae	13	0.5	1	2.9
Sepia officinalis Linnaeus, 1758	1	*	1	2.9
Sepia spp. Linnaeus, 1758	12	0.4	1	2.9
Sepiolidae	9	0.3	6	17.1
Heteroteuthis dispar (Rüppell, 1844)	2	0.1	2	5.7
Sepiolidae unidentified	7	0.3	4	11.4
Cephalopoda unidentified	2	0.1	2	5.7
Total Cephalopoda	434	15.5	26	74.3
Total preys	2792			

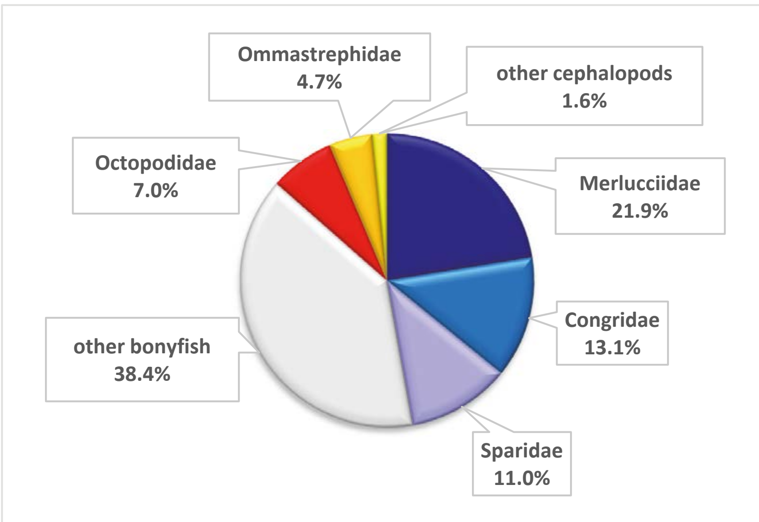

Figure 2 – Stomachs contents of *T. truncatus*. Numerical abundance (percentage) at level of Families.

Discussion

The results of this dietary study showed that in the investigated area, the Tuscan Archipelago, north-western Mediterranean Sea, the trophic spectrum of the bottlenose dolphin was highly diversified; in spite of the rather low number of stomachs analysed (35), 76 different taxa, belonging mainly to bony fishes and also to cephalopods. Nevertheless, the bulk of the predation is based on a restricted group of species, in particular the European hake and the conger eel. Sparidae (fishes) and Octopodidae (mollusk cephalopods) can be considered as prey of secondary importance. The importance of these preys in the diet of *T. truncatus* was previously reported in the Gulf of Cadiz [5], except for Octopodidae which were relevant in the diet of female bottlenose dolphins in the western Mediterranean Sea [3].

The presence of European hake as main prey for the bottlenose dolphin agrees with previous data from European Atlantic coasts [5,12,14] and in the western Mediterranean Sea [3]. Most of the prey identified from the stomach contents of *T. truncatus* are species with benthic and necto benthic habit, as reported by [13], for this same study area, and by [3], for the wester Mediterranean Sea, but also some pelagic fishes [12,14]. This aspect could be related to the generalist habits of this predator, as shown by the presence of the conger eel that may change according to the different location investigated [3,12,14].

Moreover, it is worthy to mention the remains of set nets (e.g. trammel nets, gill nets) found in the stomachs of two specimens of bottlenose dolphin analysed, which showed evident signs of bycatch, such as net wrapped on the head and severed caudal fin. This aspect confirms the opportunistic interaction of *T. truncatus* with fishing activities and can be an indication that those dolphins died trapped in the nets in attempt to feed [2].

Conclusions

The results obtained confirm that the feeding behaviour of *T. truncatus* predator is mainly coastal. In addition, most of the diet if based on species of commercial relevance, as *M. merluccius*, *I. coindetii* and some species of Sparidae and Octopodidae.

Therefore, further investigations are needed to investigate the role of this cetacean in the natural mortality of commercially exploited species, subjected to regular stock assessment, as well as to deepen the knowledge of food and feeding of *T. truncatus*, and important species in the marine coastal ecosystems. Supplementary investigation will be possible only continuing to supervise stranding, to collect and analyse stomachs content of this top predator.

Acknowledgements

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ISOLATION AND MOLECULAR CHARACTERIZATION OF *FUSARIUM* SPECIES (FUNGI, ASCOMYCOTA) FROM UNHATCHED EGGS OF *CARETTA CARETTA* IN TUSCANY (ITALY)

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Abstract – Fungal infectious diseases have dramatically increased in marine ecosystems during the past two decades and actually represent one of the main threats to biodiversity, likely due to the occurrence of emerging pathogens in new environments and the stress conditions induced by global climate change. In this context, the loggerhead sea turtle (*Caretta caretta* L.) is a vulnerable species according to the International Union for Conservation of Nature (IUCN) and it is included as a protected species under several international conventions. Sea Turtle Egg Fusariosis (STEF) is a worldwide emergent fungal disease associated with egg and embryos mortality in endangered sea turtle nests such as those of *C. caretta*. The disease can lead to a significant mass mortality in the infected nests and is caused by a complex of species belonging to *Fusarium* genus with isolates included in the Fusarium Solani Species Complex (FSSC); however, many questions regarding the aetiology and epidemiology of this disease as well as the biology and ecology of the causal agents are still open. *C. caretta* is the only sea turtle species nesting along the Tuscan archipelago where nests are becoming more numerous and widespread. At the same time, in the recent years a continuous monitoring of nesting and hatching sites allowed to record an increased number of affected nests, probably due to STEF. During the monitoring activities conducted in 2019-2020 in several localities on the Tuscany coast (province of Grosseto), a large number of eggs showing symptoms resembling those caused by STEF were found. Symptomatic eggs were so collected from nests located in three beaches and a total of 32 fungal isolates were obtained and submitted to a morphological identification followed by a molecular characterization. Amplicons were sequenced and used to assign the species, thus allowing to identify our isolates as *Fusarium solani*, *Fusarium oxysporum* and *Fusarium nodosum*. Finally, the phylogenetic relationships between our strains and those already known was rebuilt. While *F. solani* and *F. oxysporum* were already associated with *C. caretta* eggs showing symptoms of fungal infection, as far as we know, this is the first time that *F. nodosum* was isolated from affected eggs. Furthermore, this work represents the first report of STEF on Tuscan coast. Although Tuscany does not represent a primary nesting area of *C. caretta* in the Mediterranean basin, the record of the disease on this coastline, in line with what is happening across the globe, confirms that STEF may represent a major risk for the conservation of the loggerhead sea turtle also in this region.

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Introduction

Fusarium represents one of the most important genera of plant-pathogenic fungi known in agriculture, currently including approximately 300 species distributed in 23 monophyletic groups, referred to as species complexes [1]. It is responsible for a range of diseases on hundreds of plant species, and it is commonly recognized as one of the most relevant pathogens based on scientific and economic importance [1, 2]. Furthermore, many *Fusarium* species can produce relevant quantities of mycotoxins, such as trichothecenes, zearalenone and fumonisins, that can adversely affect the marketability of the product and cause adverse effects on human and animal health [3, 4]. In addition, under specific environmental conditions, a variety of species also cause infection (opportunistic mycosis) in humans with consequences that can be devastating, particularly in immunocompromised patients [5, 6]. In addition, some pathogenic *Fusarium* species are now widely recognized as a major threat to animal health and biodiversity conservation [7, 8].

Emerging infectious diseases caused by fungi have dramatically increased in marine ecosystems during the past two decades and actually represent one of the main threats to biodiversity, likely due to the occurrence of emerging pathogens in new environments and the stress conditions induced by global climate change [7, 9]. In this context, the loggerhead sea turtle (*Caretta caretta* L.) is a vulnerable species according to the Internationsal Union for Conservation of Nature (IUCN) [10] and it is included - as a protected species - under several international conventions. Sea Turtle Egg Fusariosis (STEF) is a worldwide emerging fungal disease associated with eggs and embryos mortality in endangered sea turtle nests such as those of *C. caretta* [11, 12]. The disease can lead to a significant mass mortality in the infected nests and is caused by a complex of species belonging to *Fusarium* genus with isolates mainly belonging to the Fusarium Solani Species Complex (FSSC) [13, 14]. This situation has recently increased concerns about the developing of fungal infection caused by *Fusarium* in endangered sea turtles, which causes hatching failure in sea turtle eggs [11, 12]. Pathogenic fungi can infect and grow within *C. caretta* nests by first creating a mycelial network on eggs, whose surface results completely covered; at a later time, they produce enzymes and organic acids that destroy the shells by dissolving organic substrates and calcium carbonate [12, 13, 15]. Affected eggs show coloured infection zones, which can turn into necrotic lesions and kill the surviving embryos [11, 12].

However, many questions regarding the aetiology and epidemiology of this disease, as well as the biology and ecology of the causal agents, are still open. As an example, it is unclear whether these pathogens are invasive species or natural nest inhabitants able to cause disease under a changing environmental scenario [12]. It is worthy of attention that species belonging to the FSCC are globally recognized also as among the most important plant pathogenic fungi, causing severe diseases on several cultivated, thus representing a significant threat to human food supply and agricultural biosecurity. This trend in the transmission of emerging pathogens into new environments, such as marine one, reinforces the importance of deeply investigating those factors responsible of this situation [12]. In addition, nevertheless the environmental conditions may not be the only aspect determining pathogenic fungi development, during embryonic development, the eggs survive for a long period under constant conditions of high temperature and humidity, parameters that favour the growth of soil-borne fungi [12, 13, 14].

C. caretta is the only sea turtle species nesting along the Tuscan coastline and the Tuscan archipelago, where nests are becoming more numerous and widespread. At the same time, in the recent years a continuous monitoring of nesting and hatching sites allowed to record an increased number of affected nests, presumably due to STEF. During the samplings carried out in 2020 in several localities on the Tuscan coast (province of Grosseto), a large number of eggs showing symptoms resembling those caused by STEF were found. In this work, we analysed eggs from natural nests of *C. caretta* that showed visual symptoms of egg fusariosis, with the aim to (i) isolate *Fusarium* spp. isolates present in unhatched eggs, (ii) morphologically and molecularly characterize the isolated fungi and, finally, (iii) reconstruct the phylogenetic relationships between our isolates and those already known (animal and plant pathogens).

Materials and Methods

Symptomatic eggs, characterized by an unusual, coloured area compared with healthy ones and/or covered with mycelium, were collected from nests located in three beaches along the coast (Table 1) and placed in sterile containers. Egg portions were plated on Sabouraud Dextrose Agar (SDA, Biolife Italiana S.r.l., Milan, Italy) in order to isolate associated fungi. By transferring individual hyphal tips, following a first step of mass isolation, to Potato Dextrose Agar (PDA, Biolife Italiana S.r.l., Milan, Italy), or, when sporulating, by monoconidial isolations, we were able to obtain axenic cultures of the fungal outgrowths. Pure cultures of the isolates are actually stored at the fungal collection of the University of Pisa, Italy (Department of Agriculture, Food, and Environment).

Fungal gDNA was extracted from all pure cultures according to the Chelex 100 (Chelex® 100 sodium form, MERCK SERONO S.P.A., Rome, Italy) protocol [16]. To identify and analyse the genetic variability within *Fusarium* isolates, a region including the Translation elongation factor 1 alpha (Tef1-α) gene, a useful region for fungal taxonomic and phylogenetic studies [16], was amplified. PCR reaction (25 μL) contained 2 μL of gDNA (around 10 ng), 2.5 μL of each primer (0.5 μM), 5.5 μL nuclease free H_2O and 12.5 μL GoTaq® Green Master Mix (Promega Italia S.r.l, Milan, Italy). Primers Tef1-α (5'-CATCGAGAAGTTCGAGAAGG-3' as forward and 5'-TACTTGAAGGAACCCTTACC-3' as reverse) were used. The amplification program consisted in 2' of preliminary denaturation (95 °C), 30 cycles of amplification (1' at 94 °C for denaturation, 1' at 55 °C for the annealing and 1' at 72 °C for the extension) and a final extension at 72 °C for 5 min. All amplifications were performed in a Q-Cycler 24 (HAIN, Lifescience, Nehren, Germany). The PCR products were checked by 2.0 % gel electrophoresis run and purified using a QIAquick PCR Purification Kit (QIAGEN, Hilden, Germany). PCR products were sequenced (both forward and reverse direction) by the Bio Molecular Research Genomics (BMR Genomics, Padova, Italy).

For phylogenetic analyses, reference Tef1-α sequences of strains belonging to the *Fusarium* species were retrieved from previously published works [17]. All the sequences obtained were aligned using MAFFT v. 7.402 [18]. Multiple sequence alignments were trimmed to get comparable sequences and exported to MEGAX [19] where the best-fit substitution model was calculated. Using MrBayes 3.2.6 [20], the Markov chain Monte Carlo (MCMC) algorithm was performed to generate phylogenetic trees with Bayesian posterior probabilities for sequence dataset, using the nucleotide substitution models previously determined. Four MCMC chains were run simultaneously for random trees for 2 000 000 generations and sampled every 1000 generations (*p*-value reached a value lower than 0.01). The first 25 % of trees were discarded as burn-in phase of each analysis and posterior probabilities were determined from the remaining trees.

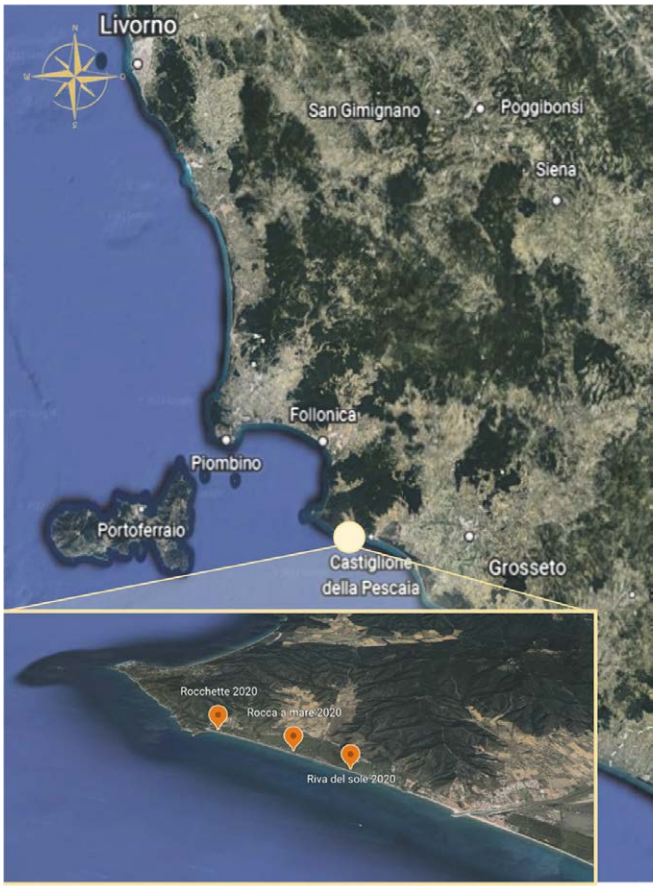

Figure 1 – Geographical distribution of the nests sites.

Table 1 – List of sampling locations and corresponding nest ID number, sampling period, geographic coordinates (GCS) and number of eggs collected in each site.

Nest site (ID)	Sampling period	GCS	Eggs n°
Rocchette (2080970)	before hatching	42°46'9.75" N | 10°50'43.07" E	4
Rocchette (20106236)	after hatching	42°46'9.75" N | 10°50'43.07" E	4
Rocca a mare (20106837)	after hatching	42°46'22.04" N | 10°49'31.76" E	5
Riva del sole (20106864)	after hatching	42°46'35.28" N | 10°47'50.08" E	5

Results

After the development of fungal colonies, a total of 32 isolates (Table 2) were obtained and submitted to a morphological identification followed by a molecular characterization. Morphological identification, by microscopic observation, allowed to preliminary assign all the isolates to the *Fusarium* genus, according to size and shape of conidia, conidiogenic cells and conidiophores structures (Figure 2). In order to assign a species to the isolates, a molecular approach, consisting in the amplification and sequencing of Tef1-α regions was performed. Amplicon analysis allowed to identify our isolates as *F. solani*, *F. oxysporum* and *F. nodosum* (Table 2). Specifically, at the Rocchette sites, a total of 14 different isolates (t7, t2, t6, 1A, 1B, 1C, 2A, 2B, 2C1, 2C2, 3A, 3B, 3C), belonging to *F. solani* (*Fusarium solani* Species Complex), *F. oxysporum* (*Fusarium oxysporum* species Complex) and *F. nodosum* species, were collected from eggs taken before hatching (ID 2080970), while only two isolates (t21, t5; *F. solani*) were found in samples taken after hatchling (ID 20106236). A total of eight isolates were found from samples collected at the Rocca a Mare site (ID 20106837): five of these were found to belong to the *F. oxysporum* Species Complex (t11, t12, t14, t19, t22), while the remaining three to the *F. solani* ones (t16, t13, t18). The remaining nine isolates were collected from the Riva del Sole site samples (ID 20106864), and they included five isolates of *F. solani* (t3, t8, t9, t10, t15) and three of *F. oxysporum* (t1, t4, t17, t20). Overall, 18 strains of *F. solani* (56 %), 12 of *F. oxysporum* (38%) and two of *F. nodosum* (6 %) were identified (Figure 3).

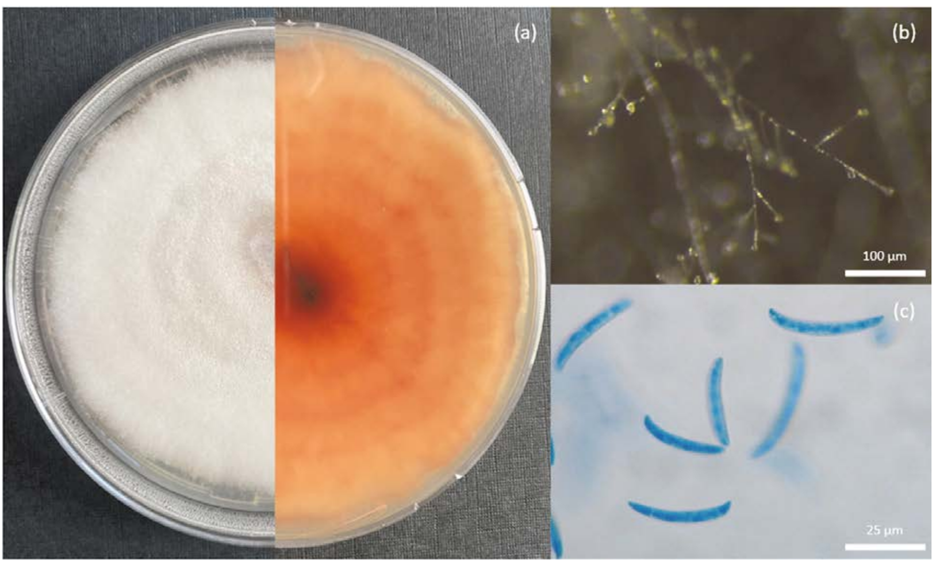

Figure 2 – Morphological features of a *Fusarium oxysporum* isolate from unhatched sea turtle eggs. Front and reverse of mature colony (a), conidiophores (b) and macroconidia (c)

Table 2 – Identification of *Fusarium* spp. isolates, according to Tef1-α DNA sequence, collected from sea turtle eggshells. Abbreviation: Egg ID, identification number of nest site and unhatched egg number (nest | egg); Sample ID, identification number of fungal isolates.

Egg ID (nest | egg)	**Sample ID**	**Species**
2080970 | 70	70_1a	*Fusarium oxysporum*
2080970 | 70	70_2a	*Fusarium nodosum*
2080970 | 70	70_3a	*Fusarium solani*
2080970 | 1	1a	*Fusarium solani*
2080970 | 1	1b	*Fusarium solani*
2080970 | 1	1c	*Fusarium solani*
2080970 | 2	2a	*Fusarium solani*
2080970 | 2	2b	*Fusarium nodosum*
2080970 | 2	2c1	*Fusarium oxysporum*
2080970 | 2	2c2	*Fusarium oxysporum*
2080970 | 2	2d	*Fusarium oxysporum*
2080970 | 3	3a	*Fusarium solani*
2080970 | 3	3b	*Fusarium solani*
2080970 | 3	3c	*Fusarium solani*
20106236 | 16	36_16b	*Fusarium solani*
20106236 | 18	36_18a	*Fusarium solani*
20106837 | 1	37_1b	*Fusarium oxysporum*
20106837 | 1	37_1a	*Fusarium oxysporum*
20106837 | 2	37_2b	*Fusarium solani*
20106837 | 2	37.2a	*Fusarium oxysporum*
20106837 | 3	37.3a	*Fusarium solani*
20106837 | 4	37_4c	*Fusarium oxysporum*
20106837 | 5	37_5a	*Fusarium oxysporum*
20106837 | 5	37_5b	*Fusarium solani*
20106864 | 18	18a	*Fusarium solani*
20106864 | 19	19b	*Fusarium oxysporum*
20106864 | 92	92b	*Fusarium solani*
20106864 | 92	92a	*Fusarium solani*
20106864 | 93	93b	*Fusarium solani*
20106864 | 93	93c	*Fusarium solani*
20106864 | 93	92a	*Fusarium oxysporum*
20106864 | 104	104b	*Fusarium oxysporum*

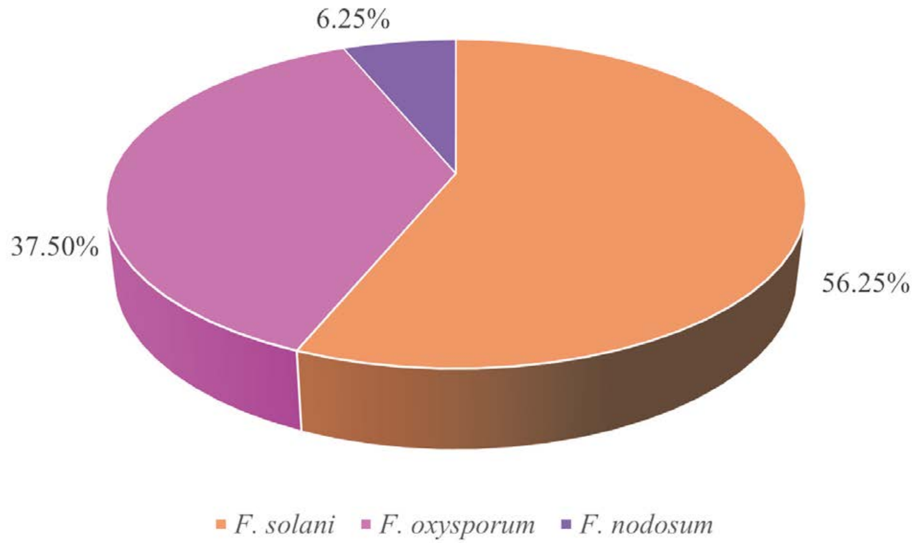

Figure 3 – Distribution of *Fusarium* species among the 32 fungal isolates from unhatched eggs.

Discussion

This work represents the first report of STEF on Tuscan coast. Although Tuscany does not represent a primary nesting area of *C. caretta* in Italy and in the Mediterranean area, the record of the disease on this coastline, in line with what is being recorded across the globe, confirms that STEF may represent a major risk for the conservation of the loggerhead sea turtles also in this region, especially considering how natural systems can be affected by the present climate change perspective [12]. While *F. solani* and *F. oxysporum* were already associated with *C. caretta* eggs showing symptoms of fungal infection, together with other FSSC members such as *F. keratoplasticum* and *F. falciforme* [13, 14, 21], as far as we know, this is the first time that *F. nodosum* was isolated from affected eggs. This is a noteworthy result, since *F. nodosum* is a mycotoxigenic plant-pathogenic fungus, belonging to the complex of *Fusarium* species causal agents of Fusarium head blight of wheat, recently reported for the first time in Italy on *Triticum durum* [22].

These results confirm a global spread of the problem and the need for further studies concerning the biology and ecology of the pathogenic agents, as well as the aetiology and epidemiology of the disease. As the frequency of fungal infections in marine habitats is severely increasing, it is critical to identify the biological and ecological components that contribute to disease epidemic outbreak and severity. In this context, further studies focused on pathogen phylo-biogeography, mechanisms of dispersion and colonization of coastal habitats, and environmental and physiological parameters for infection are needed. For these reasons, isolation and characterization of fungal pathogens will help us to reveal their biology and epidemiology and will allow a better management of disease and to better understand the current and future impact of STEF on sea turtles' conservation worldwide.

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EFFECT OF CLIMATE CHANGE AND ANTHROPOGENIC PRESSURES ON THE EUROPEAN EEL *ANGUILLA ANGUILLA* FROM RAMSAR WETLAND ICHKEUL LAKE: PREDICTION FROM THE RANDOM FOREST MODEL

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Abstract – The present study aims to assess the trophic level of Ichkeul ecosystem and predict the effect of climate change and anthropogenic pressures on European eels.

Multimetric trophic index (TRIX) and Random Forest (RF) model were performed using a dataset consisting of 14 parameters for the period 2010-2020.

The observed TRIX values inside the lake show a non-uniform distribution and a variation between seasons reflecting poor water quality mainly in the river's discharges. While the RF model outcomes show that the most important predictors of eels landing appear to be water level, followed by turbidity and salinity. These results are consistent with the relationships found with the Pearson Correlation.

For comparison, the RF model yielded an R^2 of 58.4 % while the Multiple Regression Linear MLR yielded an R^2 of 40.3 %, confirming that the RF model is significantly better than the MLR and that the model predictions are statistically reliable. This study also demonstrated that the sustainable approach, which combines the two models, can be used in decision-making by civil authorities and other interested stakeholders.

1. Introduction

Coastal ecosystems are known for their wealth of biodiversity and biogeochemical processes and are among the richest environments in the worldwide [1]. Nowadays, these ecosystems are threatened by the fast growth of the human activities, which are the most impacting problems for ecosystem ecological quality [1]. Even though the Mediterranean ecosystems have been identified as some of the word's main biodiversity hotspots, these sites are no exception to the unfavourable biological biodiversity as they are in steep decline [2]. In North Africa, specifically, the Tunisian ecosystems are threatened by the deterioration of their water quality since the development of industry, touristic activities and agriculture [3].

Predicting the impact of climate change on ecosystems is complex due the interplay among different variables [4]. Thus, multiple models have been developed. In particular, the Random Forest (RF) model, which have recently gained popularity in marine ecology [5].

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In the present study, we develop the idea that the diadromous specie (European eel) is the most pertinent bio-indicator to assess the ecological state of the ecosystem. An exhaustive collection of data is used to build a predictive model of effect of climate change on coastal area, by coupling a RF model and a TRIX index. Our goals are as follows: (i) Characterize the seasonal contrasting state of the Ichkeul Lake (ii) Assess the trophic state of water body using the TRIX index and, (iii) Develop a predictive model to evaluate the most important factors influencing the presence of eels' species.

2. Materials and Methods

2.1. Study area

Ichkeul Lake is located in the northeast of Tunisia. It is surrounded by a temporary swamp and is bounded on the south by a mountain called Jebel Ichkeul (Fig.1). The hydrological regime of the lake is controlled by freshwater from precipitation and the watershed area (2600 km^2) and by marine water from Bizerte Lagoon. The lake is fed by six rivers that have been steadily cut off by dams since the 1990s [6].

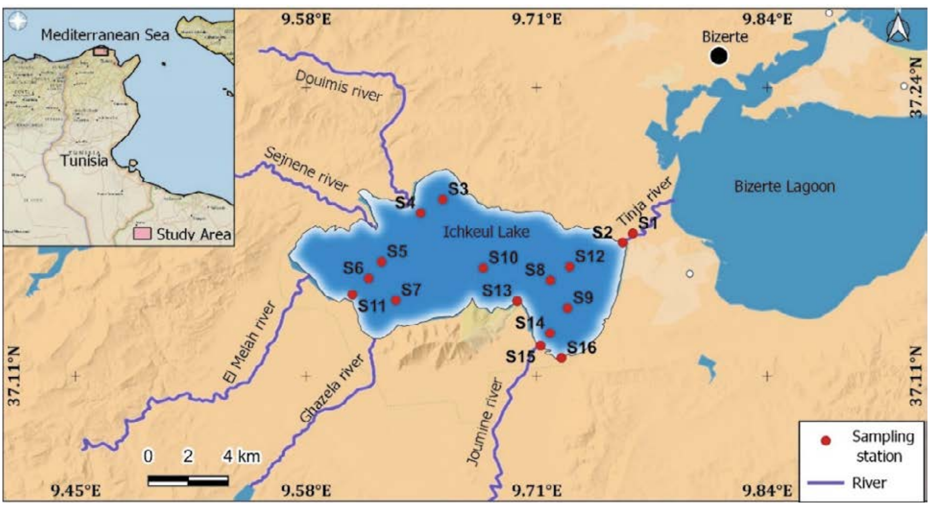

Figure 1 – Geographic localization of Ichkeul Lake and location of sampling stations.

The specific hydrology and the ecological importance of the lake have prompted its inclusion in multiple international conventions: UNESCO Biosphere Reserve, UNESCO World Heritage Element, Wetland of International Importance known as RAMSAR Convention, National Park of Tunisia and Important Wetland for Bird Conservation (ZICO) [7]. However, this wetland is an example of an impacted lake due to anthropogenic pressures such as damming of main rivers, agricultural intensification, and urbanization [7].

2.2. Data collection

The dataset used in the present study consists of 14 environmental variables at 16 sites for the period 2010-2020 (Fig.1). It was collected from different sources; from the DGPA (General Direction of Fisheries and Aquaculture, Tunisia), the platform of BASSIANA database, which is performed within the framework of the IMAS-Ichkeul project, through an extensive literature search and from a sampling campaign. The monitoring fieldwork was conducted in August 2020 and covered 10 sampling sites in the lake. The sampling points were selected at the mouths of the tributary rivers (S1 to S10).

Physico-chemical parameters were measured in the field by using a WTW multiparameter (Multi 340i). Surface water samples were analysed for chemical variables using an Auto-analyser [10], While the chlorophyll a (Chl a) concentrations were measured using the spectrophotometric method of [11] and following the procedure given by [12].

2.3. Data analysis

The derived dataset consists of 13 predictors and 1 response variable. To conform to the requirements of normality when using regression models, the target variable was transformed using the Box-Cox transformation [13].

The resulting dataset is derived from a variety of sources, that caused the insufficient information on some parameters. Overall, 30 % of the values were missing in the dataset. To avoid the adverse negative effect of any missing information, two solutions were conducted. Firstly, we removed the spatial information from the dataset (i.e., longitude and latitude columns) and average the rows of each feature that had the same date. Consequently, the proportion of missingness was decreased to 18 %. Secondly, we statistically imputed the 18 % of the missing values (NA) with a machine learning algorithm called 'missForest'[14]. This method is based on prediction and estimation from the non-missing value available from the original dataset [13]. The performance of this algorithm is assessed using the normalized root mean squared error NRMSE [14].

2.4. TRophic IndeX (TRIX)

TRIX index is a numeric expression that used to provide the degree of trophic status of coastal ecosystem, based on nutrient concentrations and productivity. TRIX index was originally tested in NW Adriatic Sea [15] and then applied to several coastal areas and seas, such as the Tyrrhenian Sea [16], the Greek coastal lagoon [17], Bizerte Lagoon [4], Ghar El Melh Lagoon [18] and Tunis Lagoon [3] . TRIX analytical expression is the following:

$$\mathrm{TRIX} = \mathrm{Log10}(\mathrm{DIN} * \mathrm{DIP} * |\mathrm{D\%O2}| * \mathrm{Chla})/\mathrm{b} \quad (1)$$

where: DIN, DIP and Chla concentrations are expressed in µg/l, $|D\%O_2|$ represents the absolute percent deviation of DO from saturation (%), and the parameters a=1.5 and b=1.2. The value 0 corresponds to extreme oligotrophic conditions and the value 10 corresponds to extreme eutrophic conditions [16].

2.5. Random Forest model (RF)

The RF model is a statistical technique introduced by Breiman [19], and it is a popular algorithm that aims primarily to categorization by classification, then to obtain a consensus prediction by regression [19].

RF combine several decisions trees to achieve a reliable regression. In general, two-thirds of the data are used as a training data, while one-third is the out-of-bag OOB, used for testing set. An interest feature of RF is the use of OOB to evaluate the model and to estimate the OOB error [19]. The performance of the RF model was evaluated using the coefficient of determination (R^2).

3. Results

3.1. Parameter's properties

Concerning the meteorological parameters, the mean annual precipitation was 59.28 mm for the period 2010-2020. In dry period, 9.42 % of the rainfall occurred and 90.57 % in wet period (Table.1). While the mean wind intensity was approximately 6.01 m s^{-1} and 5.22 m s^{-1} in dry and wet period, respectively, and the dominant wind was originating the north-western side.

Table 1 – Summary of environmental parameters in Ichkeul Lake for the period 2010-2020

Parameter	Abbreviation and Unit	Dry period			Wet period		
		Min	Max	Mean	Min	Max	Mean
Season	Se	Summer and Spring			Winter and Autumn		
Precipitation	P (mm)	0.00	73.91	15.96	0.00	249.93	82.61
Wind Intensity	W (m.s-1)	3.64	8.90	6.01	2.41	8.82	5.22
Temperature	T (°C)	12.76	28.60	21.11	10.00	62.76	15.39
Water Level	WL (cm)	3.00	113.00	44.29	3.00	156.00	67.44
Salinity	S (psu)	11.30	71.00	44.68	3.43	59.59	21.42
Dissolved Oxygen	DO (mg. l-1)	4.20	11.00	7.29	3.20	14.00	7.13
Turbidity	Tur (NTU)	10.14	34.20	18.90	12.10	46.00	27.34
Dissolved Inorganic Nitrogen	DIN (µM)	6.21	73.51	22.05	11.01	56.60	29.46
Total Nitrogen	TN (µM)	16.70	32.58	22.66	18.69	22.84	20.97
Dissolved Inorganic Phosphorus	DIP (µM)	0.11	7.62	2.08	0.25	2.57	1.06
Total Phosphorus	TP (µM)	3.56	36.42	12.80	4.29	13.03	7.60
Chlorophyl a	Chl.a ($\mu g \cdot l^{-1}$)	1.24	9.80	6.80	1.21	9.14	3.36
Eels landing	Eels (tons)	0.02	11.80	1.84	0.07	45.00	9.34

Regarding the physico-chemical parameters, the water level was between 44.29 cm in dry season and 67.44 cm in wet season. Whilst the average annual water temperature was 21.11 °C with a maximum of 28.60 °C and a minimum of 12.76 °C. The salinity level was likely to be homogenously distributed with a mean of 44.68 psu and 21.42 psu in dry and wet seasons, respectively. Mean annual dissolved oxygen levels were approximately 7 mg l^{-1}, and mean turbidity was varied between 18.90 NTU and 27.34 NTU.

The chemical parameters also exhibit a seasonal trend and they showed two episodes during a year: high level in wet period and low concentrations in dry period. Overall, the chemical parameters in the lake were mainly high in the estuaries of rivers.

The chlorophyll-a concentration, that approximate the phytoplankton biomass, was ranged between 6.80 µg l^{-1} and 3.36 µg l^{-1}, while the highest quantity of European eels hidden in the lake was during the period between November and March, with a peak in December (45 tons).

3.2. Statistical analysis

The MissForest algorithm was used in the present study to deal with missing values, and it gave an NRMSE of 0.22 indicating a sufficiently good performance. The Pearson correlation result (Fig.2) showed that eel landing was positively correlated with water level (r=0.73) and turbidity (r=0.61), and negatively correlated with S (r=- 0.44).

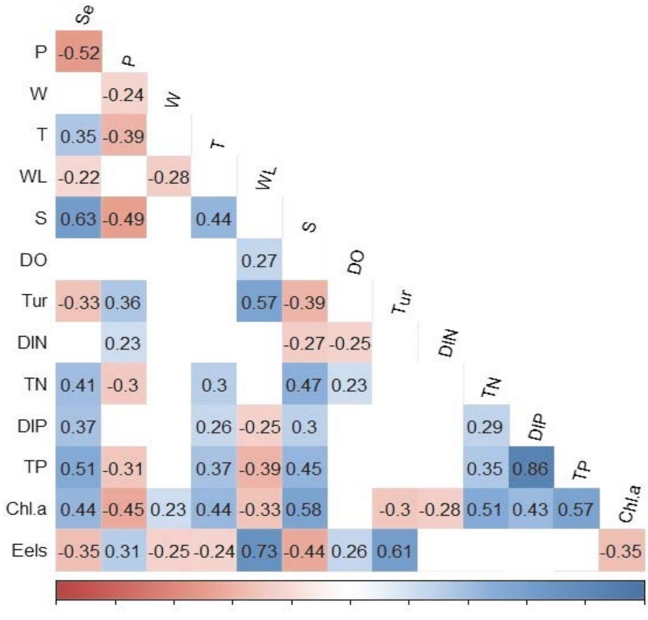

Figure 2 – Lower triangular correlation matrix of the predictors and Eels landing in Ichkeul Lake.

3.3. TRIX derivation

The calculated seasonal averages of the TRIX index inside the lake are shown in Fig 3. Overall, the index values show a non-uniform distribution and a variation between seasons. Indeed, in dry period, the water quality was poor, and the highest values (between 4 and 6) were recorded in the eastern side of the lake close to Tinja, Tine and Joumine rivers, while the eutrophication level in the west side was relatively medium. As opposite, in wet period, the high values (from 4 to 5) were recorded in the north region where the Douimiss river take place, while in the eastern sector, the eutrophication level was between 3.5 and 4.

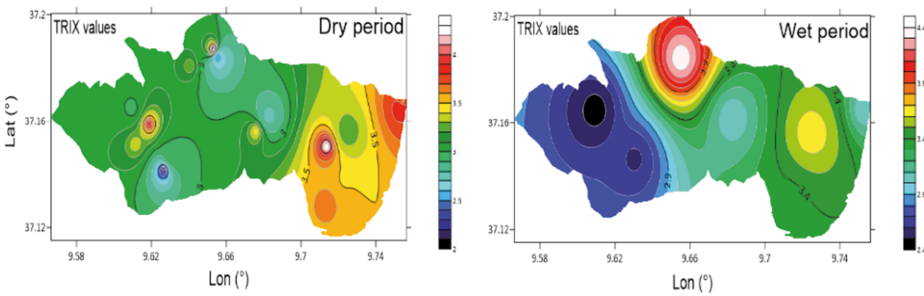

Figure 3 – Distribution of TRIX values in Ichkeul Lake for the period 1995-2020.

3.4. Random Forest RF deviation

The RF model was implemented in R [20], and it resulted in an R^2 equal to 58.4 %. The automatic evaluation of the model using the test set is similar to cross-validation.

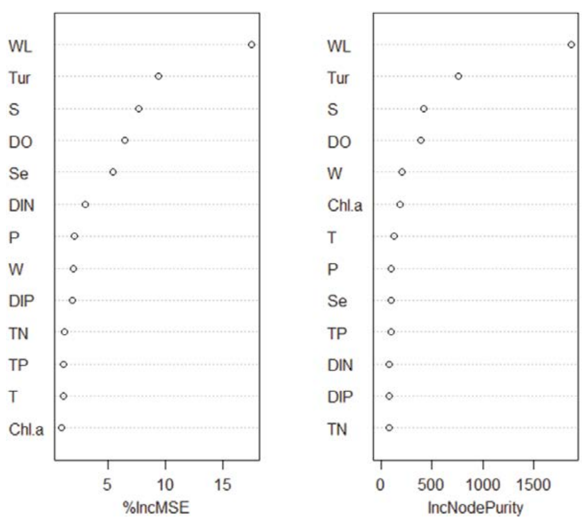

Figure 4 – Predictor's importance ranking for the RF model for the period 1995-2020.

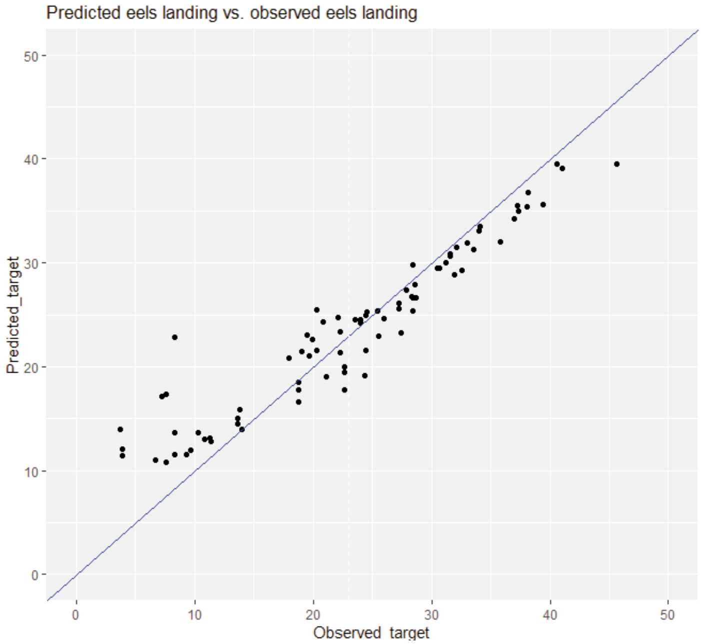

Figure 5 – Scatter plot of the observed and the predicted eels landing.

The most important predictors contributing to the estimation of eel biomass are water level, followed by turbidity and salinity (Fig.4). Figure 5 showed that the observed eel landing was correctly predicted. In addition, the MLR gave an R^2 of 47.4 % which is lower than the RF model.

4. Discussion

The data analysis suggested that the Ichkeul ecosystem is characterized by a seasonal variation of its environmental factors and that the values of these factors are generally recorded in Mediterranean ecosystems [4], [18]. Yet, the present study also revealed that the above-mentioned parameters experienced exceptional values within the lake, such as the increase in salinity (70 psu in dry period) and the decrease in water level (30 cm in dry season). This is presumably related to several anthropogenic stressors and climate change. Indeed, the construction of six dams on the main rivers flowing into the lake, low precipitation and high evaporation have reduced the water level of the lake. Furthermore, under the pressure of climate change, the water level has been drastically reduced, resulting in a very high salinity and a lower water depth.

These stressors have also led to an increase in the eutrophication level in the lake, as evidenced by the low concentration of dissolved oxygen and the significant nutrient budget. On an annual basis and according to the TRIX index results, the lake can be considered a mesotrophic ecosystem with good to poor water quality. The high eutrophication on the eastern and northern sides is mainly due to rural settlements without sewage treatment systems and extensive agricultural activity [21].

Climatic conditions and human activities have equally affected the marine resources of the lake. In fact, results obtained from the RF model and Pearson correlation indicated that the most important variables for eels landing were water level, following by turbidity and salinity. In fact, water level and turbidity promote eel migration and facilitate the foraging process [22]. Furthermore, salinity plays a key factor in the cycle life of European eels [22]. In decreasing the order of importance of predictors, the other descriptors were dissolved oxygen, season, and nutrients. In agreement with several studies.

Climatic and anthropogenic pressures have disturbed eel's growth by causing habitat alteration, niche width, and non-food availability[22]. The presence and the trophic strategies of this species reflect the quality of the water body. In fact, the eels enlarged its trophic niche under eutrophic conditions and become omnivore predator and shift from pelagic (fish) to benthic (invertebrates) prey, which demonstrated in Ichkeul Lake by the study of [23]. Thus, this confirmed the high eutrophic conditions in the lake.

The present research is the first to investigate the relation between abiotic variables and ichthyological resources in Ichkeul wetland using the machine learning algorithms. The dependence between environmental parameters and chlorophyll-a concentration was studied in Bizerte Lagoon [4], Ghar E Melh Lagoon [18]. The fitted RF model in Ichkeul Lake (present study) was similar to that found in Ghar El Melh L (R^2= 0.64), yet it was better than in Bizerte Lagoon (R^2= 0.45). This is presumably due to the type of dataset used, the hydrological process of each ecosystem and the different impacts that threaten.

5. Conclusion

Being a biosphere reserve and a RAMSAR site, Lake Ichkeul does not allow the use of biomanipulation measures to control eutrophication, and therefore the best procedures to control localized anoxia and eutrophication would be improved management of water flows and organic waste from the towns and villages bordering the lake. The sustainable approach, which combines the RF model and the TRIX index, could be useful to assess the evolution of trophic status and improve our understanding of the effects of anthropogenic pressures and climate change on the biological status of these ecosystems. It can be used in decision making by civil authorities and other interested stakeholders.

6. Acknowledgment

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MONITORING CHANGES OVER A 10-YEAR PERIOD, THROUGH VEGETATION MAPS, IN A COASTAL SITE IN APULIA REGION (SOUTHEASTERN ITALY)

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Abstract – This study aims to detect, analyze, and evaluate the habitat changes, between 2010 and 2020, occurred in the Mediterranean wetland system of "Zone Umide della Capitanata e Paludi presso il Golfo di Manfredonia". We classified habitats in 2020 using Eunis classification and compared the obtained map with the Eunis map of 2010, obtained using the same approach, in terms of class area, Magnitude of Changes and the corresponding Trend Percentage of Change. It emerged that expansion of agricultural activities and alterations of the hydrological regime are behind most of the observed changes.

Introduction

Coastal wetlands are among the most essential and valuable ecosystems on Earth, characterized by high biological diversity and providing a variety of ecosystem services [18; 7]. In Mediterranean, these environments are considered biodiversity hotspots, including a wide range of endemic species, but subject to numerous threat factors, such as land claim, agricultural intensification, hydrological modifications, urbanization, coastal erosion and introduction of alien species [11; 15; 12; 13].

Consistent monitoring procedures, as well as awareness of the ongoing socio-economic dynamics, are fundamental to implement effective management policies and conservation strategies. Assessing changes in landscape ecological elements through habitat monitoring over a long period is essential to: a) understand the drivers of the temporal changes; b) make provisions for future trends, c) design appropriate conservation policies [10; 14; 5].

The aim of this work is to detect, analyze, and evaluate the habitat changes occurred in one of the largest components of the Mediterranean wetland system, between 2010 and 2020.

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Material and methods

The site "Zone Umide della Capitanata e Paludi presso il Golfo di Manfredonia" [Site of Community Importance (SCI) IT9110005; Special Protection Area (SPA) IT9110038], located in the north-eastern part of the Puglia region and partially enclosed in the Gargano National Park (Figure 1), is one of the most extensive wetlands of the Italian peninsula (more than 14 000 ha) and one of the largest components of the Mediterranean wetland system. It is also classified as Ramsar site and Important Bird Area (IBA 230 M).

The site has been subject to human exploitation for a long time, mainly for agricultural purposes, resulting in the conversion of large part of the wetland areas into cultivated lands and the subsequent reduction and fragmentation of the original natural habitats. Due to this process, at present, a large part of the area is either devoted to agriculture or else abandoned. The remaining humid areas consist of a system of lagoons, characterized by brackish or saltwater, depending on the specific water regime. The natural vegetation is formed mostly by halophytic scrub and reed thickets and by annual pioneer salt marsh communities [16].

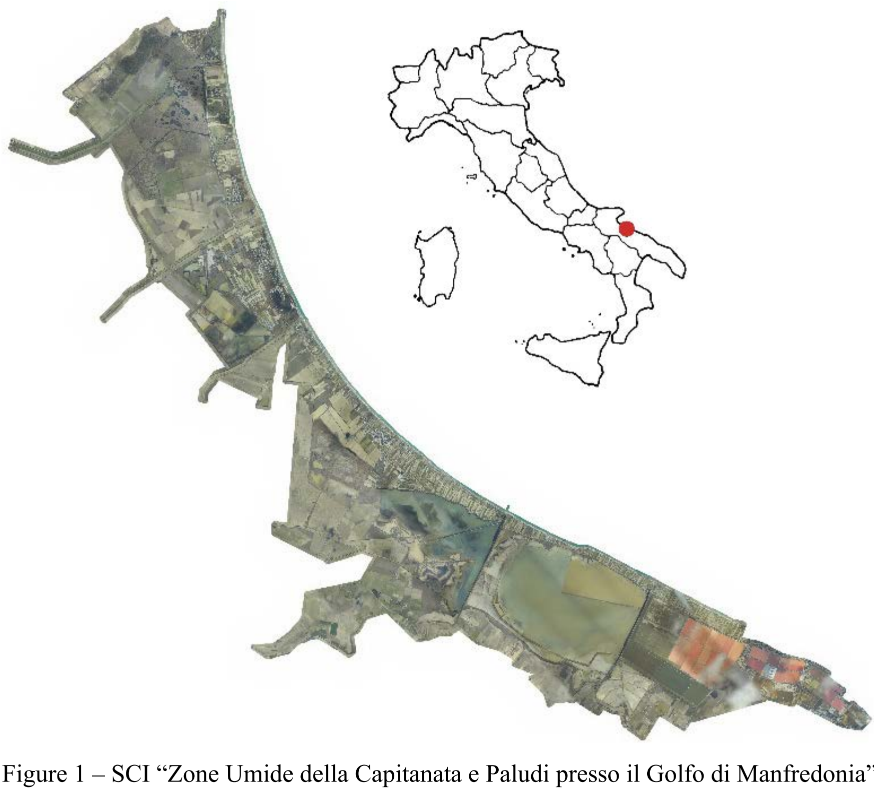

Figure 1 – SCI "Zone Umide della Capitanata e Paludi presso il Golfo di Manfredonia".

The habitat map was produced by visual photointerpretation at a scale 1:5 000, digitized in ArcGis 10.2 from colour orthophotos realized between 2019 and 2020 within the project COHECO (https://www.coheco.it) in three different months (February, June and October).

After the identification of natural and semi-natural landscape elements as vegetation types, defined on the base of phytosociological units according to the Zurich-Montpellier method [3], vegetation units were reclassified in habitat types based on the EUNIS classification scheme, according to the habitat classification revised 2004 (levels III and IV; [9]). The map thus generated was compared to a EUNIS habitat map, referring to 2010 and produced at the same spatial scale [17].

Trend Percentage of Changes (TPCs) in class area occurred between 2010 and 2020 for each habitat class was calculated by using the following formulas [1; 2]:

$$TPC_i = \frac{MC_i}{CA_i(T1)} \cdot 100$$

where: $MC_i = CA_i(T2) - CA_i(T1)$

i is the habitat considered and, for the case under study, *T1* and *T2* correspond to 2010 and 2020, respectively. *CA* represents the Class Area recorded for each class.

Results and discussions

Cultivated areas are the predominant type, covering about the 40 % of the site. Natural and artificial water bodies cover about the 38 %, with the class X02 (saline coastal lagoons, corresponding mostly to the Margherita di Savoia salines) amounting to the 30 %, thus making up the dominant element of the natural landscape.

The most represented vegetation types are helophytic communities (with numerous habitat types, of which the most extensive is C3.2 [Water-fringing reedbeds and tall helophytes]) and halophytic shrubs and annual herbaceous communities of saline to hypersaline environments (with the habitat types A2.526 [Mediterranean saltmarsh scrubs]; A2.516 [*Suaeda vera* saltmarsh driftlines]; A2.551 [*Salicornia*, *Suaeda* and *Salsola* pioneer saltmarshes]).

Despite the coastal strip having an extension of over 30 km, the sandy coast system, including both vegetated and not vegetated areas, covers less than 1 % of the whole area. This is due to the severe coastal erosion and other anthropogenic pressures that are exerted on this environment, as will be discussed below.

It can be said that the general composition of the landscape, in terms of large categories (salt marshes, coastal lagoons, sandy dune system) has not changed much from 2010 to 2020. However, if we look in detail at the single habitat types that make up these systems, numerous changes can be described, some of which are also very significant. The class area (CA) recorded for each class in 2010 and in 2020, and the corresponding TPC, are reported in Table 1.

Table 1 – Class area (CA) in 2010 and 2020, and Trend Percentage of Change (TPC).

Habitat	CA in 2010 (ha)	CA in 2020 (ha)	TPC (2010-2020) (%)
A2.1	-	9.59	-
A2.5	306.65	-	-100.00
A2.515	30.31	15.65	-48.37
A2.516	-	65.89	-
A2.522	44.05	129.26	193.43
A2.525	-	190.65	-
A2.526	1000.39	863.25	-13.71
A2.53C	38.68	47.04	21.61
A2.53D	111.97	15.60	-86.06
A2.551	257.36	110.06	-57.23
B1.1	1.51	4.33	186.85
B1.2	81.50	67.56	-17.11
B1.31	20.64	25.68	24.43
B1.4	16.00	6.44	-59.76
B2.1	2.28	0.84	-63.15
C1.3	218.33	263.77	20.82
C2.3	64.251	72.90	13.47
C2.4	11.69	11.37	-2.73
C3.2	850.98	923.13	8.48
E1.61	573.75	374.84	-34.67
F5.514	-	0.62	-
F9.31	34.65	33.58	-3.11
FB.4	18.50	23.68	27.97
G1.D	1.83	15.48	744.77
G2.81	21.00	18.85	-10.23
G2.83	-	10.24	-
G2.9	0.32	0.33	0.00
G2.91	66.67	76.35	14.52
G3.F	35.75	34.03	-4.80
I1.1	3700.56	3649.68	-1.37
I1.2	1329.28	1749.22	31.59
J1.1	36.68	36.95	0,73
J1.2	141.76	145.58	2.69
J2.1	54.82	54.79	-0.06
J2.3	52.38	41.45	-20.89
J2.4	52.77	52.45	-0.64
J2.6	2.03	1.465	-28.04
J2.7	0.23	-	-100.00
J4.2	17.96	53.10	195.70
J4.5	4.89	3.90	-20.22
J4.6	23.04	18.47	-19.86

Habitat	CA in 2010 (ha)	CA in 2020 (ha)	TPC (2010-2020) (%)
J5.1	9.89	42.09	325.68
J5.2	6.54	10.29	57.33
J5.3	2.59	2.53	-2.40
J5.4	1.85	1.96	6.04
X02	4402.13	4372.01	-0.68
X03	442.33	460.10	4.22

In general, most of the observed transformations is borne by habitats referable to the EUNIS high level categories A (marine habitats, included saltmarshes and coastal lagoons), and B (coastal habitats, included coastal dunes and beaches) [9].

As shown in Table 1, class A2.5 (Coastal saltmarshes and saline reedbeds), covering more than 300 ha in 2010, in 2020 is totally converted in other classes, due to:

a) thematic redefinition of this coarse class in more detailed types (e.g., A2.526 and A2.551); this increment in thematic resolution resulted from a more detailed in-situ survey of the investigated plant communities, thus allowing a more accurate discrimination between different habitat types (according to the same EUNIS classification scheme);
b) real changes, such as the conversion of A2.5 into A2.522 (Mediterranean *Juncus maritimus* and *Juncus acutus* saltmarshes) and A2.525 (Mediterranean *Juncus subulatus* beds). These transformations have occurred because of alterations in the hydrological regime, both in terms of water salinity and of the flooding period.

On the other hand, five new classes have been introduced in 2020: A2.1 (Littoral coarse sediment), A2.516, A2.525, F5.514 (Lentisc brush), G2.83 (Other evergreen broadleaved tree plantation), because of a higher thematic redefinition.

In terms of change in surface area, the most striking changes within the group A concern the classes A2.5, A2.522, A2.53D, A2.551. As mentioned above, the class A2.5 is entirely replaced by other classes. A2.526 undergoes a quite relevant reduction (TPC = -13.7) with multiple conversions in numerous other classes, mainly in arable lands, with a loss of natural areas; this trend is quite widespread throughout the whole area, and particularly evident in the marginal areas bordering the cultivated fields (Figure 2).

Figure 2 – Conversion of A2.526 into arable land.

Numerous helophytic communities of salt marshes show important changes in cover: the surface area of class A2.522 triplicates, from 44 to 129 ha (TPC = 193.4 %); the class A2.53D suffers a drastic reduction, from 112 to 16 ha (TPC = -86 %); A2.515 (*Elymus repens* saltmarsh driftlines) reduced too, halving its surface from about 30 to 16 ha (TPC = -48.4 %); A2.53C (Saline beds of *Phragmites australis*) increases its surface (TPC = 21.6 %). These dynamics are particularly evident in the northern part of the site, mainly due to complex modifications of the water regime (Figure 3). Finally, habitat A2.551 drastically reduces, from about 260 to 110 ha (TPC = -57.2 %), in this case due to changes in land management.

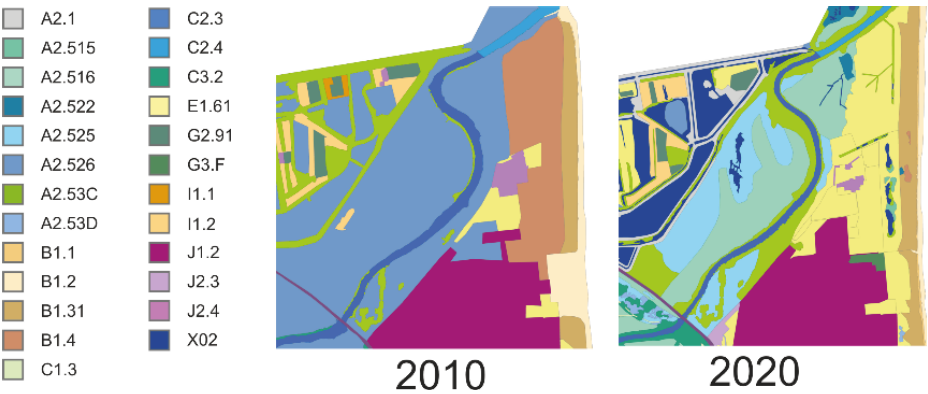

Figure 3 – Drastic reduction of class A2.53D in the northern part of the study area.

As regards the sand dune system, important transformations have been observed, with processes of erosion (in the southern part of the site) and accretion (in the northern part of the site) resulting in a general reshaping of the coastline. Class B1.1 (Sand beach driftlines) expands (TPC = 186.8 %), and class B1.31 as well (TPC = 24.4 %), even if this increment is the result of drastic rearrangements of the surface areas of these habitat types, with multiple conversions in various other classes, such as E1.61, B1.4, B1.2 (Figure 4). Habitat B1.4 is interested by a general reduction (TPC = -59.8 %) and drastic transformations: in fact, the area covered in 2010 is entirely converted, mostly in E1.61 (Figure 3), while new areas of B1.4 derive from the conversion of B1.31, B1.2 and B1.1. It should be pointed out that coastal erosion is an ongoing trend in a large extend of the sandy coats of almost the entire Apulia Region. In fact, since the early twentieth century, the realization of coastal railway lines and road system, along with a massive reclamation of wetlands, has triggered the transformation of the coastline; moreover, sediment trapping and river regulation actions contributed to reducing watershed sediment input. This coastal evolution has led, along with intensive touristic exploitation of coastal areas, to a gradual reduction of dunes belts and the related habitat types [8; 4].

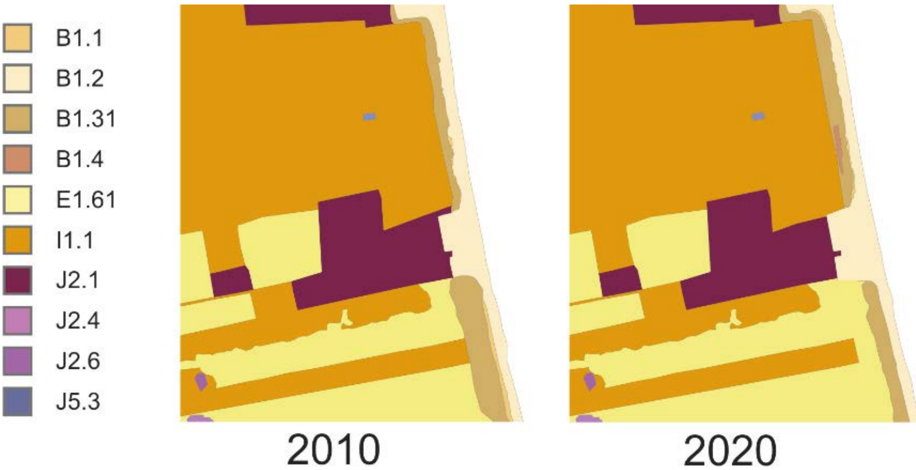

Figure 4 – Rearrangement of the sand dune system in the middle part of the site, with expansion of cultivated areas.

Class C1.3 increases its surface (from 223 to 264 ha; TPC = 18.1 %), especially from the transformation of the classes A2.551, E1.61 and C3.2. This is the result of important interventions of a LIFE+ project realized in the Natural Oasis "Lago Salso" (Figure 5).

Class F9.31 (*Tamarix* communities) undergoes a reduction (TPC = -3.1 %) but with important rearrangements of its spatial distribution, with conversions in the classes A2.522 and C3.2.

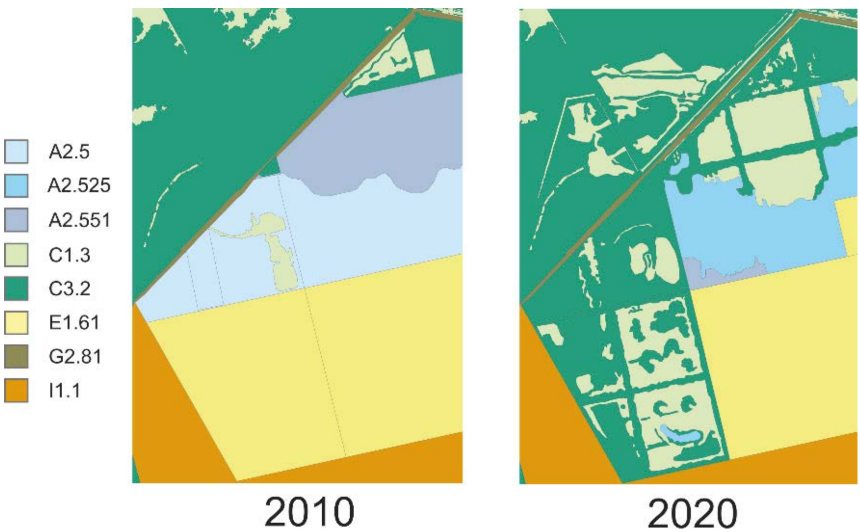

Figure 5 – Increasing of class C1.3 at "Lago Salso".

Class E1.61 reduces its surface (TPC = -34.7 %) with the conversion in arable lands. There is the significant increase of cultivated areas, in particular arable lands I1.2 (TPC = 31.6 %), from conversion of E1.61 but also from saltmarsh natural areas, especially A2.551, A2.526; this trend corresponds to loss in natural areas.

Numerous anthropogenic pressures are behind most of the observed changes. Intensification and expansion of agricultural activities and alterations of the hydrological regime are among the main driving forces exerting pressures on the observed natural systems. The uncontrolled extraction of groundwater seems to be at the basis of the subsidence which is occurring in some parts of the site, and which is leading to radical landscape transformations [6].

Conclusions

The impact of human activities on the Mediterranean wetland systems may undermine their future ability to survive as self-regulated systems. For this reason, the need for economic growth should be compatible with environmental policies avoiding overexploitation of natural resources, with particular attention to the management of the water resources.

Understanding the complex and intricate connections among ecological, social, and economic goals is essential in implementing management and conservation policies. Policymakers at different administrative levels should try to find a compromise between both private and public goods for an efficient and consensual program of the management of natural resources.

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STAND STRUCTURE AND NATURAL REGENERATION IN A COASTAL STONE PINE (*PINUS PINEA* L.) FOREST IN CENTRAL ITALY

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Abstract – In Italy, Stone pine forests (*Pinus pinea* L.) have traditionally been cultivated to produce both wood and pine nuts. To this end, forest management is based on even-aged stands and the clearcut system with artificial regeneration. However, in the last decades Stone pine forests have become even more important for their social and cultural role, as well as for landscape conservation, especially those included within protected areas along the coast. For this reason, it is important to investigate whether the traditional silvicultural system is the most appropriate to achieve the current public needs or if there is a need to shift to more sustainable and close-to-nature silvicultural methods based on natural regeneration. Despite the relevance of this topic, in Italy few studies have focused on natural regeneration of Stone pine. This study was carried out in the Regional Park of Migliarino, San Rossore and Massaciuccoli (Tuscany, Central Italy) where we found natural regeneration of Stone pine in an even-aged stand of pine. The objectives of our study were (1) to characterize the forest structure of the Stone pine stand and (2) to quantify the natural regeneration of pine.
Our results show that natural regeneration of *Pinus pinea* L. in the Park of San Rossore is a reachable target, however an adequate management is needed. The results are discussed with the intention of providing knowledge to support management of Stone pine forests along the Tyrrhenian coast.

Introduction

In the Mediterranean basin Stone pine (*Pinus pinea* L.) forests cover more than 0.7 million ha [1], mainly in Spain, Portugal, Turkey, and Italy, offering a variety of products and functions.

The *Pinus pinea* forests have stabilized dunes and protected agricultural lands from sea winds; provide wood products and pine nuts, a highly valued product by the food industry; support production of other non-wood products, such as turpentine and truffles (*Tuber borchii* Vittad.); offer pasture and shelter for sheep and cattle. In addition, Stone pine forests offer valued recreational uses and provide habitats for plant and animal species of

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conservation interest, explaining why these forests are often included into sites of the Natura 2000 network [1, 2, 3, 4, 5] as an important component of the habitat 2270* Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*.

Stone pine forest stands are mostly of artificial origin and usually present even-aged structures with a rotation length ranging between 80 and 120 years depending on site index. Traditional even-aged stand management in *Pinus pinea* is based on clearcuttings, which was maintained up to the end of the decade of 1970's [6] and then replaced with the uniform shelterwood system to get a close-to-nature regeneration system [5, 6, 7]. However, selection cutting with diametrical criteria is fairly widespread in multiaged complex structures [2, 8].

In Italy, the surface area of Stone pine forests amounts to 46290 ha, of which 11201 ha are in Tuscany [9], characterizing the coastal landscape for approximately five centuries, and providing important goods and services that have contributed to the socio-economic development of the area and also to the wellbeing of the inhabitants [10].

In Italy, the forest management system for Stone pine forests is still based on clearcutting with artificial regeneration used to optimize the production of seeds and/or wood. Today, this system is considered to reduce the environmental and landscape quality, and is often cause of conflicts, especially in protected areas and landscapes. This is one of the reasons behind a lack of active management of coastal Stone pine forests in recent decades, which brought forest owners and managers to ask for new silvicultural models [10, 11].

Therefore, it is important to investigate whether the traditional silvicultural system applied in Italy is the most appropriate one to achieve the current public needs or there is a need to shift to more sustainable and close-to-nature silvicultural methods based on natural regeneration.

Despite the relevance of this topic and the relative availability of phytosociological data from relevés in *Pinus pinea*-dominated forest across the Mediterranean [12], in Italy little information is available on natural regeneration of Stone pine and only few studies have focused on this issue [13, 14, 15, 16].

Accordingly, the objectives of our study were (1) to characterize the forest structure and (2) to quantify the natural regeneration in an even-aged coastal Stone pine forest in Central Italy.

Materials and methods

The study was carried out in Tuscany, in the Regional Park of Migliarino, San Rossore and Massaciuccoli (Central Italy). The Park hosts historical coastal Stone pine forests, which are included in the Natura 2000 site Selva Pisana (IT5170002). Forest structure consists of a composite of even-aged pine stands with a vertical structure comprising one or two canopy layers. Forest management is based on clear cutting with a rotation age of 90 years, and the regeneration is achieved artificially through plantations (or direct seeding as it was done in the past).

In the forest unit 27 (Lat 43.745690°, Long 10.294118°), we found an even-aged 103 year old *Pinus pinea* stand with natural regeneration of pine, which was selected as study area. This area is characterized by sandy soils, with average annual rainfall of 932 mm and average annual temperature of 14.8 °C, with maximum temperatures of 23.2 °C in July and a minimum of 7.1 °C in January [17]. The shrub layer was scarce, with a height ranging between 1 m and 2 m.

In the study area, field works were carried out in 2020 in three experimental plots (50x100 m), hereinafter referred to as A, B, and C (Figure 1).

Figure 1 – Study plots A, B and C.

In each plot, the x,y coordinates of all trees with height > 20 cm were recorded using a Topcon total station and a Global Navigation Satellite Systems (GNSS) Trimble Geo 7x dual frequency receiver, observing the pseudorange of both GPS and GLONASS; the recorded GNSS positions were post-processed with correction from a base station into a sub-meter precision.

For trees with a diameter at breast height (DBH) > 2.5 cm, the DBH, the total tree height (H), crown length and crown projections (four perpendicular radii along north, east, south, and west directions) were measured.

For trees with a DBH < 2.5 cm (i.e., the regeneration), the diameter at the base of the stem and H were collected.

The stand structure was characterized using the following structural indicators: number of stems (N), basal area (BA), wood volume (V, from NFI double entry volume equations [18]), quadratic mean diameter (QMD, the diameter of the mean basal area tree); dominant height (DH, the mean height of the 100 trees per hectare with the largest diameters), standard deviation of DBH (SDDBH), standard deviation of H (SDH), and canopy cover (CC); CC was computed modelling the shape of the crown as a circle with a radius equal to the arithmetic mean of crown projections measured in the field. The vertical structure (number of strata) was assessed using the TSTRAT function, which defines strata based on an assumption related to a competition cut-off height among tree crowns in a given area [19].

For natural regeneration, we computed N and the frequency of seedlings (NSE, 20 cm < H < 130 cm) and saplings (NSA, H ≥ 130 cm) [8], the arithmetic mean of diameters (MD) and H (MH), the standard deviation of diameters (SD) and SDH, and the regeneration index (RI) of Magini [20]. In addition, we used the Ripley's *K* function (bivariate L-function) to assess the spatial relationships between the regeneration and parent trees with DBH > 2.5 cm using the Programita software [21]. The bivariate L-function ($L_{12}(r)$) was computed for distances (r) ranging between 1 m and 25 m. To test the significance of deviation from null hypothesis of spatial independence between the regeneration and parent trees we adopted a 95 % confidence interval from the toroidal shift null model. In case of attraction between the regeneration and parent trees, $L_{12}(r)$ is greater than the confidence interval; in case of repulsion $L_{12}(r)$ is lower than the confidence interval; in case of spatial independence $L_{12}(r)$ is within the confidence interval.

Results

Stand structure

The structural indicators computed for each plot are reported in Table 1 and the stem number–diameter class distribution is shown in Figure 2.

Plot B was a pure stand of *Pinus pinea*, while in plots A and B some scattered trees of *Quercus ilex* L. were found (Figure 2). In plots B and C, the shrub layer (*Erica scoparia* L.) was scarce, with a cover < 10 %; in plot A, shrubs were absent.

In plot A, wood volume (V), basal area (BA), and canopy cover (CC) were lower than in plots B and C. Indeed, in plot A, where the number of stems was similar to that found in plot B and larger than in plot C, the 36 % of the stems fell in the 5 cm diameter class, which was not represented in plots B and C (Figure 2). The dimensional variation in diameters and heights (SDDBH and SDH) were also higher in plot A than in plots B and C due to young trees of pine in the 5 cm diameter class.

The number of vertical strata was three in plot A (cut-off heights for strata 1, 2, and 3 = 22.3 m, 7.7 m, and 1.8 m, respectively) and two in plots B (cut-off heights for strata 1 and 2 = 22.1 m and 18.0 m, respectively) and C (cut-off heights for strata 1 and 2 = 20.0 m and 7.2 m, respectively).

Table 1 – Structural indicators for each plot.

Plot	N	BA	V	QMD	DH	SDDBH	SDH	CC
	n ha^{-1}	m^2 ha^{-1}	m^3 ha^{-1}	cm	m	cm	m	%
A	84	19.2	283.3	53.9	26.9	32.2	12.8	58
B	82	26.1	365.7	63.7	26.4	5.9	3.2	78
C	64	23.1	315.8	67.9	26.8	12.9	4.0	71

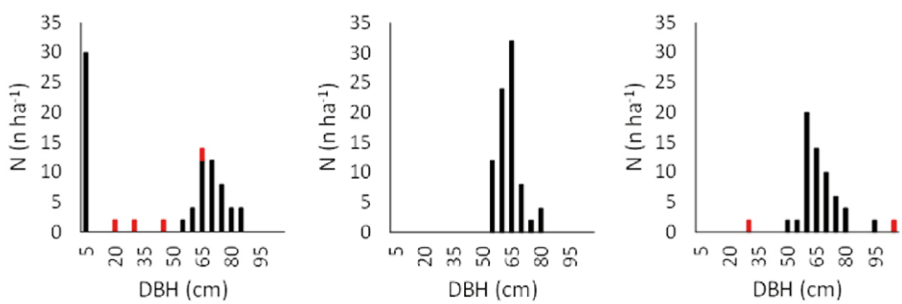

Figure 2 – Stem number–diameter class (5 cm interval) distribution for each plot (*Pinus pinea* L. in black, *Quercus ilex* L. in red).

Natural regeneration

The stem density of the natural regeneration of pine varied between 362 trees ha^{-1} in plot C and 688 trees ha^{-1} in plot A.

Most of the regeneration was represented by seedlings (> 80 % in all plots) and the remaining by saplings. In plot A, where the density of the regeneration was higher than in plots B and C, the regeneration had a greater dimensional variation for diameters, as showed by SD. The regeneration index of Magini (RI) ranged between 3.1 in plot C and 6.3 in plot A (Table 2).

Table 2 – Characteristics of the natural regeneration of pine in each plot.

Plot	N n ha^{-1}	NSE %	NSA %	MD cm	MH m	SD cm	SH m	RI
A	688	82	18	1.7	0.9	1.1	0.4	6.3
B	466	90	10	1.3	0.7	0.8	0.4	3.4
C	362	86	14	1.5	0.9	0.7	0.4	3.1

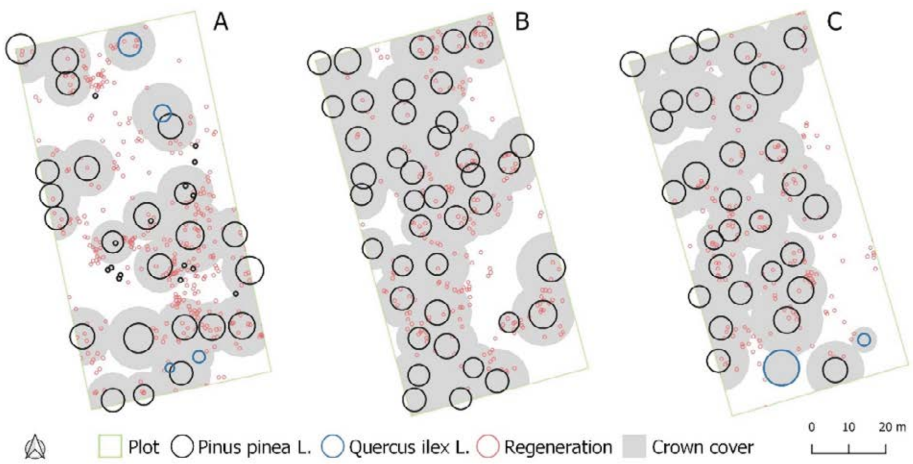

Figure 3 – Spatial distribution of trees in the plots (the circles are proportional to DBH, except for regeneration).

The spatial distribution of the regeneration within the plots was almost uniform, except for some areas corresponding to large openings in the canopy cover due to natural disturbances where regeneration was scarce. The frequency of the regeneration growing below the crown of adult trees was 72 %, 90 %, and 82 % in plots A, B, and C, respectively (Figure 3). This pattern indicates that the regeneration of *Pinus pinea* L. tends to grow within or nearby the influence area of the crown of parent trees, as can be expected from a tree species with heavy seed and a mainly gravity-based dispersal process [22]. Such pattern was confirmed by the results of the bivariate spatial point pattern analysis, which shows that the regeneration was aggregated to trees (DBH > 2.5 cm) in plot A at every distance considered (95 % confidence interval); in plots B and C, the pattern was aggregated at distances between 2 m and 10 m and between 3 m and 5 m, respectively, while the pattern was random at larger distances (Figure 4).

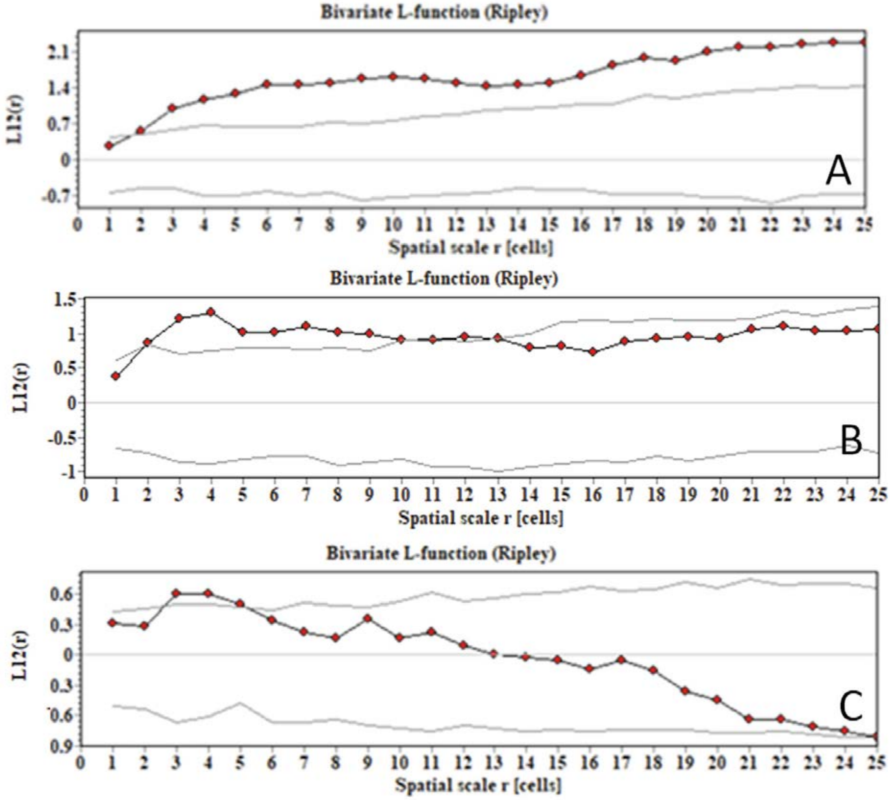

Figure 4 – Results of the bivariate L-function ($L_{12}(r)$) for distances (Spatial scale r) ranging between 1 m and 25 m used to assess the spatial relationships between the regeneration and parent trees with DBH > 2.5 cm. In case of attraction between the regeneration and parent trees, $L_{12}(r)$ is greater than the confidence interval (grey line); in case of repulsion $L_{12}(r)$ is lower than the confidence interval; in case of spatial independence $L_{12}(r)$ is within the confidence interval.

Discussion

The results of our study show that natural regeneration of *Pinus pinea* L. in the Regional Park of San Rossore is possible in pine stands with environmental conditions (e.g., light conditions) and structural characteristics similar to those found in the study plots.

In all plots, the stem number–diameter class distribution was typical of an even-aged stand structure, with wood volume, basal area and canopy cover lower in plot A than in plots B and C.

The highest density of regeneration was found in plot A. Here, the lower number of pine plants with DBH > 20 cm and a lower canopy cover than in plots B and C due to natural disturbances occurred in the past (e.g., lightning and windstorms) have probably favoured the germination of pine nuts and seedlings emergence. It is worth noting that the influence of lightning in opening gaps and encouraging Stone pine regeneration was also reported by [13] for a pine forest in the Regional Park of Maremma, in southern Tuscany.

In our study plots, most of the regeneration was represented by seedlings. However, the percentage of saplings ranged between 10 % in plot B and 18 % in plot A. In addition, in plot A, 36 % of pines with DBH > 2.5 cm were in the 5 cm diameter class (Figure 2), indicating that the regeneration dynamic is in progress.

The establishment of regeneration in *Pinus pinea* forests is affected by stand structure, which is the result of natural disturbances and the type of management carried out in previous years.

Calama et al. [23] found that the most favourable photosynthetic conditions for Stone pine seed dispersal, germination and seedling emergence are achieved in the mid-shaded positions, just below the area of the crown, at least in the initial stages of the regeneration process, although parent trees should be progressively removed to release the young pine trees as their light requirements increase. Aggregation of regeneration within or near to the area of crown influence is also explained by the limited seed dispersal capacity of Stone pine [8]. These findings are in accordance with what we observed in our study plots, where most of the regeneration was under the crown of adult trees (Figure 3) and the spatial pattern of the regeneration was aggregated to parent trees as indicated by the results of the point pattern analysis (Figure 4).

The studies of Manso et al. [24] and Calama et al. [6] report that the even-aged management practices used for the uniform shelterwood system may be behind the failure to support natural regeneration in Stone pine stands, particularly due to the low stand densities and large gap size occurring during the regeneration period. Indeed, due to incapacity to disperse seeds in large gaps created by intensive seed cut and secondary cuts, large areas remain without regeneration for years after the fellings. Although no cuts were carried out in our study area in the Park of San Rossore, at least in the last decades, this seems to explain the scarce presence of the regeneration in the large gaps occurring in plots A, B, and C (Figure 3).

Thus, to ensure seed arrival into gaps, thinning schedules should target to densities of about 125-150 stems ha^{-1} at the beginning of regeneration fellings, and intense fellings (e.g., intense uniform shelterwood system) should be replaced by more gradual fellings [6]. Simultaneously, it may be necessary to control the density of the understory vegetation [13]. However, as an alternative in those locations with abundant advanced regeneration, a shift towards uneven, multi-aged management by means of group selection system should be applied [8, 13, 14].

Conclusions

Natural regeneration-based silviculture has been increasingly regarded as a reliable option in sustainable forest management. However, successful natural regeneration is not always easy to achieve, especially in the Stone pine forests.

In the present study, we report the structural characteristics and the amount of natural regeneration found in a coastal *Pinus pinea* forest in the Regional Park of San Rossore, Central Italy, where regeneration has been historically unsuccessful.

Our results show that natural regeneration of *Pinus pinea* in the Park is a reachable target, although an adequate management is needed to support it. This means that the traditional silvicultural system based on clear cut should be replaced with more sustainable and close-to-nature silvicultural methods.

To this end, we encourage experimental cuts to favour advanced regeneration, by ensuring mid-shaded optimal conditions for seed germination and seedling survival in initial stages of the regeneration process, and preventing the creation of large gaps. Intensive fellings should be avoided and substituted by more flexible schedules, including e.g. shelterwood systems and group selection systems.

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ECOLOGICAL STATUS OF THE TUSCAN ARCHIPELAGO ROCKY HABITATS ASSESSED BY THE *MEDSENS* INDEX

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Abstract – *MedSens* is a biotic index developed to provide information on the environmental status of subtidal rocky coastal habitats, based on data collected by trained scuba diver volunteers using the Reef Check Mediterranean Underwater Coastal Environment Monitoring (RCMed-UCEM) protocol. The index is based on 25 selected species, incorporating their sensitivities to the pressures indicated by the European Marine Strategy Framework Directive (MSFD) and open data on their distributions and abundances.

The large availability of data collected by volunteers using the RCMed-UCEM protocol offered the opportunity to assess the ecological status of the subtidal coastal rocky habitats, including the coralligenous reefs, in the Tuscan Archipelago National Park. *MedSens* index was applied along the coasts of the National Park Islands' (Capraia, Elba, Giannutri, Giglio, Gorgona, Montecristo and Pianosa), providing the mean sensitivity of the assemblages to the physical, chemical, and biological pressures, as well as the overall mean sensitivity of the occurring assemblages. *MedSens* can help conservationists and decision-makers identify the main pressures acting in these coastal habitats, as required by the MSFD, supporting them in implementing appropriate marine biodiversity conservation measures and better communicating the results of their actions.

Introduction

In the Mediterranean Sea, subtidal rocky shores and coralligenous reefs are among the most threatened marine habitats [6]. Environmental quality assessment tools for these habitats, based on the integrity of marine communities, are not only urgent but also essential to fulfil to the European Marine Strategy Framework Directive (MSFD, 2008/56/EC). Marine citizen science (MCS) projects may provide community-based ecosystem monitoring, expanding our ability to collect data across space and time. However, the data from MCS are often not effectively integrated into institutional monitoring programs and/or not effectively used for conservation purposes. This limitation is partially due to difficulties in accessing the

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data and the lack of tools and indices for proper management application at intended spatial and temporal scales. The growing need to assess the environmental status of Mediterranean habitats and the large availability of data collected by Reef Check Mediterranean Sea volunteers along subtidal rocky shores and coralligenous reefs [13] offers the opportunity to apply innovative and reliable indices that may support decision-makers in applying conservation strategies, particularly important for Marine Protected Areas (MPAs). *MedSens* is a biotic index developed to provide information on the ecological status of subtidal rocky coastal habitats, filling a gap between MCS and coastal management in the Mediterranean Sea [12].

The Tuscan Archipelago National Park (TANP) was established in 1980, its major islands are Capraia, Elba, Giannutri, Giglio, Gorgona, Montecristo and Pianosa. The park has a sea surface area of 56 766 ha and is located in the Tyrrhenian Sea. Elba Island (223 km²) is the largest of the Tuscan archipelago islands and is administratively divided into 7 municipalities, which are part of the province of Livorno [17]. In 2021, as part of the NEPTUNE project (submerged natural and cultural heritage and sustainable management of recreational diving, formally "PatrimoNio naturalE e culTUrale sommerso e gestione sosteNibile della subacquEa ricreativa"; http://interreg-maritime.eu/web/neptune), co-financed by the cross-border cooperation program Interreg Italy-France (Maritime) 2014 - 2020, the "ISLEPARK Divers Monitoring Network" was developed. This action aimed to build and consolidate a network of specifically trained scuba dive guides involved in monitoring the ecological status of coastal marine environments.

The aims of this study are to provide an overview of the commitment over the years of volunteers in applying the RCMED U-CEM protocol in the TANP and to assess the ecological status of the area by using the *MedSens* biotic index from 2006 to 2021.

Materials and Methods

Since 2006 trained snorkelers, freedivers, and scuba diver volunteers (hereafter called as EcoDivers; Figure 1) make independent observations along random swim [4] and collect data on the occurrence, distribution, abundance, prevailing habitat, and bathymetric range of selected key marine species along the TANP coasts by using the Reef Check Mediterranean Underwater Coastal Environment Monitoring (RCMed U-CEM) protocol, developed by Reef Check Italia onlus (www.reefcheckmed.org). Not encountered but actively searched taxa are reported as absent, while no data are provided for not searched taxa [1, 14].

The taxa, including algae, invertebrates, and fishes, were selected by a combination of criteria, including ease of identification and being a key indicator of shifts in the Mediterranean subtidal habitats due to local pressures and climate change. Following the ten principles of Citizen Science [5], the dataset collected using the RCMed U-CEM protocol is openly accessible across different platforms according to the FAIR (findable, accessible, interoperable, and reusable) data principles (sensu [18]) [13, 14].

Figure 1 – EcoDiver applying the RCMed protocol (photo courtesy Eva Turicchia).

The *MedSens* index is based on a subset of 25 species, among the 43 available in the RCMed U-CEM protocol, incorporating their sensitivities to the pressures indicated by the European Union's MSFD and open data on their distributions and abundances, collected by the EcoDivers [1, 13, 14]. The species sensitivities were assessed relative to their resistance and resilience against physical, chemical, and biological pressures, according to benchmark levels and a literature review following the marine evidence-based sensitivity assessment approach [15]. The *MedSens* index was calibrated on a dataset of 33 021 observations carried out by 569 volunteers from 2001 to 2019, along Croatian, French, Greek, Italian, Spanish, and Tunisian coasts [12]. A free and user-friendly QGIS plugin was developed to allow easy index calculation for areas and time frames of interest (https://plugins.qgis.org/plugins/medsens).

The *MedSens* index provides the mean sensitivity of the species assemblages recorded by EcoDivers within a territorial unit and time frame. It can be calculated for the physical ($MedSens_{phy}$), chemical ($MedSens_{che}$), biological ($MedSens_{bio}$), and overall pressures ($MedSens_{tot}$) on the species, based on the corresponding mean sensitivity values derived from the sensitivity assessment, weighted for the abundance of the taxa [12].

The *MedSens* index was calculated at the TANP for the overall fifteen years period, from 2006 to 2021. For this purpose, a 2 km radius buffer was created around the coastline of each major island (i.e., Capraia, Gorgona, Giglio, Giannutri, Montecristo, Pianosa, and Elba). The buffer area around the Elba Island, given its extension and the high number of observations available, has been further divided according to its 7 administrative municipalities: Rio, Porto Azzurro, Capo Liveri, Campo nell'Elba, Marciana, Marciana Marina, and Portoferraio.

Results

The number of EcoDivers involved in monitoring the TANP coasts have shown a fluctuating trend over the years. Between 2006 and 2021, an average of 11 ± 3 EcoDivers

(± standard error, se) took part in the surveys. Thanks to the establishment of the "ISLEPARK Divers Monitoring Network", in 2021 the involved EcoDivers were 54 (Figure 2a). Monitoring dives have been carried out in the TANP since 2006, applying the RCMed U-CEM protocol. The years 2014, 2019 and 2021 showed the highest numbers of observations, with 548, 531 and 672 observations, respectively (Figure 2b). The average time per dive dedicated to searching for target species between 2006 and 2021 was 31.3 ± 2.7 minutes (± se). The three years in order in which more time was devoted were 2021 with 43.3 ± 0.2 minutes (± se), 2011 with 47.3 ± 1.1 minutes (± se) and 2017 with 50.1 ± 0.6 minutes (± se; Figure 2c).

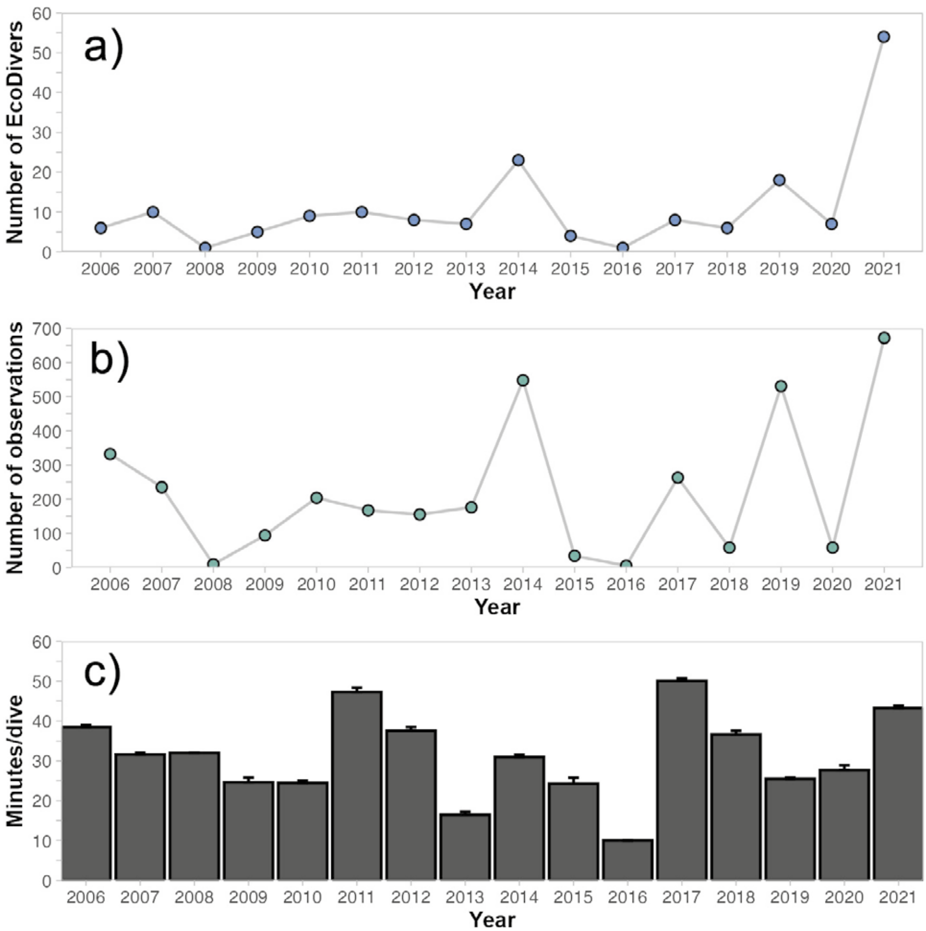

Figure 2 – In the Tuscan Archipelago National Park from 2006 to 2021, applying RCMed U-CEM protocol: a) number of EcoDivers per year; b) number of observations per year; c) mean (+ standard error) time spent searching for species by dive per year.

Between 2006 and 2021, the most searched species was the invasive algae *Caulerpa cylindracea* (Figures 3a, b), followed by the yellow gorgonian *Eunicella cavolini* and the noble pen shell *Pinna nobilis* (Figure 3a).

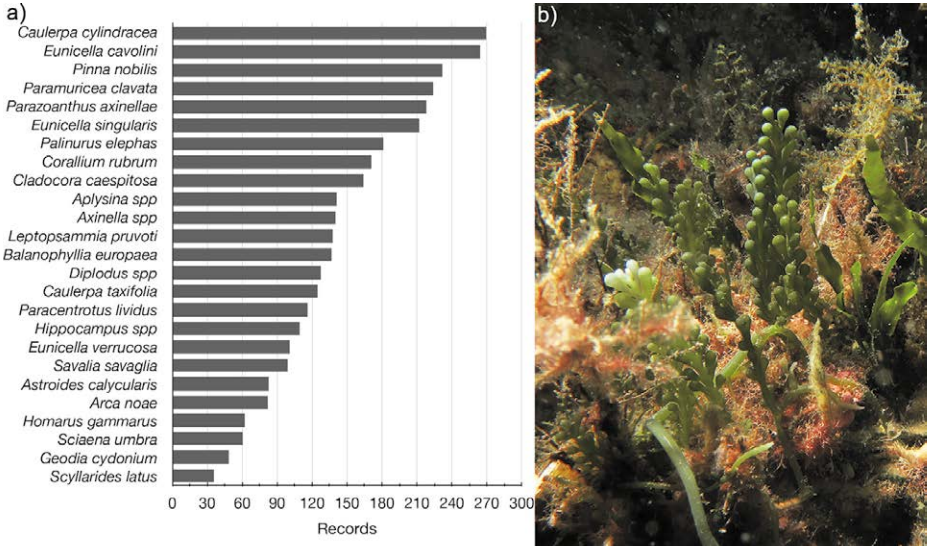

Figure 3 – a) Number of records (including absences) for each target species searched in the Tuscan Archipelago National Park from 2006 to 2021; b) *Caulerpa cylindracea*, Punta San Francesco, Giannutri Island, 2021 (photo courtesy Eva Turicchia)

The *MedSens* index was calculated for the 5 out of 7 major islands, whereas Gorgona and Capraia Islands were not assessed due to lack of data.

In the period 2006-2021, the mean overall sensitivity of the assemblages varies from very high (i.e., at Giglio Island) to very low (e.g., at the municipality of Rio, Elba Island; Figure 4a). The sensitivity of the assemblages to physical pressures also follows the same pattern (Figure 4b). Physical pressures may include variations in salinity or temperature to a decrease in water transparency. The two extremes were represented by Rio (very low sensitivity) and Giglio Island (very high sensitivity). Assemblages characterised by high sensitivity were found at Marciana, Marciana Marina and Montecristo Island. Intermediate values were observed at Capo Liveri and Giannutri Island (Figure 4a, b). Assemblage's sensitivity toward chemical pressures, including for example pollution and organic enrichment, ranged from very low sensitivity (at Rio, Elba Island) to very high sensitivity (Giglio Island; Figure 4c). The sensitivity of the assemblages toward biological pressures (e.g., invasion of non-indigenous species) resulted very high at Giglio Island, whereas at Capoliveri, Campo dell'Elba and Pianosa Island it was low (Figure 4d).

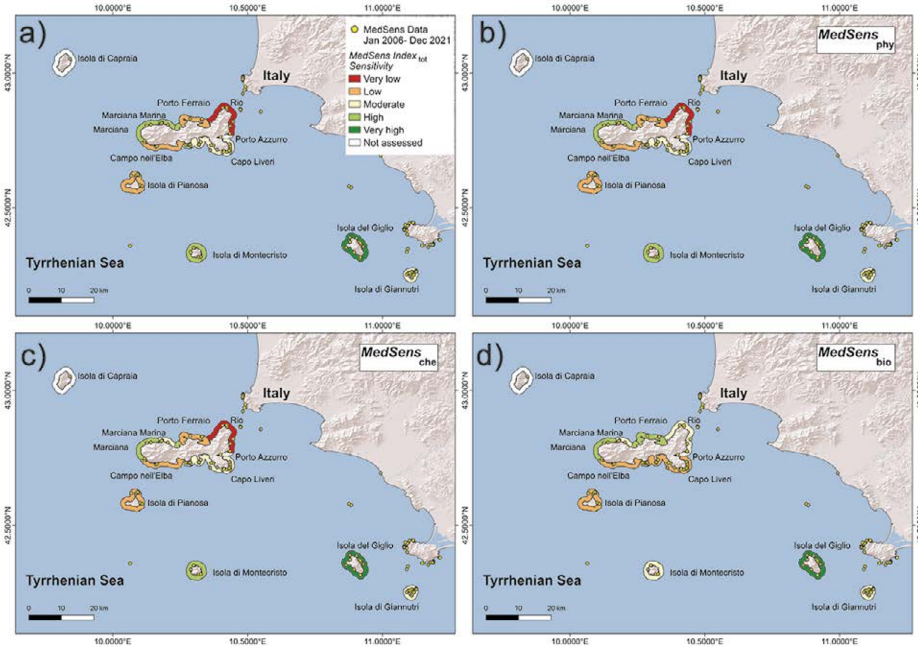

Figure 4 – Sensitivity assessments in the Tuscan Archipelago National Park from 2006 to 2021: a) overall assessment (*MedSens*$_{\mathrm{tot}}$) and physical pressures (*MedSens*$_{\mathrm{phy}}$), b) chemical pressures (*MedSens*$_{\mathrm{che}}$), and c) biological pressures (*MedSens*$_{\mathrm{bio}}$). Yellow dots display Reef Check Mediterranean Sea MedSens data points (WGS 84 EPSG: 4326).

Discussion

Marine citizen science is a promising and powerful tool to enhance engagement in marine conservation worldwide, as envisaged by the United Nations Decade of Ocean Science for Sustainable Development Goals 2021–2030 (SDG 14, Life Below Water). The RCMed U-CEM protocol is a simple but effective visual census with species that encompass the key ecological aspects of the Mediterranean subtidal habitats. It can provide a large amount of timely, up-to-date geo-referenced data. Its data quality is ensured by rigours participant training courses (subject to learning tests), numerous surveys by independent observers, and quality control procedures [1, 13, 14].

By applying the RCMed U-CEM protocol, monitoring dives have been carried out in the Tuscan Archipelago National Park since 2006, with a variable number of EcoDivers involved. In the first years of application of the protocol, few volunteers were involved, probably due to the reduced availability of adequately trained people. In 2021, on the other hand, the number of participants involved largely increased (i.e., 54 EcoDivers), thanks to the commitment of the park administration and the resources provided by the NEPTUNE project. Indeed, the largest number of observations were carried out in 2014, 2019, and 2021, when main EcoDiver training courses were delivered in the region. The discontinuity in promotion and training actions, also due to the COVID19 pandemic in 2020, can largely affect the consistency with which monitoring is conducted. The monitoring effort may also depend on dive location, the divers' certification level and their commitment. Before diving, each participant has to choose which and how many of the 43 taxa will be searched for, according to the expected habitat typology and to personal motivations. This freedom of choice ensures greater attention and accuracy by the volunteers; however, this can generate a different distribution effort among taxa. Indeed, the most searched taxa at TANP were the very attractive species such as the sea fans *Eunicella cavolini*, *Paramuricea clavata* and *Eunicella singularis*, the noble pen shell *Pinna nobilis*, and the yellow cluster anemone *Parazoanthus axinellae*. The non-indigenous green alga *Caulerpa cylindracea* is the most searched at TANP, possibly because it is an easily recognizable organism and well-known invasive species.

The *MedSens* index provides a proxy of the mean sensitivity of the rocky bottom and coralligenous assemblages to natural and anthropic pressures listed by MSFD. Higher average assemblage sensitivities are associated with low levels of disturbance, thereby indicating good environmental conditions. It is particularly suitable for monitoring marine national parks and other protected areas or specific dive spots. However, it is not intended to replace detailed studies and the indices applied by professional researchers [2, 3, 8-10, 16], but it can complement professional investigations in spatial gradient analysis, time series analysis, and before/ after-control/impact studies. Moreover, the QGIS plugin provides an easy freeware tool to calculate the index whenever data are available.

Giglio is the second-largest island in the Tuscan Archipelago. The island is less than 15 km west of the Mount Argentario peninsula and hosts less than 2000 inhabitants [17]. Besides the proximity to the coast, the high tourist influx, and the lack of specific marine protection measures, Giglio showed the highest sensitivity values of the assemblages (i.e., very high sensitivity) both for the overall sensitivity and for the physical, chemical, and biological pressures. Here, the Costa Concordia ship grounding may have caused some local impacts on the rocky coastal assemblages, but a detailed analysis with the *MedSens* index is beyond the scope of this paper. Montecristo Island shows overall high sensitivity of assemblages especially toward physical and chemical pressures despite a recent gorgonian mass mortality [11], however here data is strictly limited to a few scientific dives, since its inaccessibility. On average, the sensitivity of the assemblages at Giannutri Island was moderate. This result could be due to the lack of data in the no-entry/no-take area. *MedSens* index detected a low sensitivity of the assemblages at Pianosa Island; this unexpected result is probably due to the morphology of the island's seabed that alternates stretch of rocks with posidonia meadows and sandy bottoms [17], for which the application of the index is not well suited. At Elba Island, the assemblage sensitivities ranged from low to high. The Rio municipality section had the lowest mean species sensitivity, especially as concern physical and chemical pressures. This may be related to the marine traffic to/from Piombino and the legacy from ancient iron mines activities [7]. The area of the Elba Island facing the Italian mainland (i.e., Rio) have achieved worse results in terms of sensitivity of the assemblages, perhaps because they are affected by greater human pressures.

Conclusion

Based on the RCMed U-CEM open-access dataset, the *MedSens* index represents a bridge between MCS and coastal management in the Mediterranean Sea, allowing the effective integration of lasting community-based environmental monitoring into ecosystem-based management policies. *MedSens* converts the data collected by trained volunteers into an effective monitoring tool for the Mediterranean subtidal rocky coastal habitats. It can help conservationists and decision-makers identify the main pressures acting in these habitats, as required by the MSFD, supporting them in the implementation of appropriate marine biodiversity conservation measures and better communicating the results of their actions.

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SESSION

UNDERWATER AND COASTAL CULTURAL HERITAGE

Chairperson: Marinella Pasquinucci
University of Pisa

UNDERWATER AND COASTAL CULTURAL HERITAGE

The session "Underwater and coastal cultural Heritage" covers specific aspects of the tangible and intangible cultural heritage concerning the coastal areas and related seabeds. A wide spectrum of archaeological, historical, geographical, landscape subjects is considered both in a multidisciplinary and in diachronic perspective.

The papers here published were selected by the Symposium scientific Committee either for oral or poster presentation at the meeting. They investigate several Italian districts applying different approaches and cover a wide chronological range from Prehistory to the present.

Archaeology, landscape archaeology, urbanism, territorial planning, architectural, anthropological/identity studies are represented and thoroughly linked with the coastal heritage development and protection.

Following an ideal chronological thread of the contents, in this brief introduction I highlight *just some of the topics* that make each of these contributions worthy of attention by researchers and local authorities with various expertise.

In *Making a site otherwise inaccessible accessible: 3D laser scanner scanning of the Grotta dei Cervi di Porto Badisco in Otranto (LE)* Giovanna Muscatello and Carmine Mitello focus on the famous numerous pictograms which decorate part of the cave. They are dated to the 5th-4th millennium BC and interpreted as propitiatory scenes of deer and wild boar hunting, initiation and religious rites. The 3D laser scanner survey performed in the cave provides a complete digital archive of the complex and relates it with the external environment. The extraordinary corpus of collected images allows the digital preservation of the very fragile figurative apparatus. Moreover it provides scholars, policy makers and the public with extensive documentation for further studies and the enhancement of the cave. In other words, an inaccessible site becomes virtually accessible.

In *Natural Resources and Coastal Productive Settlements in Southern Puglia* Patrizia Tartara examines the substantial results of systematic researches in the Tavoliere and the Salento peninsula which largely increase our knowledge of coastal sites often dated from the Ancient Bronze Age to the modern one. Contacts with the Aegean world are documented since the early Bronze Age. Very consistent heaps of murex (*Phyllonotus trunculus*) associated with large quantities of specific ancient finds document the collection of molluscs and the subsequent production of purple in several sites. The author examines productive/economic

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Laura Bonora, Donatella Carboni, Matteo De Vincenzi, Giorgio Matteucci (edited by), *Ninth International Symposium "Monitoring of Mediterranean Coastal Areas: Problems and Measurement Techniques". Livorno (Italy) 14th-16th June 2022*, © 2022 Author(s), CC BY-NC-SA 4.0, published by Firenze University Press, ISBN 979-12-215-0030-1, DOI 10.36253/979-12-215-0030-1

activities connected with purple in a longterm perspective including the Roman period and Late Antiquity. Such sites are particularly at risk because of tourism and uncontrolled urbanization, therefore these researches are fundamental also to document and safeguard the coastal heritage.

In *The port of Neapolis: memories and traces of the coastal landscape in ancient times,* Clelia Cirillo , Giovanna Acampora, Luigi Scarpa, Marina Russo, Barbara Bertoli and Loredana Marcolongo stress the importance of the archaeological excavations and related geognostic surveys carried out in Naples on the occasion of the construction of two new subway lines in the late 20th-early 21stcenturies. The digs were conducted and thoroughly published by the Soprintendenza Speciale per i Beni Archeologici di Napoli e Pompei. These complex archaeological interventions remain exemplary for the technical complexity, the relevance of the scientific acquisitions and the strict relationship with public works. To be noted: they were carried on long before the current rules governing public works came into force and brought extremely significant acquisitions for the knowledge of the ancient city; e.g. the Greek-Roman port re-emerged with its docks and wrecks. As shown by the integrated researches, the transformations of the Neapolitan bay shorelines depended on anthropic and natural phenomena including bradyseism and silting.

In *The building materials of "Rocca Vecchia"("Old fortress") in the Gorgona Island*, Fabio Fratini, Francesca De Vita , Daniela Pittaluga and Silvia Rescic focus on the construction materials used to raise the Rocca Vecchia (Old Fortress), built by the Republic of Pisa in the Gorgona Island in the 13th century. Special attention is given to the composition of the bricks, bedding mortars, plasters and renders, in order to identify the various phases of construction and the origins of the raw materials. The research shows they come partly from the island and partly from the opposite Tuscan coast. These results will be useful both for historical studies and for future preservation and restoration works. The latter could be part of a project of activities in which to employ a group of the local jail prisoners, who could also be dedicated to the subsequent manteinance.

In *The Torre del Marzocco and the widening of the entry channel to the industrial port of Livorno,* Enrico Pribaz, Ilaria Lotti, Raoul Raffalli and Pietro Chiavaccini describe an important plan drawn up by the North Tyrrhenian Sea Port Network Authority. It regards the Marzocco tower and part of the harbour area north of the city. The well known watchtower, dated to the 15th century and subject to the Italian laws for the protection of the historical and cultural heritage, symbolizes the past, the present and the future of the city, rooted in its port activities. The project aims to redevelop and renovate the ancient marine landscape area: a water basin will be created around the Marzocco tower basement and the entry channel to the port will be widened, in order to secure the access of the great ships of new generation to the industrial area of the port.

In *Territorial transformations, landscape and architectural features of the "Tenuta di Isola Sacra" in the reclamation of the early 1900s*, Maria Chiara Alati examines the transformations of the territory of Isola Sacra (Agro Romano) in the period between the earliest reclamation actions started by the Genio Civile around 1885 and the complex reclamation works aimed at promoting agriculture carried out by the Opera Nazionale Combattenti (1920-1950 ca.). Based on graphic and photographic archive documentation, Alati recomposes a diachronic picture of this territory located between the archaeological/environmental system constituted on one side by ancient Ostia, Portus and the imperial Ports of Claudius and Trajan, and on the other by the international airport Leonardo da Vinci. Here many relevant architectural and landscape features were cancelled by uncontrolled transformations in the last decades. The research provides data of particular importance for the preservation and enhancement of this area characterized by extraordinary potentialities of a sustainable valorization but exposed to strong anthropic pressure.

In "*Massa Lubrense coast and its modifications during the twentieth century*" Barbara Bertoli, Marina Russo , Loredana Marcolongo and Clelia Cirillo analyse the anthropogenic activities that have modified the landscape in some stretches of the Massa Lubrense (NA) coast embracing the two sides of the Sorrento and Salerno gulfs, naturally divided by Punta Campanella. The exceptional landscape values of this district began to be altered in the early 20th century due to the progressive emergence of new models of economic development. Quarries opened for the extraction of limestone in some of the most beautiful inlets of this coastal stretch, easily accessible by cargo boats, modified the coastal structure. They were closed only in the 1970s. In the second half of the 20th century the building activities related to seaside tourism have definitively transformed the landscape and the environmental values of the district. The research is based on documents preserved in the Archivio storico of the Massa Lubrense Municipality and in other archives, and on the vast repertoire of images related to mass tourism.

In her paper "...In finibus Lucaniae. *Historical cartography of the Thyrrhenian coast and demographic fluctuations*" Antonella Pellettieri focuses on the coastal stretch located on the border between Basilicata and Calabria, more precisely between Castrocucco di Maratea (Basilicata) and Praia a Mare-Fiuzzi with the opposite island named Dino (Calabria). Pellettieri examines the history of the settlements and their population. She investigates the birth, depopulation and disappearance of some sites, and the cases in which the population settled on the coast abandoning the high ground sites or vice versa, as well as the impact of recent cultural and seaside tourism.

In her paper *Tuna: underwater natural and cultural heritage.The* Tunèa *case study, a project for the re-connection between coastal community and marine ecosystem*, Maria Pina Usai faces a cultural/anthropological/economical problem: the progressive thinning of the traditional strong relationship between a coastal community, in the specific case Carloforte (San Pietro Island, Sardinia) and the sea, caused by the changes in fishing regulations and the resulting tuna market at a global scale. The Carloforte tonnara is one of the last fixed tuna traps in the Mediterranean Sea, located on the route of the Eastern Atlantic Bluefin Tuna (*Thunnus thynnus*). Tuna fishing and the tonnara practice have strongly linked the culture and some specific buildings of Carloforte to its sea. The project *Tunèa* was created by Usai in order to involve the entire community and a group of artists and researchers in understanding if and in what ways it is possible to re-create the relationship between a coastal community and the marine ecosystem, with a view to sustainable development from an environmental, social and economic point of view.

As mentioned above, this concise Introduction is aimed at highlighting only some central topics covered in the various contributions to researchers and local authorities with various competencies.

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TERRITORIAL TRANSFORMATIONS, LANDSCAPE AND ARCHITECTURAL FEATURES OF THE "TENUTA DI ISOLA SACRA" IN THE RECLAMATION OF THE EARLY 1900s

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Abstract – This paper presents the early acquisitions relating to the transformations of the territory of Isola Sacra, in the Agro Romano, between the end of the 19th century and the first half of the 20th century, implemented through the land reclamation and enhancement work initiated by the Genio Civile, and definitively completed by the *Opera Nazionale Combattenti* (O.N.C., Soldiers' National Foundation).

The paper describes, also by means of the graphic and photographic documentation preserved in the archives, a crucial phase of the territorial development of the area, which left deep traces, although they are not easily recognizable. Added to this, it recomposes an overall image of a context that, faster than others, in the course of the last decades has been suffering from the effects of an often-unguided transformation and in which it is difficult, today, to identify the signs of a past as recent and significant as it has been obliterated in many of its architectural and landscape features.

Today appreciated and known, above all for its immeasurable archaeological treasures, including the Necropolis, the Matidia Baths, the Portuense Iseo, the early Christian Basilica of S. Ippolito, this territory testifies of an importance that lasted centuries, also bound by its landscape values. In this sense, the protection and enhancement it requires must also pass through the rediscovery of historical events and landscape features that have defined the most recent structure.

The study examines the period between the first reclamation actions, started around 1885 by the Civil Engineers, and the vast transformation work for agricultural use carried out between 1920 and 1950 by the O.N.C., the "Tenuta di Isola Sacra" being one of the widest created in this period. These transformations, investing all aspects of the territory, from reclamation infrastructure and roads to vegetation asset and architectural characters, were decisive for the structure of the area.

The research is still in progress, aiming to frame either the economic and social development of the area and its most recent transformation, in view of the strong requirements it shows in terms of protection and cultural enhancement.

In fact, the strategic role of the area for its pivotal position between the archaeological and environmental system, constituted from ancient Ostia with the imperial Ports of Claudio and Traiano on one side and the international hub of the airport Leonardo da Vinci on the other, exposes Isola Sacra to strong anthropic pressure**.**

At the same time this role can offer extraordinary potentialities of a sustainable valorization, if guided by a deep understanding of the identifying and structuring characters that render this place still unique, from the historical and the landscaping point of view.

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Introduction

Known as Isola Sacra since antiquity, the coastal belt portion is bounded on its eastern and southern borders by the terminal stretch of the Tiber, called Fiumara Grande, and on its northern border by the artificial canal of Fiumicino, well known as Fossa Traianea or Fiumara Piccola, whose excavation was due to the construction of the imperial ports of Claudio and Traiano.

This little landscape portion, entirely bounded by the waterways leading the commercial routes to Rome, was between the city of Ostia, first colonial expansion and commercial harbor of Rome, and the great settlement of Portus, risen with the construction of the imperial harbors of Claudio and Traiano, as one of the most important commercial hubs of the Mediterranean Sea. [16-17-18]

The territory of Isola Sacra is nowadays much more expanded towards the sea than in the imperial age, due to the progressive advancement of the coastline (about 4 km) for the fluvial sedimentation [23, 25]. Its morphology and extension were also transformed by a violent flood of the Tiber in 1557, that definitely diverted the course of the river, cutting out a large meander and separating the intercluded portion of land from Isola Sacra.[1]

A prosperous and populated land in the imperial period, as shown by the relevant archaeological findings [14], Isola Sacra suffered from the decline of Ostia and Portus and slowly turned into one of the several marshes and malarial areas, sparsely inhabited, along the Tyrrhenian coast.

After a century-long neglect, in the framework of the politics of “integral reclamation” of land, pursued by the Italian Government [11], Isola Sacra was object of massive interventions of hydraulic and agricultural reclamation, to bring it back to agricultural productivity. The main part of this activity was realized in the context of the huge effort of economic and social reconstruction of the country following the Great War. [19-21]

A declared priority of these interventions was the reintegration of veterans in society and in the productive life of the country, which in this period meant, above all, agriculture. This proposal was mainly purchased by the activities of the O.N.C. [2]

Figure 1 – Reclamation areas in the Pontine countryside. Isola Sacra is circled in red [19].

Materials and methods

Moving from the direct knowledge of the existing asset of the territory with its historical and landscape values[1], the research is mainly based on the analysis of archival documents kept in the Central State Archives (A.C.S), and in the archives of the Archaeological Park of Ostia Antica. In particular, the work was addressed by the photographic documents and the projects in the archives of the Opera Nazionale Combattenti (O.N.C. or Soldiers' National Foundation), sited in ACS[2]. These documents allowed to reconstruct the details of the infrastructural and architectural development, that substantially was completed in the late 1950s. The intention is to identify and possibly preserve what is still remaining despite the recent transformations in the area. Particular attention is also paid to the architectural aspects by identifying, through the archive sources and the original projects, the architectural typologies of rural buildings adopted in this area, with the different "models" of rural houses that are repeated in the farms, together to the agricultural annexes, functional to the activities, also in order to identify the buildings that still exist despite extensions and transformations.

Results

The Opera Nazionale Combattenti

The O.N.C. was established in 1917, in the framework of the initiatives aimed at supporting and reintegrating war veterans.

Initially O.N.C. operated through measures of early unwinding of insurance policies or the granting of guaranteed loans to veterans, with the general tasks of financial, technical and moral assistance. After the approval of its Statute and Legislative Regulation, its purposes and sectors of activities were definitely outlined: *"The Opera […] helps to promote the technical, economic and civil conditions which will enable the nation's labour force to become more productive"*.

Assistance was subordinated to the general objective of the reconstruction and development of the national economy. The branches of activity are: social action; financial action, through guaranteed loans for farmers, artisans and little entrepreneurs; agricultural development. This will soon become the main activity of this institution.

According to its legal system, the O.N.C. had legal personality under public law and autonomous management, like a semi-public body. It operated with autonomy, albeit under the Government supervision, not only with the scope of individual assistance, but primarily of the "national reconstruction" by means of agricultural development. [20]

In the framework of the laws for land reclamation, promulgated since the last decades of the 19th century, a large campaign of expropriation of fallow land for public benefit was launched. It concerned lands formerly subdued to reclamation obligations that

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[1] In addition to several archaeological bonds, Isola Sacra is submitted to landscape direct bonds. DM. 22 may 1985, Declaration of considerable public interest of Isola Sacra and Casale Santa Lucia; State Natural Reserve of the Roman Coast - DDMM. 428 of 28.07.87 - 29.03.96.

[2] ACS Archivio Centrale dello Stato, Fondo Opera Nazionale Combattenti,Servizio Ingegneria, Serie Progetti (A.C.S., Fund O.N.C. Engineering Service, Project Series. In italian in the footnotes).

the owners had not completed or realized at all, or that are left uncultivated. Actually, it means that expropriation primarily should have affected latifundium [3-4-5-6].

The territory and landscape of Isola Sacra between the end of 19th century and the early 20th century

Like most of the Lazio coast, at the end of the 19th century, the area of Isola Sacra was swampy and almost completely uninhabited. The reclamation of the area, already planned by law in 1876[3] started in 1885 with some hydraulic arrangement activities implemented by the Civil Engineers, following a mixed system. The estate was divided into two areas, one with natural drainage remediation, the other with drainage due to mechanical exhaustion. The heart of the system was the network of main and secondary collectors and, most of all, the dewatering pumps for exceeding waters, necessary in the second area, closer to the sea, swampy and malarial[4].

After the hydraulic draining was executed, land owners, united in consortia, were committed to complete the minor reclamation interventions, such as ditches and drainage

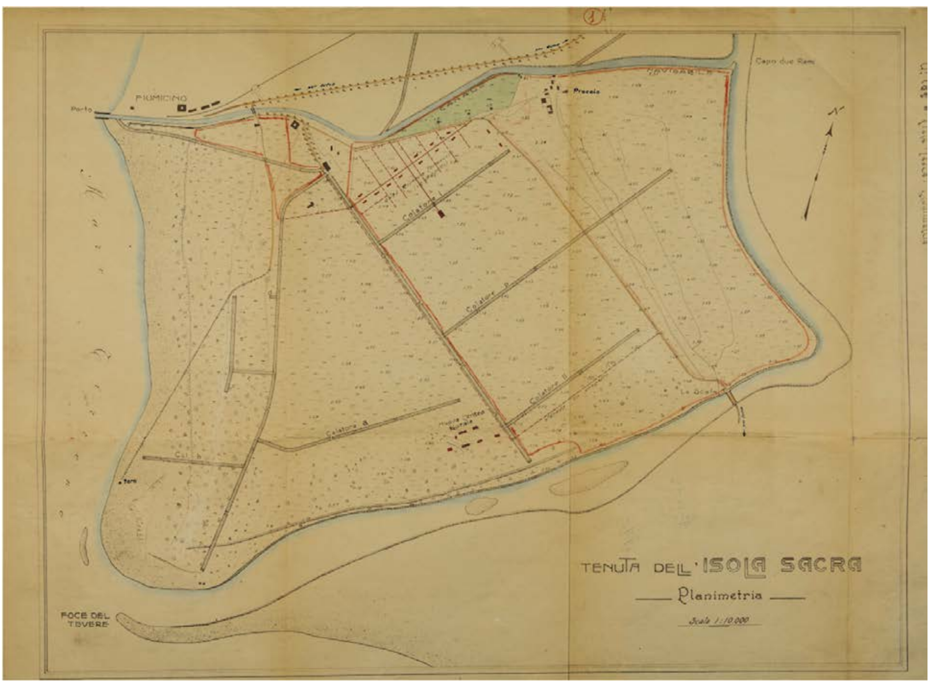

Figure 2 – Tenuta di Isola Sacra. Land reclamation and colonization project, 1922[5].

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[3] L.11 Dec 1876[3] No. 4642, 2nd series, for the Reclamation of the Agro Romano.

[4] A.C.S.,Fondo Opera Nazionale Combattenti. Servizio Ingegneria Serie Progetti, B 266, Land reclamation and colonization,1922, Report.

[5]A.C.S., Fondo Opera Nazionale Combattenti. Servizio Ingegneria Serie Progetti, B 266, All1. General plan. There are reports of the water reclamation carried out by the Civil Engineers in 1885.

channels for the runoff of standing water in the individual properties. The owner, the Marchesa Guglielmi, did not fulfil her obligations; in 1914[6], Isola Sacra was subdued to the *Testo Unico sul bonificamento dell'Agro Romano* and was assigned to the O.N.C. [7]

O.N.C.'s projects

The first land reclamation and colonization project of the O.N.C. offices was filed on May 15, 1922[7]. It describes with accuracy the situation of the estate, illustrating the previous interventions and the presence of pre-existing buildings for agricultural uses, in bad conditions and in need of renovation. At that time the estate was already divided into Reserves, left for the most part uncultivated or to pasture[8]. Exceptions are: S. Biagio and Cioccati, rented and cultivated with wheat and oats; Reserves of Casone, Ponti and Capo due Rami di sotto illegally occupied by former combatants from Fiumicino, ploughed and partly sown (for 110 ha); Riserva del Crocifisso, occupied and cultivated with wheat (for 10 ha); Riserva del Torraccio (7 ha) granted as sharecropping and always cultivated with fruit trees. The "pools" are still present, permanent marshy areas scattered in several parts, not only in the coastal area. The report mentions at least 13 major ones and mentions other minor ones.

The coastal area, *"in the past always used as pastureland, is by siliceous nature, with very marked dunes and is a thankless and sterile soil. In this part alternate areas infested with asphodeles with brambles, brooms and other weeds"*[9]. The estate is also totally devoid of drinking water, which is brought from Ostia or Fiumicino with barrels. The water for the animals is collected in cisterns and raised by pumps with wind engines, existing in number of 10.

The technical report enclosed in the project mentioned: *"At this date, a small number of buildings, some of which were already in existence, were equipped with the estate: the Torraccio; little house near the pontoon bridge; barns near the Church of the Crucifix; a little*

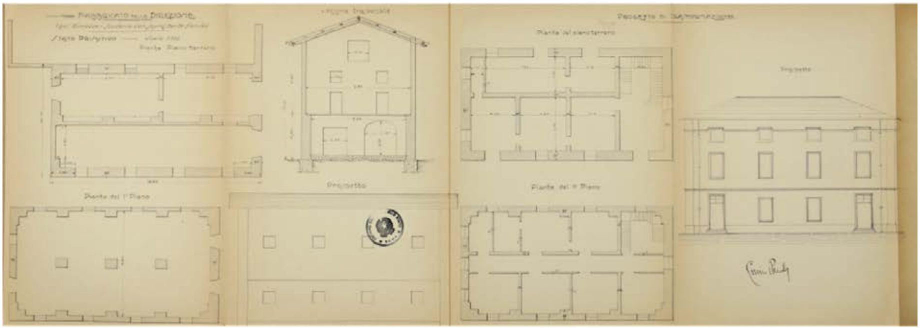

Figure 3 –Land reclamation and colonization project, 1922. Building of the Direction[10].

[6] With Royal Decree n.200 (1914, 15 February).
[7]A.C.S., Fondo Opera Nazionale Combattenti. Servizio Ingegneria Serie Progetti, B 266. Land reclamation and colonization project, 1922.
[8]A.C.S., Fondo Opera Nazionale Combattenti. Servizio Ingegneria Serie Progetti, B 266., All.2. The Reserves.
[9]A.C.S., Fondo O.N.C., Servizio Ingegneria Serie Progetti, B 266, General Report.
[10]A.C.S., Fondo O.N.C., Servizio Ingegneria Serie Progetti, B.266, All.8.a.

house for temporary staff towards Ostia; the group of building near the Procoio (now called S. Ippolito, ndr) with little the two storey houses of the "Massaro" (the farmer, ndr), the house of the "facocchio" (who builds or repairs carriages); stable for calves; butter processing room; room for the processing of butter, not registered, with the entrance to a labyrinth of caves. Near "Tenuta di mezzo"a building under construction…" All premises are not in good conditions".

The O.N.C plan provided to divide the Estate in two parts, each one headed by a Rural Centre; the first one in the area of Procoio, near the canal, the second one near the Scafa Bridge. This one, in the overall plan is defined "New Rural Centre". A third part of the estate was devolved to semi-wild breeding, and headed by Torraccio, where some barns already existed. In a second moment this part should have been divided into 3 ha vegetable plots to be equipped with a house and ancillary buildings, a little stable, and awning.

In this regard, an application for license for water withdrawal from the Canal was submitted in March 1922 to turn part of the area into orchards through two water lifting systems (one at the bridge of boats, the other one facing the Cemetery of the Port of Fiumicino).

The idea of "integral land reclamation"[11], developed as an essential element of the socio-economic policies in Isola Sacra is achieved in a series of project that complete the Hydraulic drainage with agricultural colonization. The complete set of infrastructures necessary to lead the resettlement and cultivation of the area: roadways and farm roads, drainage ditches, irrigation systems, rural an residential buildings, schools, either trees planting along the streets.

A few years later (June 15th, 1927)[11] the project for the system of farm roads, partly on natural background, partly with a crushed stone surface, was developed. It included the construction of another group of farmhouses adjoining the plots, silos for the products, the primary school[12]. This project is followed shortly after by another one concerning the general irrigation system and canals[13]. It provided a secondary network of canals, linked to the primary canals, water lifting cabins, a loading tanks and intake works, like the one that is still visible near the Terme di Matidia. It is completed by the empowerment of the irrigating system of the vegetable gardens of Torraccio, near the canal, which existed since 1922[14].

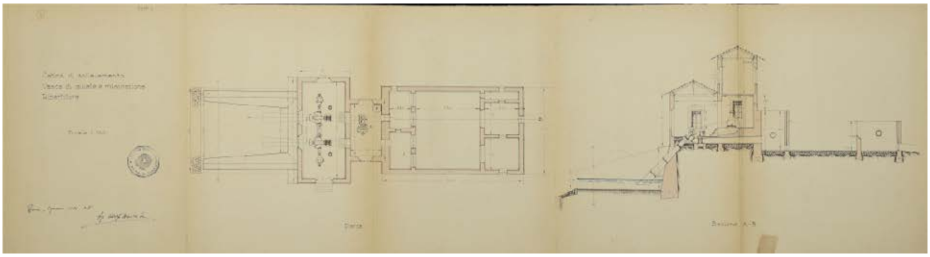

Figure 4 – Lifting cabin. Gripping work, loading tank and distribution[15].

[11]A.C.S., Fondo O.N.C., Servizio Ingegneria Serie Progetti,B 267, Fasc.2. Project of farm roads for the Estate of Isola Sacra, Roma 15 June 1927.
[12]A.C.S., Fondo O.N.C., Servizio Ingegneria Serie Progetti,B 267, Fasc.2, all. 6,7,9.
[13]A.C.S., Fondo O.N.C., Servizio Ingegneria Serie Progetti,B 268.
[14]A.C.S., Fondo O.N.C., Servizio Ingegneria Serie Progetti, B 271.
[15]A.C.S., Fondo O.N.C., Servizio Ingegneria Serie Progetti, B 268, all. 9.

At that time, the drainage of the several swamps widely disseminated around the estate was yet uncompleted. The pools, as they are called on the maps and documents, needed grave digging or filling according to their position and conditions, with huge and expensive earth moving, as included in a project of 1930; the swamps are obviously predominant in the Western part of the estate, the coastal side, the most insalubrious and difficult to cultivate, and the last one to intervene in.

Between 1936 and 1939[16], two projects are conceived to bring and distribute drinkable water to 14 farms and plots, including the construction of another 12 farmhouses, two stables, shelters, and some rural buildings. This farmhouse plans show the strong influence of rationalist architectural language, although, in the reality, the farmhouses will be built in traditional shapes, using two prevalent distribution and dimensional types.

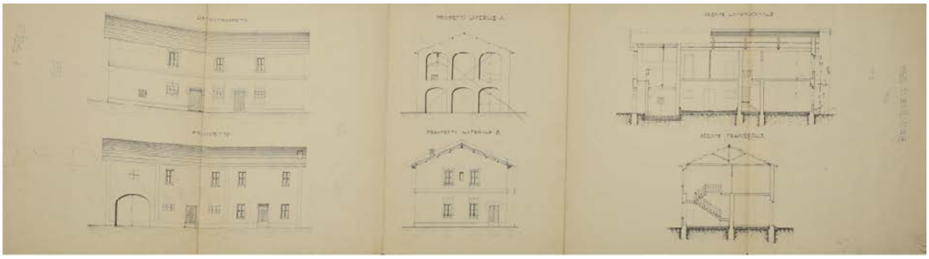

Figure 5 –Tenuta di Isola Sacra. Farmhouse with adjoining farm of 20 ha,1927.

The land reclamation works allowed the archaeological discovery of one of the most significant sites of the area, the ancient Necropolis of Portus, along the Via Flavia. The ancient structures were widely excavated in a huge archaeological campaign lead by Guido Calza between 1925 and 1930; and inaugurated in 1934[17]. The event appears in ideal conjunction with the enormous effort spent to complete the excavation of Ostia Antica in time for the great Universal Exposure of Roma in 1942 (E42). [8-9]

In the documents, films and photographs of this period, the Rural Centre of Procoio appears to be totally completed. The complex is shown entirely in some perspective views preserved in the Ostia Archives, deployed with new buildings and with the three silos that, still nowadays, make it visible from all over the surroundings.

The farm centre completion marks the definition of the general asset of the area yet before the World War Two. In the same way are detailed, beside the agricultural asset, the landscape, architectural, vegetal characters and the first elements of the archaeological landscape.

After the conflict, the interventions are mostly finalized to restore buildings, structures, and plantations seriously damaged by the war. The main damages were caused by the floods, provoked in order to stop German troops in the first months of 1944. The floods involved more than 600 ha of land.

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[16]A.C.S., Fondo O.N.C., Servizio Ingegneria Serie Progetti, B 272, all. 9.Project for the construction of 12 farmhouses; all.10 Distribution network for drinking water supply to 14 farms.

[17] Cfr. Archivio Istituto Luce, Serie Foto attualità, codice foto: A00057658, A00057659.

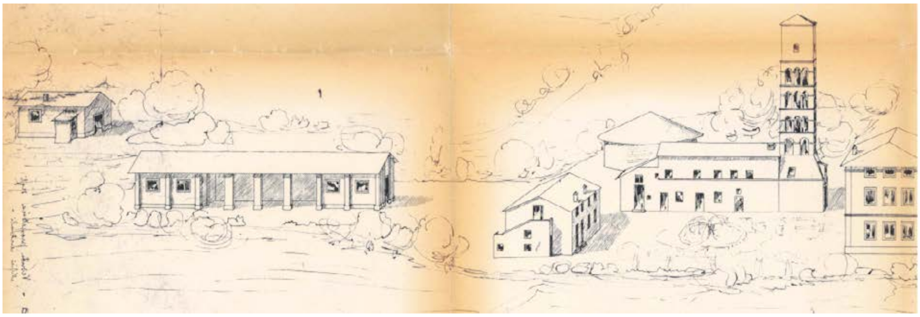

Figure 6 – The Farm centre near Procoio, near the chapel and tower of S. Ippolito.

One of the last relevant architectural and functional interventions was the construction, in 1946-47, of a great factory for the processing and conservation of tomatoes produced in Isola Sacra. The construction was led by O.N.C. through the Società Industrie Lavorazioni Prodotti agricoli (S.I.L.P.A., Society of Industries processing agricultural products) owned for 99,5 % by O.N.C. It was established along the main street connecting Isola Sacra with Ostia e Fiumicino, now leading to the International Airport Leonardo da Vinci.

A little Church, commissioned by the settlers for a vow during German occupation and dedicated to the Madonna del Grano (Our Lady of Grain), was also built in these years.

After these last efforts in reconstruction, maintenance and land improvements went on at a reduced pace. This historical phase ideally concluded on February 12th, 1955, when the settlers received the property acts for their plots and officially became owners.

O.N.C. retains the ownership of some buildings, in particular the ones of the Rural Center. In the seventies, due to the archaeological findings of the basilica di S. Ippolito, near the chapel in Procoio, part of the land and buildings are transferred to Minister for Cultural and Environmental Affairs; the remaining part passes to Regional property offices, which still own them.

Conclusions

Although Isola Sacra is known mostly for the importance of its archaeological remains, and for its strategic position in the coastal area between Rome, the airport and the sea, its importance is also bound to its environmental and landscape values and to his recent historical events, that that have defined its actual landscape structure.

Its factual protection and enhancement, however, can only go through the rediscovery of historical events and the transformations that have determined its structure and the most recent landscape features. These are strongly determined by the presence of waterways and the combination of reclamation infrastructures, agricultural fabric, and rural construction, now incorporated into recent building fabrics to the point of being almost no longer recognizable.

Without a path of collective and shared cultural re-appropriation, able to give meaning and continuity to the historical, architectural and landscape values still present in this territory, no protection and no exploitation can never be effective and sustainable.

Figure 7 – General asset of Isola Sacra in 1955[19].

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MASSA LUBRENSE COAST AND ITS MODIFICATIONS DURING THE TWENTIETH CENTURY

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Abstract – This contribution, which comes from the study experiences of the research group The Landscape in Laboratory (*Il Paesaggio in Laboratorio*) (CNR – IRET), aims to analyse the stages of the anthropogenic activities that have marked and modified the image of some stretches of the coast of Massa Lubrense during the twentieth century.
The gradual impoverishment of the identity matrices of this "enchanted" place, the land of Ulysses and the mermaids, the destination of travelers and writers of every age, is the result of the progressive affirmation of new models of economic development. At the beginning of the twentieth century, the strong landscape values that through the centuries had defined the originality and uniqueness of this territory began to be altered; following the mining activities, the coast was literally devoured and modified in its secular structure.
During the second century the construction of bathing establishments, hotel complexes, private parks for second homes, not regulated by careful planning, has changed definitively the environmental and landscape parameters of this wonderful coast.
Both through the rich archival documentation, partly found during the research in the Historical Archives of the Municipality of Massa Lubrense, and through the vast repertoire of stereotyped images related to the phenomenon of mass tourism, we intend to analyze situations and cases that in the second half of the twentieth century changed the coastline in the two sides of Sorrento and Salerno.

Introduction

The natural theater that embraces the twenty kilometers of the suggestive Massa Lubrense coast is a variegated hilly landscape. The place is characterized by cultivation of olive and citrus trees sloping down to the sea, sometimes consisting of rocky ridges, and a wild spontaneous vegetation typical of the Mediterranean that is reflected in the blue sea. The progressive depletion of the coastal landscape identity began in the early twentieth century when, following the mining activities, the coast was literally devoured and modified in its secular structure.

In the twenty kilometers of the Lubrense coast, from Puolo to the Crapolla fjord, six quarries were opened for the extraction of limestone. Strategically, the quarries arose in the most sheltered bays and easily accessible by cargo boats and represent some of the most beautiful inlets of this coastal stretch.

The more sheltered bays, later converted for new activities related to the increase of tourism, changed again their identity and image. From the second half of the twentieth century, the building of bathing establishments, hotel complexes, private parks for second

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homes, not regulated by accurate town plan, have definitively changed environment and landscape of this wonderful coast. In fact, the coast embraces the two sides of the Sorrento and Salerno gulfs, naturally divided by Punta Campanella, and morphologically very different[1].

There were several historical-cultural and socio-economic factors that determined the Italian coasts assault, from the fifties. The progressive occupation of coastal areas was defined in many cases during the second half of the twentieth century, through unsustainable development models that led to an increasing consumption of soil and natural resources. Also, the Lubrense coast, as happened in the more general case of Italian coasts, was not spared by the complex dynamics, which had as consequences plotting and building speculation along the coast. Furthermore, it must be pointed out that the intensification of construction, without adequate urban planning tools, has resulted in the construction of new roads which in many cases, altered the high landscape values of the entire coastal stretch of the Peninsula.

The image of the Lubrense coast, which over the centuries became a true literary and aesthetic myth thanks to the descriptions of travelers, gradually fell into a profound decline during the twentieth century[2].

The activities related to limestone extraction, the degradation resulting from a building disorder generated by the exploitation of the tourist vocation of the place during the economic boom, therefore the numerous private buildings combined with the lack of adequate urban planning tools, have contributed to a progressive and irreversible decline and modification, even morphological, of the valuable coastal landscape.

Despite this, Lubrense coast still preserves natural landscape beauties, as well as a dense and stratified cultural and biodiversity heritage to be enhanced and safeguarded[3].

Transformations along Massa Lubrense coast, from Puolo to Crapolla, during the twentieth century

Massa Lubrense coast remained intact for millennia, risked to be seriously compromised in its integrity because of the mining activities started in the early decades of the twentieth century. The limestone mining activity linked to the building use of Massa stone, until then marginal for that area, in the early Twenties turned into an intensive activity[4]. It should be noted that the replacement of traditional mining activities in favor of more intensive exploitation, generated irreparable damage, even morphological to the coastal landscape[5]. Seven limestone extraction plants were opened only in Massa Lubrense municipal boundaries: Merlino quarry in Puolo, Chianella in Capo Massa, Vitale in

[1] Cfr. R. Pane, *Sorrento e la sua costa,* Napoli, E.S.I.,1955, p. 31.
[2] Cfr. C. de Seta, *Il sacco della penisola sorrentina*, in Id., *Città territorio e mezzogiorno in Italia*, Torino,1977, p. 100.
[3] Cfr. M. Mautone, M. Ronza, B. Bertoli, *Pressione Turistica, Quadri ambientali e Morfogenesi paesistica: La gestione delle qualità territoriali nei sistemi costieri della Campania*, Gangemi Editore, Roma, 2009, p. 87.
[4] Cfr. R. Filangieri di Candida, *Storia di Massa Lubrense*, 1910, p. 738.
[5] Cfr. G. Pignatelli, *Le cave dismesse sulla costa sorrentina tra storia locale danni ambientali e forme di riuso,* in: « Bollettino della società geografica Italiana », Roma, 2014, p. 595.

Marcigliano, Cenito and Mitigliano quarries insistent in the Gulf of Naples, while in the side of Salerno those of Jeranto and Recommone. The local and the many immigrant workers who arrived in the Lubrense area in those years, worked tirelessly and in inhumane conditions in the numerous quarries that dotted the coast[6]. The quarries arose in the most beautiful and sheltered parts of the coastal stretch, strategically easily reachable by cargo boats[7]. After the crisis of the forties, this economic sector under the weight of the very high costs of a muddled management went into crisis. The mining activities gradually ceased, until the final closures in the 1970s. The coast was therefore hit by new problems and dynamics related to the reconversion of the areas of disused quarries.

Puolo bay, which owes its toponym to the presence of Pollio Felice villa and insistent in the municipal boundaries of Massa Lubrense, was the first to be profoundly modified by limestone extraction[8].The small fishing village, naturally protected by two promontories, retained its valuable landscape features unaltered until the early nineteenth century when, following the opening of two kilns for lime production, it underwent serious transformations[9]. The exploitation of of Puolo field was increased by the twenties of the twentieth century, when two quarries were dug close to the mountain, one east on the promontory called Calcarella, and the other west open in the area that from 1927 was acquired by Merlino company. Already in 1929 was denounced the gutting of the bay and the loss of the Roman domus of Pollio Felice al Portiglione[10].The devastating impact on the environment and the coastal landscape, distorted by the massive presence of industrial and transport structures for the extracted limestone, was studied by Roberto Pane and archaeologist Amedeo Maiuri. When Merlino company definitively ceased its activities in the bay in the mid-seventies, the vast area of the disused quarry was the object of an advanced building speculation attempt by the private company “Cala di Puolo”[11]. The speculative project, called "Marina Verde", if carried out would have again attacked the coastal landscape, already marred by mining activities even in the morphological structure[12].

[6] P. Esposito, S. Ruocco, *La Lobra culla della Città di Massa Lubrense*, Castellammare di Stabia, 2000, p. 173.
[7] Cfr. G. Pignatelli, *op. cit.*, p. 596.
[8] Cfr. R. Filangieri di Candida, *op. cit.*, p. 40.
[9] The poet Publio Papilio Stazio in the two Carmi: "Villa Sorrentina Polii Felis" and the "Hercules Surrintinus Polli Felicis", describes the place before the construction of the Villa di Pollio as: "a desolate beach that served only as a shelter for passing sailors".
[10] R. Filangieri di Cancia, *Sorrento e la sua penisola*, Bergamo, Istituto Italiano d’Arti Grafiche, 1929, p.55.
[11] In March 1978, the private company "Cala di Puolo" requested the administration to grant a fifteen-year concession for a maritime area in the Cala di Puolo area, in order to provide a tourist port. The concession license was issued in 1979, also for the state-owned part of the former quarry, but at the same time it became necessary to provide for the delimitation between private and state property.
[12] Crf. Senate of the Republic Assembly n.26 of 9/10/1979. In the parliamentary session, PCI Senator Fermariello, addressing the Minister of Merchant Marine, denounced the speculative aims of the Cala di Puolo company which intended to carry out a “pharaonic” tourism project.


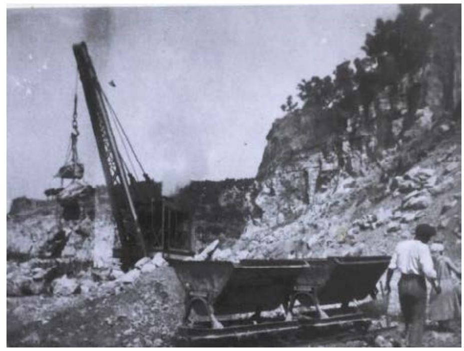

Figure 1- 2 – Puolo quarry in the early 1950s, di Leva family private collection.

Figure 3 – Model of the tourist village project to be built in Cava Merlino area, by ACML.

Fortunately, landscape protection associations and political groups, engaged to preventing the arbitrary privatization of bay state property, while preserving the public use of the only free beach on the coast from there to Amalfi, managed to hinder the speculative project. Currently the vast esplanade of the quarry area, dug into the rocky promontory close to the bay, houses a private parking, while the piers and docks close to the beach are occupied by seasonal bathing facilities. Continuing along the coast, after the small inlet of Chianella, which housed a series of small quarries for the production of rubble, we meet the bay of Marcigliano with the opening of the Cava Vitale, since 1910 had begun to irreversibly erode the high rocky ridge. The abandoned quarry area, in the sixties of the twentieth century, as happened in many other quarry areas insistent in the bays of the coast, was converted for tourist use. A hotel complex with a bathing establishment called “Conca Azzurra” was built in the bay. The hotel of modest architectural value is spread over three floors, the adjoining parking area was built on the esplanade of the quarry, while the swimming pools were built in an embankment close to the sea. In the small beaches annexed to the hotel complex, the "brutal" concrete structures (partially eroded by the sea), built in the years in which the quarry was active and invading the coastline, are still clearly visible today. It should be remembered that starting from the 1950s, most of the Italian coastal coasts were hit by unregulated growth. The progressive occupation of coastal areas was defined during the second half of the twentieth century through development models that were unsustainable in many cases, due to various historical-cultural and socio-economic factors, which caused an increasing consumption of land and natural resources[13].

Even the Lubrense coast was not spared by such dynamics. There are many cases of allotments authorized that then led to emblematic cases of building speculation. Meaningful episode of this new unsustainable way of occupation of the coastal territory is represented by the partition started in 1957 in the locality of Riviera San Montano[14].The small promontory, bounded to the east by Vitale di Marcigliano quarry to the west by Marina della Lobra, at the end of the 1950s appeared as a hill sloping down to the sea, characterized by Mediterranean scrub and olive groves without houses and connecting roads[15].

Figure 4 - 5 – Vitale quarry in the 1930s. The Conca Azzurra tourist complex at the end of the nineties.

Analyzing the considerable archival documentation, it has been possible to reconstruct the stages of the complex history that in a few years led to one of the largest plotting speculative background, built on Massa Lubrense coast. The speculation began in 1956 when Mrs. Maria di Leva in Pontelli, bought a parcel of land in a place she called Riviera di San Montano (from the name of the ancient church existing in the place), to

[13] In the 1960s, faced with the intensification of speculative phenomena and the opening of new road arteries, the drafting of a Territorial Plan by the Ministry of Public Works became urgent. The commission chaired by R. Pane and L. Piccinato completed the work in 1968, despite the efforts made, they were unable to stem the reckless interventions along the peninsula.

[14] Cfr. Riviera San Montano Lotting Project, Massa Lubrense Municipality Archive (hereinafter ACML), service no. 8 Urban Planning and Public Works, practices: n. 48, lot 42, no. 60 lot n. 3, no. 61 lots n. (4-5-6), n. 62 lot 18, no. 63 lot n. 19, n. 68 lot 13, no. 69 lot 16, no. 70 lot 17, no. 71 lot n. 23, n. 72 lot 35, no. 118 lot n. 14, n. 119 lot n. 12, n. 120 lot n. 8.

[15] Crf. General Plan and Riviera di San Montano Lotting Projects in ACML.

build its own house[16]. Analyzing this event, it appears evident that the intentions from the beginning were to create a speculative subdivision. The application for a building permit was presented to the Municipality in 1957, and the first stone was laid in March 1958[17]. In fact, the villa projects, signed by Eng. Matteo Mosca and Arch. Gino d'Andrea, were conceived respecting the panoramic views and following a general harmonious overall plan.

Figure 6 – The subdivision by Società Immobiliare S.P.A. on the promontory of Riviera di San Montano, the first villas under construction. Photo from Massa Lubrense Archeoclub.

Subsequently, the subdivision resulted in speculative activity never seen before in the municipal areas. At the end of 1959, fifteen villas had already been built, the road, the aqueduct, the power line and the waterfront, but thirty villas had already been built the following year. Although the Allotment Project insisted on an unconstrained fund, the Superintendency tried diligently to obstruct the project. In 1960 an order was in fact issued for the suspension of the works, soon revoked thanks to an amnesty[18], and in the end the parceling took place anyway with a number of buildings higher than the concessions obtained. Continuing along the coast, past the Marina della Lobra and around Capo Corbo, another significant development started in those years also in Punta Lagno[19]. These were the years when the construction of the second house for the summer holiday became within

[16] Maria Di Leva in Pontelli, will subsequently appear as sole director of the Sorrentina real estate company s.p.a.
[17] Crf. with the Technical Report of the Sorrentine Real Estate Company. (S.I.S.) of 09/21/1957, in ACML. The Riviera San Montano Allotment Project provided for the division of the area into 65 lots, and together with the construction of a carriage road, of about 20 villas, a small church, a promenade, and a cliff to protect the beach below.
[18] Cfr. telegrams no. 9075-10068-10069, in ACML. The works were suspended in application of art. 9 of the law 29/6/1939 n. 1497.
[19] Cfr. Subdivision project in Punta Lagno of the rustic land owned by Dr. Perusino Perusini in Punta Lagno signed by Eng. R. de Rosa, for which the building permit was issued in 1966 in: ACML, Historical Archive, provisional classification, S2-R2-n. 8, Allotment practices various letters a-b-c.

the reach of a large segment of the population. This phenomenon caused the aggression of the coastal areas of greater landscape value; along the coastal belts of Campania in those years were built houses of little value and perpetuated building abuses of all kinds.During the 1960s, a general awareness of the potential of Italian tourist destinations began, accompanied by a growing construction activity, aimed at increasing the tourist offer. Along the Lubrense coast in those years, there were many initiatives carried out by companies and private entrepreneurs, who created new tourist settlements, even in inaccessible coastal areas where in the past it seemed impossible to build.

In the bay bordered to the west by Punta San Lorenzo, in a locality called Gesiglione sul Nastro d'Oro, Guglielmo La Via on behalf of the Dutch company S.N.V. Hotel Maatashappij, realized in those years the Hotel Delfino[20]. The hotel complex built on the impervious rocky ridge overlooking the sea, still in use and recently expanded, has profoundly altered the skyline of the bay. Along the coast, another emblematic case of the conversion of a disused quarry into a tourist facility is that of the "Romantic Garden". The tourist village built by Pasquale Ricci in the Cenito quarry, insisted on a vast soil that included the two promontories that delimit the bay, to the east that of Marciano and to the west that of Punta Baccoli[21]. The tourist complex was built in one of the most evocative stretches of the Lubrense coast, on the scenic landscape of the island of Capri. Already in the early 1960s, “Il Giardino Romantico” became one of the most fashionable structures of the coast.

Figure 7 -8 – Project for the construction of a hotel-type tourist park Mitigliano, 1965. From ACML. Tourist poster, Giardino Romantico, 1970s.

The project approved in amnesty in 1968, provided for the construction of 136 wooden bungalows and a bathhouse with stable facilities for services[22]. Later the owners

[20] Cfr. Project for the Hotel Delfino swimming pool, signed by Arch. Francesco Scarpato in ACML, Historical Archive, provisional classification, S2-R2-n. 8, Allotment practices various letters a-b-c.

[21] Before the settlement of the Quarry on the promontory of Punta Baccoli, a coastal watchtower stood, as evidenced by the period images prior to the 1920s.

[22] Cfr. Floorplan, technical reports, period photos, in ACML, Historical Archive, provisional classification. Issue n. 1970, File 350/14905. The approval in amnesty excluded the construction of the pier present in the drawings.

obtained from the municipality a remodeling of the project, with a significant increase in the number of bungalows which rose to two hundred units[23]. At the same time, an application was submitted by the designers to convert the construction of the one hundred bungalows (to be built in wood) into fifty single-family brick houses. This subsequent application was rejected in March 1969, but in 1970, the construction of masonry buildings with wood finishes was granted. Fortunately, the association "Italia Nostra", committed to safeguarding the landscape of the territory, with a report presented to the Municipality of Massa Lubrense, urged to provide detailed information on the implementation of the project. The Superintendency issued two orders to suspend the works in 1970 and 1971 which, if completed, would have irreparably compromised the coastal profile of the promontory that opened onto the nearby Mitigliano cove, already altered by the opening of access road to the tourist facility. Currently, the complex of Giardino Romantico houses a bathing facility called "Baia delle Sirene", along the access road some of the brick houses built in those years and the other disused service structures remain clearly visible.

Even the nearby Mitigliano bay was not spared during the early twentieth century from the mining activity. Here there was a small quarry for the extraction and processing of the breach, and a small concrete loading dock forms the backdrop to the coastline. In the 1970s the bay was affected by various speculative projects such as the construction of a tourist park (for which the building permit was rejected), and the opening of a cableway connecting with Termini which, if built, would have disfigured the wild nature of the place.

After Punta della Campanella, the extreme offshoot of the Sorrento peninsula and a place of enormous mythological, historical, environmental, geological and landscape value, on the Salerno side of the peninsula we meet the bay of Jeranto, defaced in the early twentieth century by the quarry opened by ILVA. This quarry, unlike the other sites essentially related to the production of building material or boulders for breakwaters, has been characterized by a short-lived but very intense mining activity over the years. Having to continuously supply the blast furnaces of the Bagnoli steel plants, the material extracted daily in the quarry was transported by large cargo boats to the ILVA blast furnaces (later Italsider and then Nuova Italsider) in Bagnoli, to be transformed into cement blocks with which were built the breakwater barriers scattered in the Gulf of Naples. ILVA owned in the locality of Jeranto, a large property with an area of about 377 500 square meters, identified in two lots. In the first one fell the land of Punta Campanella, remarkably steep with limestone outcropping on the whole surface without direct roads with access from the ground, while in the second lot fell the land of Punta Penne, which was accessed via a mule track by land from inhabited area of Nerano. This last lot included a farmhouse and industrial artifacts built over the years for the exercise of the mining activity. The lot of Punta Penne, in the years in which the quarry was active, underwent the greatest modifications. An area of over thirty thousand square meters was leveled in the area below the tip. The interventions due to intense mining activities irreversibly disfigured the landscape of the bay, also morphologically changing the profile of the rocky ridge. Only on the occasion of the first Landscape Conference, held in Capri in the summer of 1922, did the Mayor of Massa Lubrense denounce the environmental destruction consumed in the

[23] Cfr. Additional variant project signed by Arch. Carlo Lapegna, approved on 04/07/1969 n. 3985, in ACML, Historical Archive, provisional classification. Issue n. 1970, File 350/14905.

bay[24]. The quarry was definitively closed in 1952, but already in the early 1960s, Jeranto bay was the object of an attempt at building speculation by a Lombard real estate company, which on a project by the engineer Antonino Cesaro, close to Punta Campanella, in a stretch of coast with a centuries-old and stratified cultural heritage, intended to create a subdivision with 46 "terraced" houses. The attack on the nature of the bay, one of the most beautiful in the Sorrento peninsula, began in August 1963, when the Massa Lubrense mayor, Pasquale Persico, granted the engineer Cesaro the license for the construction of single-family houses, to be built close to the sea, in a place indicated in the project as "Rezzaro". Culture and politics immediately undertook to block the reckless project and, thanks to the intervention led by Antonio Maresca, then president of Italia Nostra, on 12 April 1972 the building permit was revoked. Subsequently Cesaro won the appeal to the T.A.R., began the construction of five villa. To the new complaints made by Italia Nostra, were added those of the Archeo Club Lubrense and the political groups, the new Mayor of Massa Lubrense Alfonso Gargiulo. Adhering to the unanimous vote of the City Council, in October of '76 Gargiulo revoked the building permit, but once again Cesaro recourse to the TAR, got a new ruling that leaded off the allotment project. Only after years of "struggle", thanks to the tenacity opposition of the municipal administration and the political and cultural groups involved in the protection of the site, the assault of Jeranto bay was definitively thwarted with the sentence issued by the Council of State published in December of 1982.Moreover, in 1977 the Campania Region included the entire area of the Jeranto Bay and Punta della Campanella, up to the Mitgliano Bay, among the natural parks to be defended and enhanced in the Territorial Landscape Plan of the Sorrento-Amalfi area.


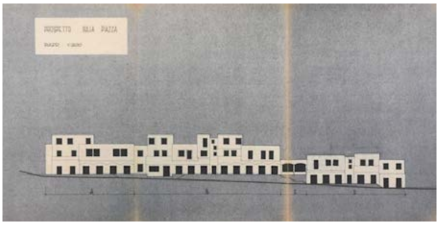

Figure 9 - 10 – Jeranto Bay, Punta Penne defaced by the Ilva quarry, in the image can be seen the remains of the buildings built for quarrying activities, from Google hearth. Hotel le Sirenuse, statement. from ACML.

In March 1977, with a deed of donation, all the land owned by Nuova Italsider in the Jeranto bay passed to the FAI (Italian Environment Found), so that the bay was definitively removed from the dangers of speculation. Over the years of FAI's management, the entire area has been the subject of major environmental restoration interventions aimed at recovering the original Mediterranean scrub. Jeranto is currently recognized as a Site of Community Interest, included in the Marine Protected Area of Punta Campanella, also appreciated for the high level of biodiversity preserved. Having rounded Punta Penne, a

[24] Cerio E. (a cura di), *Il Convegno del Paesaggio*, Napoli, Casella, 1923, p.72

little further along the coast, we meet Nerano Bay. The legend handed down that owes its name to Tiberio Nerone who, struck by the beauty of the place, decided to build a further villa in addition to the twelve in Capri. From Mortelle to Marina del Cantone with the progressive affirmation of mass tourism in the second half of the twentieth century, connected to the economic boom, various subdivisions were also started in Nerano. As in other parts of Italy, the generalized type for tourist accommodation of those years was the cottage. Typical elements of the new seaside expansion of the time are also found along the bay hotels, campsites and facilities intended for the entertainment of vacationers such as bars, restaurants and bathing establishments. The bay skyline was certainly irreversibly changed in those years. The construction of the Hotel le Sirenuse, built at the end of the 1960s in the small square near the beach of Marina del Cantone[25], is emblematic. After Marina del Cantone bay, Recommone cove finally opens up, where a small quarry which gutted the tip of the Sciuscelluzza up until the 1950s. Also, in this case the quarry area was subsequently occupied by a bathhouse belonging to an accommodation facility.

Conclusions

The beautiful coast of Massa Lubrense has always been an evocative place and has been chosen since Roman times as an enchanting holiday resort. The place is characterized by a hilly landscape typical of the Mediterranean scrub, rich in olive and citrus trees sloping towards the sea. During the second half of the twentieth century, activities related to limestone extraction along the coast led to the beginning of a gradual degradation of the coast. During the 1960s, with the economic boom in Italy, an enormous building disorder was also generated due to the tourist exploitation of the place. The intrusiveness of many private initiatives and the lack of urban planning tools have contributed over the years to a progressive and irreversible degradation of the coastal landscape, contained only thanks to social and cultural initiatives aimed at protecting the environment.

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[25] Crf. Building Construction Practice # 1311, ACLM.

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THE PORT OF NEAPOLIS: MEMORIES AND TRACES OF THE COASTAL LANDSCAPE IN ANCIENT TIMES

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Abstract – During the excavation for the construction of two new subway lines, which run from East to West along the city of Naples, traces and memories of the ancient Neapolitan coastal landscape emerged. Most of the ancient coast finds were discovered during the railway stations building in the historic center of Naples.
Moreover, thanks to geo-archaeological investigations conducted during the construction of the urban transport infrastructure, in Municipio square the Greek-Roman port of Naples has been brought to light. As confirmed by geognostic surveys, the transformations of the Neapolitan bay shore lines depended on anthropic and natural phenomena. Bradysism, silting of the coast with the accumulation of debris carried by the lavas, as well as the waters coming from the hills surrounding the plains where the Greek colonies of Parthenope/Palepolis and Neapolis were founded, were responsible of bay transformation. From the huge quantity of traces found it has been possible to reconstruct the urban layout of the ancient port re-emerged with its docks and ships.
The studies of archaeologists and geologists through the reconstruction of stratigraphy and data of geoarchaeological prospecting campaigns, have clarified how the bay has been disappearing over the centuries. This disappearance was caused by the overlapping of natural (subsidence, swamps, and coverings) and of anthropic phenomena, until the complete transformation of the coastline by the castings for the construction of the modern port.

Morphological evolution of the Neapolitan Coastal landscape

The geomorphology of the Neapolitan physical landscape in its main features is due to the volcanic and tectonic activity of the late Quaternary. The morphostructural features of the landscape are characterized by a hilly area, with the main river formed with the oldest phlegraean eruptive events, and by many reliefs connected to the eruptive centres of the Neapolitan Yellow Tuff. In the second part of the Holocene period the landscape began to take shape acquiring, on the western and eastern sides of the territory, a morphology characterized by depressions, aggravated by volcanoclastic sedimentation and by coastal plains partly artificially prograded [17]. Along the coast, the genesis of the Neapolitan landscape morphology originated in the middle and upper Holocene, as documented by the complex coastline and transition that marks the apex of the post-glacial transgression and subsequent progrades [1].

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The evolution of the morphology of the Neapolitan coastal landscape has been further documented by new geoarchaeological data obtained from cores and excavations carried out for the work of the new subway lines. The analysis of the coastal sediments that filled the final tracts of the torrential incisions, have integrated the useful data to reconstruct the course of the paleolines of the shore of the ancient coastal landscape. Studies carried out on samples of shoreline and beach deposits taken from the excavation wells of the Duomo (Nicola Amore Square) and the University (Bovio Square) stations documented traces of human activities attributable to the Middle Bronze Age [10]. It has also been documented a phenomenon of marine ingression and a subsequent rise of the seabed to be traced back to an environment that emerged near the shore, datable between the Bronze and the first Iron Age.

To complete the study of the genesis of the Neapolitan coastal landscape, related to events preceding the anthropization of historical times, contributed geo-archaeological data from the excavation wells of the Garibaldi, San Pasquale, and Arco Mirelli stations. These last two wells belong to the line 6 subway, which runs along the Chiaia Riviera, an area formerly occupied by the sea. In this area, geo-archaeological investigations have revealed the presence of subsequent deposits of a coastal environment, identifying the whole belt as a transition zone between a submerged and an emerged shore. The results of these researches have contributed to the knowledge of the progradation phases of the ancient coastline and of the anthropic presence in the neighbouring areas from the Neolithic to the Late-Ancient Age [6].

In Garibaldi Square, a stratigraphic sequence was detected, attributable to a coastal marsh, an emerged beach and a black paleosoil with traces dating back to the recent Middle Bronze Age [1]. The successive chronological phases up to the Modern Age have been traced back to a silty sandy stratigraphy due to frequent flooding, perhaps coming from a nearby stream descending from the surrounding hills [5]. The discovery of some archaeological finds documents the anthropic presence in the Neapolitan bay since the Prehistoric and Protohistoric Age. More traces that are consistent indicate the existence of a naval port on the shores of the Megaride islet as well as the settlement of a Greek colony dating from the mid-7th century BC on the promontory of Mount Echia. Another Greek colony (between the end of the 6th and the beginning of the 5th century BC) was settled on the Pendino plain [19]. A sub-flat area carved by valleys and corrivation grooves, coming from the north and the west flowing to the sea, were spaced from the reliefs on which the colonies of Parthenope/Palepolis and Neapolis were founded [20]. Therefore, it can be assumed that the hills and environments near the shore were inhabited from the end of the Neolithic Age. In fact, numerous ceramic finds, dating from the Middle Bronze to the Iron Age, were found in N. Amore square [5]. In addition, in the wells dug for the construction of the Municipio, University and Duomo stations, respectively located in Municipio, Giovanni Bovio and Nicola Amore squares, were found deposits of seabed, emerged shores and humid environments dating from the sixth to the second century BC [13].

The geognostic and geo-archaeological coring carried out in the excavation well in Municipio square have highlighted the reconfiguration of the seabed of the bay (occurred between the end of the fourth and the second century BC) through dredging operations for port use in the innermost area of the square [12]. Between the 2nd century BC and the 3rd century AD in this sector of the inlet, the waterline underwent a slight expansion due to the submersion of the bay. This was evident due to the corrosion on the support poles of the two pontoons found, probably realized and abandoned during the 2nd century AD. Moreover, the excavations have brought to the light of a busy boat, trace of the existence of a submerged environment between the 2nd and 3rd century AD. During the 5th century AD, dunes formed in the harbour basin that gradually became cordons transforming much of the bay into a lagoon [19]. Over time the subsequent progradation and the raising of the sediments barrier provoked the definitive burial of the bay and the closing of the port. In the University station excavation areas was ascertained that between the 1st century BC and the 2nd century AD shore sands were deposited, while in the excavation area of the Duomo station were found the remains of a monumental complex built at the beginning of the second century BC and refurbished in the third century AD. The peculiarities of this environmental context will have strongly influenced the methods of occupation by the inhabitants, appearing diversified in chronology, functions, and monumental consistency of the remains [5].

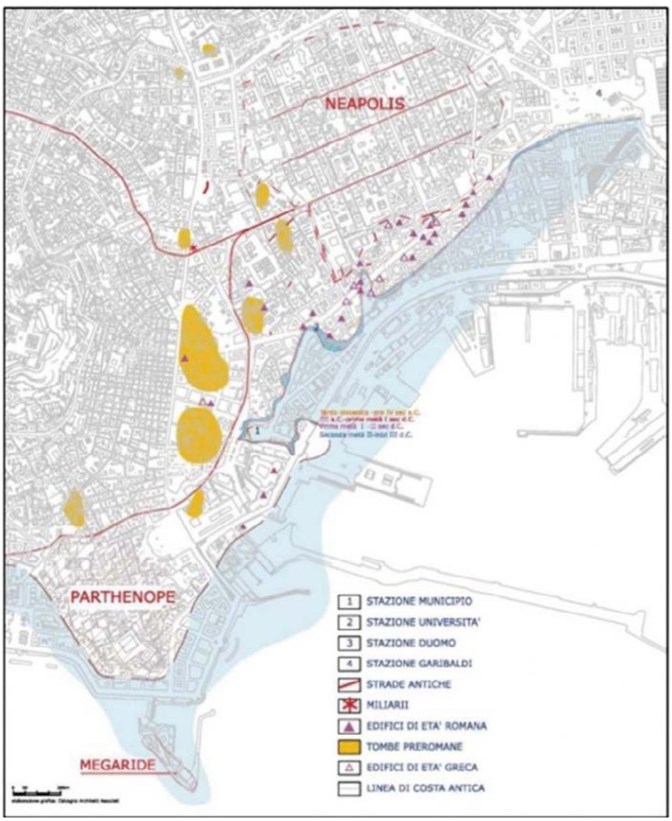

Figure 1 – Naples. Reconstruction of the coastline from ancient to late ancient times.
[www.researchgate.net/publication/40020600_Archeologia_e_citta_La_ricostruzione_della_linea_di_costa]

In Nicola Amore square a stratigraphic articulation has been recovered, dating from around the middle of the 5th century BC, which documented the presence of a shore grooved by naturally formed beds. Other finds have attested that at the beginning of the 4th century BC the area was occupied by a building probably of a sacred character, in which we recognize the origin of the settlement phenomenon that will culminate with the realization in the Augustan age of the Sanctuary of the Isolympics games [14].

The study of the University station excavation revealed that up to the beginning of the fifth century AD in the area the conditions of submerged environment persisted. The shoreline made a series of oscillations that brought in a condition of emerged shore. Starting from the sixth century AD the conditions of bad drainage were created, as already found in the area of the well of excavation of the Municipio station, but of such an entity that did not prevent the construction of an extramoenia district. Similar environmental conditions, attributable to the fourth and fifth centuries AD, have also been found in the excavation well of the Duomo station, where on the pavements of the Roman monumental complex sands and works of lifting the decks and traces of drainage canals have been found [1]. Therefore, from the beginning of the 5th century AD, the Neapolitan coastal landscape suffered widespread phenomena of swamping. In the inlet between the areas now occupied by Municipio and Bovio squares and where the port was located, episodes of stagnation of the waters began to occur, that increased during the fifth century causing the desertion of the area. The formation of a lagoon environment caused the abandonment of the port due to the silting of the inlet and the advancement of the coastline with the consequent displacement of the port to east [5]. The archaeological indicators shows that the activity of this second port, closer to the colony of Neapolis, was used in an ancient phase datable between the fifth and fourth centuries BC and continued until the chronological phase datable between the first and fourth centuries AD. In the following centuries, geomorphological analysis has indicated in Bovio Square the formation of an emerged shore between the fifth and the sixth century AD, with the advancement of the coastline detected at the southern limit of the excavation area [5].

In the stretch between Nicola Amore and Garibaldi squares, came to light the presence of an emerged shore connected to the depression of Sebeto River, the waterway delimiting the Neapolitan territory to the southeast in ancient times. Instead for the eastern area, in literature, was reported the presence of a necropolis connected to the road leading to the Vesuvian countryside, which must have belonged to the coastal road axis used from the second century BC to the second century AD and found in Garibaldi Square thanks to restoration work of the roadbed [5]. In the excavation of Garibaldi station, in the homonymous square, was found a road built in the second century AD, then raised following flooding episodes lasted until the fifth century AD. The geo-archaeological investigations have found that, despite the definitive abandonment of the road during the 2nd century AD, the frequency of man did not stop, as evidenced by the traces of cultivation and fencing [1]. The shoreline, in the Middle Ages, still shows a prograde, from the seventh to the twelfth century AD caused by bad drainage of the coastal belt in the area behind the formed shore. In the following centuries, the urban evolution tells of an intense urbanization of the coastal belt, with advances of the coastline of modest magnitude. In the Modern Age the coastal landscape of the bay of Naples, close to the line of fortifications, had a beach and a harbor basin in the area now occupied by Bovio Square, as can be seen in the historical iconography [11].

Between the sixteenth and eighteenth centuries, the coastline was subject to fluctuations due to the formation of shores on the eastern side of the coast, after breakwaters construction occurred in the middle of the eighteenth-century BC. Between the nineteenth and twentieth centuries, the profile of the coast was changed drastically from the jetties to widen the harbor docks and from the artificial fillings put into effect on the low districts of the city, to realize the sewerage infrastructures made necessary after the umpteenth epidemic that struck the city of Naples in 1884 [8].

Figure 2 – Bartolommeo Capasso: Topography of the city of Naples in the eleventh century (reproduction from specimen preserved at the Library of National History). [https://journals.openedition.org/mediterranee/2943]

The archaeological discovery of Neapolis harbor inlet in Municipio square

The excavations for the subway construction were crucial not only to reconstruct the ancient coastline but also, above all, to solve the topographical problem of Greek-Roman Naples port localization. For centuries, the studies of historical topography formulated hypotheses that placed the harbor inlet in the areas today occupied by Giovanni Bovio, Nicola Amore and Municipio squares. Among these, Bartolommeo Capasso (1815-1900) and Mario Napoli [18] studies have been confirmed by the archaeological discovery in Municipio Square, in the underground station area located in the innermost part of the ancient inlet [4-2-3].

The port facility of the Greek-Roman Naples was built in a naturally protected cove, in the area now occupied by Municipio square, in a stretch of coast sheltered by the action of the winds and easy landing for boats. The data obtained from geo-archaeological investigations, carried out by the Superintendence of "Archaeology, Fine Arts and Landscape" of Naples, in line with the activities of "preventive archaeology", have allowed to provide information of a topographical, functional and chronological nature [12]. During the geomorphological surveys, the bottom of the harbor basin was identified, placed to 13 meters deep from the floor of the square, at that time occupied almost entirely by the inlet [16]. Below the stratigraphic sequence was found the existence of a shallow submerged environment in which were distinguished about four meters of stratified sediments belonging to different sandy depths of the port basin, reporting the existence of a protected environment in communication with the open sea and contaminated by fresh water [5]. The boundaries of the harbor basin identified, are marked to the south by a tuff promontory stretched towards the coast that reached the northeast in a sandy tongue and to the north the area now occupied by Giovanni Bovio Square [12]. This reconstruction of the sea basin morphology was confirmed by the investigations carried out during the excavations for Line 1 of the subway. Datable from the end of the 4th century BC to the first half of the 3rd century BC was identified a large inlet between Castel Nuovo and the church of S. Maria di Porto Salvo, with the construction of a landing place that remained in use until the beginning of the 5th century AD [15].

The most significant traces of the ancient port of Neapolis existence in Municipio Square, where the lowest point of the seabed was measured, are documented by the discovery of the remains of piers and docks. The infrastructure of the port resurfaced belong to different historical phases. The remains of the pier perpendicular to the coastline, made with poles contained by a cast of medium and large stones set in place dry, date back to the end of the first century AD. In the second century AD two bridges/ footbridges were built at the slope of the coastline. Between the end of the 2nd and the beginning of the 3rd century AD these docking structures were no longer used, until during the 3rd century AD the harbor basin resumed its activity, as documented by the ceramic finds and the remains of some small wooden poles used for the docking of fishing boats. A more intense use of the port was found in a period datable between the fourth and the beginning of the fifth century AD, with the discovery of small masts related to wooden walkways, used in fishing activities. Later, during the fifth century AD, the formation of a lagoon environment and the progressive cover-up of the sea basin, which lasted throughout the sixth century AD, led to the definitive abandonment of the ancient port [15]. To complete the picture of what should have been the arrangement of the landing in the bay of Neapolis, contributed in a decisive way the discovery of the wrecks of ships of the Roman era, emerged during the work of the subway. The position of the boats helped to define the outline of the ancient landing place. The port, therefore, did not allow the landing and mooring of large draught ships and offshore boats, for this reason the loading and unloading of goods was facilitated by boats, such as those found, which took cargoes from ships anchored off the port. According to archaeologists, one of the boats found that was used for port servitude is unique in this part of the Mediterranean, two similar boats were found only in the ancient port of Toulon in France. The description of one of the boats is given by the archaeologist Daniela Giampaola, in charge of the excavations, observing that the wreck "has a very wide keel, with little high edges and the flat bow in order to favor the berthing to the pier and the loading and unloading of good" [13].

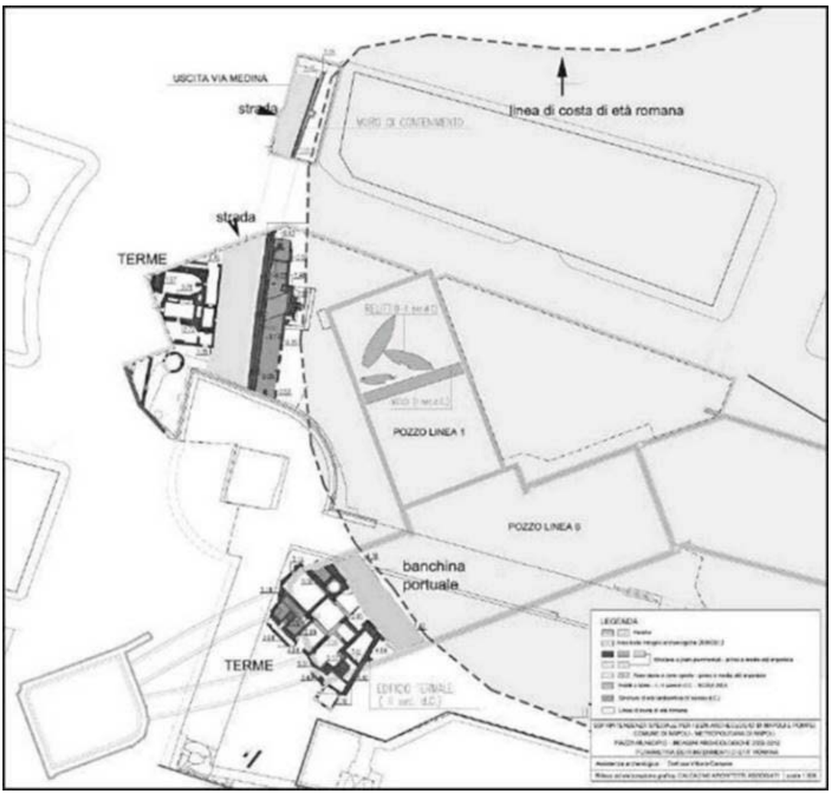

Figure 3 – Naples, Municipio Square. Plan of the Roman period. [www.academia.edu/35328745/ATTIVIT%C3%80_SOP_SPECIALE_BENI_ARCHEOLOGICI_NAPOLI_E_POMPEI_ATTI_LII_CONVEGNO_STUDI_MAGNA_GRECIA_TA_2012_pdf]

In addition, the remains of what was transported by boats were also found buried in the muddy bottom of the ancient port. The finds consist of numerous amphorae and objects of various kinds including coins, bottles, shoes along with a variety of useful tools for sailors and huge quantities of extremely varied import materials, including ropes, anchors with wooden teeth, wicker baskets and mats, all testimonies of how much it was used in the activities that were carried out in the port. The archaeological excavations followed for the recovery of the ancient port, have allowed to find, under the boats, furrows of dredging operations carried out in order to contrast the phenomena of silting up that had to be repeated in the port with a certain frequency, creating problems to the boats landing. In fact, geo-archaeological investigations have found more than ten meters from the decking, a port basin characterized by a shallow seabed and poor exchange with the open sea [12].

The deeper levels inspection of the creek has evidenced remains of dredging works that have affected the seabed. These excavations, datable between the fourth and third centuries BC were made to lower the seabed, removing sand and excavating pyroclastic rock, to facilitate the mooring of the boats. These interventions of maintenance, protracted over the centuries by man, has altered the oldest stratigraphy related to the initial stages of anthropic frequenting of the bay, linked to the settlement of the emporion of Partenope founded in the seventh century BC and to the colony of Neapolis of the fifth century BC [5]. However, in the excavation in Municipio Square were recovered, at the deepest depths of the seabed, ceramic fragments from the early seventh century BC, and comparable with the oldest materials of the town of Parthenope, found in the areas of the necropolis of Pizzofalcone and the discharge of the Chiatamone [7].

Geoarchaeological surveys have established that dredging activities in the basin of Municipio Square presumably ceased during the second half of the second century BC. Referable to that time, in fact, the sandy sediment of the bottom was little affected by dredging. Moreover, the protected position of this part of the inlet that has preserved the sandy stratigraphy from the disturbances of the wave motion, has allowed the discovery of seabed consisting of sand, silt, and marine plants. In these layers of sediment have been found numerous finds ascribable to municipal waste, objects lost during the loading and unloading of goods and equipment on board. The large amount of ceramics found dating from the end of the third century BC to the beginning of the first century BC are evidence of the intense attendance of the port of Neapolis in that period [5]. and tell uses and customs of the Greek-roman town.

Underground excavations: between remains and archaeological finds

In recent decades, urban mobility in the city of Naples has been made more fluid thanks to the construction of new metro lines. Integrated with the passing railway, a system of public transport on iron has been created that has reorganized urban mobility, making easier to move between the historic center, hilly neighborhoods and urban suburbs. Precisely the works for the construction of the new subway that crosses the historic center, allowed to bring to light the ancient vestiges of the city, preserved in the urban subsoil.

Most of the archaeological finds have been discovered in the wells for the construction of the stations of Toledo, Municipio, University and Duomo.

From the excavations of the Toledo station have emerged archaeological finds attributable to different eras, from prehistoric to modern. More exactly fields have emerged dating from the fourth millennium BC (Neolithic), while for the Imperial Age were found remains of a Roman quarter with relative thermal baths (2^{nd} century AD) and dating back to the modern era are the Aragonese fortifications of the fifteenth century AD.

In Municipio station excavation, in addition to the Greek-Roman port, the remains of Angevin buildings and Aragonese and viceregal fortifications have come to light. The construction of the interchange station between Line 1 and Line 6 of the subway, next to Castel Nuovo, revealed the presence of remains of late ancient times related to a thermal complex built on the banks of the port. The most important evidence of the port existence in the area of Municipio Square was the discovery of five shipwrecks from the Roman era. As previously reported, geomorphological investigations have highlighted the evolution of the coastline, located below the current stations Municipio and University (Bovio Square), with the identification of a large inlet. This has led to the hypothesis of a single large basin extended between Municipio and Bovio squares, then divided into several creeks because of the phenomena of burial occurred over the centuries. In the bay of Bovio square there are traces of a secondary landing, located on the edge of the ancient port closest to the urban fortifications. Thanks to the discovery of a large amount of pottery of the fourth century AD, the presence of artifacts attributed to craft activities and a building of the seventh century AD, intended for storage goods, it was possible to document the shift of the port and its commercial activities to the east [14]. Among the many finds emerged during the excavations of the Duomo station, the remains of the Sanctuary of the Isolympics Games, erected in the city of Naples by the will of the Emperor Augustus, have been found.

The archaeological findings have confirmed how the sacred complex, of which part of the temple and the portico have been explored, fell in a competitive district located outside the fortified perimeter of Neapolis [14]. During the archaeological explorations conducted between the Duomo and Garibaldi stations were found abundant ceramic finds dating from the Middle Bronze Age to the Iron Age, documenting the anthropic presence in a coastal environment emerged very close to the shore [5]. All the explorations of the subsoil stratifications have been conducted by the Superintendence "Archaeology Fine Arts and Landscape" of Naples, in the context of the activities of "preventive archaeology", specialized research activity that is carried out in sensitive areas with diagnostic surveys of the terrain. Preventive archaeology, in fact, has a considerable importance, contributing significantly to the process of reconstruction of urban archaeology. Very often, this type of investigation allows archaeological knowledge that in many cases had escaped scientific investigation, as evidenced by the unexpected findings during the excavations for the construction of the new subway line. The important archaeological finds that occurred thanks to the construction of the metro line and its stations have given rise to a large museum, allowing, in addition to the construction of modern infrastructure, also the enhancement of the urban context. With the construction of the new metropolitan railway, the historic center has returned to be an important cultural attraction, easily accessible and which has an underground railway that travels through the ancient and wonderful memories of the city.

Conclusions

A new and important opportunity to explore the stratification of the soil in the historic center of the city of Naples has been possible thanks to the realization of the subway lines 1 and 6. The activities of "preventive archaeology" carried out by the Superintendence "Archaeology Fine Arts and Landscape" have allowed putting an end to the topographic diatribe on the precise location of the port of Naples in the Greek-Roman era.

The reconstruction of the profile of the ancient port of Neapolis has become possible thanks to the elaboration of the stratigraphic data and the information obtained during the geo-archaeological prospecting campaigns. The intersection of these studies has allowed the elaboration of precise hypotheses for the transformation of the coastal landscape occurred over the centuries and caused by the overlapping of anthropogenic and natural phenomena, such as subsidence and swamps.

The research work was aimed at the acquisition and structuring of the numerous information relating to the archaeological discoveries that emerged in Municipio square, during the works for the construction of the new underground stations. In particular, the methodologies to be used in ancient landscape studies were the subject of the work.

The intersection of information from existing literature and the data on the finds, made available by the Superintendence of "Archaeology, Fine Arts and Landscape" of Naples, allowed to define the archaeological landscape of Municipio square. This enabled finalizing the work to implement the transfer of scientific and historical cultural knowledge, as required by the objectives of the DATABENC (High-tech District for Cultural Heritage) district. It is therefore necessary for the city of Naples to optimize the use of cultural heritage, as it contributes to improving the quality of life of an entire community.

For the reconstruction of the ancient Neapolitan coastal landscape, a fundamental contribution has been provided by the investigations conducted in the wells of the underground stations. Most of the traces of the ancient coast were found during the works for the construction of lines 1 and 6 that run respectively the Rettifilo and the Chiaia Riviera, while the archaeological findings inside the excavation of Municipio station have made possible to define precisely the ancient inlet where the archaic port of Neapolis was located. Along the stretch of the metro that runs along the Chiaia Riviera, stratified deposits have emerged attributable to a coastal environment, identifying in this area of the city the existence in ancient times of a transition zone between submerged and emerged shore. Fundamental to outline the profile of the ancient coastal landscape of Neapolis was the contribution of geo-archaeological inspections during the completion of the Duomo and Garibaldi stations. These stations falling in the zone between the sea and the plane on which Neapolis was founded, have shed light on many testimonies useful to rebuild the coastal landscape, ascertaining the previous existence of a shore in a context of predominantly emerged coastal environment. The excavation work for the realization of the subways helped to outline not only the profile of the harbor inlet. The port occupied the area now become Municipio square, but also that of a large inlet located in the area of Borsa square, considered by the experts a marginal area to the ancient harbor basin that remained in function also in late ancient age, as documented by the archaeological investigations.

The exceptional quantity of memories and traces found have allowed the reconstruction of the urban layout of the ancient port. It appears with its docks and its ships, clarifying the causes of the disappearance in the centuries of the creek, caused by the overlapping of natural and anthropological phenomena, up to the complete transformation of the coastline caused by works for the realization of the modern port. In conclusion, the geomorphological reconstruction of the coastline shows that the inlet identified in Municipio Square was the most suitable for landing boats and was probably used as a marina by the first Greek settlers. In this regard, it was observed that the coast to the south of the promontory, where the archaic settlement of Parthenope was founded, had a tuff coast more exposed to the sea while the west side was characterized by a long and thin shore. Moreover, the hypothesis of the harbor use in ancient times in the inlet explored in Municipio square is supported by the findings dating from the end of the 3rd – 4th century BC.

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THE BUILDING MATERIALS OF “ROCCA VECCHIA” (OLD FORTRESS) IN THE GORGONA ISLAND

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Abstract – The research examines the building materials of the ancient fortress known as Rocca Vecchia (Old Fortress), in the Gorgona Island, built by the Republic of Pisa and dated to the 13th century. Particular attention is paid to the composition of the artificial stone materials (bricks, bedding mortars, plasters and renders) in order to better understand and define the different construction phases. The results will be useful from the historical point of view (origin of the raw materials from inside or outside the island) and for the future conservation intervention which, under the auspices of the former director of the jailhouse, will have to involve a group of prisoners who will also have the task of the subsequent maintenance.

Introduction

The ancient fortress commonly known as Rocca Vecchia (Old Fortress), dominates the Gorgona island from a rocky spur on the western side, at about 200 metres a.s.l. It was built by the Republic of Pisa and dated to the 13th century, but it seems that the settlement was originally represented by a single tower dating back to the 11th century, as evidenced by the dating of some ceramic finds in a recent archaeological excavation [1, 2]. As reported by Guarducci et al. [3] "it seems that the first hermits reached Gorgona in the 4th century to be replaced, two centuries later, by an initial Benedictine nucleus" [...] in the middle of the 11th century the Benedictine monks of St. Mary and St. Gregory of Gorgona obtained a bull from Pope Alexander II, sent from Lucca on 16th August 1070 to the Abbot Adam, declaring the monastery of Gorgona to be immediately subject to the Apostolic See". The tower was erected above previous structures that could be very ancient. Around this structure, still identifiable in the current structure, other parts were added, up to give it a polygonal and asymmetrical plan, with three quarters of the perimeter exposed on a cliff overlooking the sea (Fig.1).

The access to the fortress is by means of a narrow three ramps staircase that opens into a large courtyard. The part leaning against the eastern wall (to be referred to the 13th century) shows a patrol walkway obtained in the same thickness of the masonry and a sentry box, architectural elements that allow it to be identified as a fortress. Moreover, arched windows and a machicolation above the single access door are present.

The interior of this structure is characterized by a barrel-vaulted roof, at the apex of which a square trap door opens, probably usable as a defensive hallway in the event of

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an enemy invasion to perch upstairs using a retractable ladder (Fig.2). Inside this room remains of plaster with red decorations depicting lilies can be observed.

Figure 1 – The fortress built over a rock spur on the western side of the island, (view from the south).

Figure 2 – The barrel-vaulted room with remains of plaster with red decorations (older part of the fortress).

This older part probably had a simple function as a watchtower and this would justify the most common toponym of Torre Vecchia, while the current appearance is that of a fortress.

Contiguous to this nucleus and subsequent, as evidenced by the stratigraphic reading of the masonries (clamping and texture of the masonries), a multi-storey building was built with large windows, a double-pitched roof in a wooden supporting structure and mantle made of bent tiles and imbrexes.

This part of the building, which also shows a sort of battlements, has unfortunately collapsed in the early 90's, and rebuilt in 1997.

In the courtyard, there is a cistern, and a large basin, probably dug in the early 60's of the last century, which would have involved the demolition of another cistern of ancient origin and, probably, other volumes also present, as can be seen from the old floor plans, below the current floor level. Another cistern is located near the southwest corner of the building. In front of the cockpit of this cistern there was another barrel vault construction, semi-underground. The shape and location of the cistern in relation to the above building seems to confirm the subsequent construction of this part with respect to the tower.

Regarding the masonries along the perimeter of the fortress, it is particularly striking an external arch built along the southern wall with the function of supporting the masonry above which, otherwise, would not have had a solid natural support base and which allowed to obtain a greater volume to the fortress (Fig. 3).

The fortress and the annexed building where the residence of the island parish chaplain named after Santa Maria and San Gorgonio. In 1723, inside the fortress a new church was built in substitution of the old chapel that was destroyed many times. According to the updating of the cadastral parcels dating back to 1904, carried out in 1933, it appears that the fortress, still a prison site until a few years earlier, was reserved for traffic lights and then completely abandoned [1, 2, 4, 5, 6].

Figure 3 – External arch built along the southern wall in order to obtain a greater volume to the fortress.

The whole structure is currently in a severe state of conservation both because of its location and probably because of the abundance of construction phases built at different times and with poor interlocking of the masonry. The collapses are evident with the fall of some roofs and most of the summit ridges and with the presence of structural lesions. The action of the marine aerosol, in particular on the seafront, has caused extensive phenomena of alveolization in the bricks and in the stone ashlars with erosion of the plasters and bedding mortars. On the walls less subjected to the wind action (N, NE, SE) a thick vegetation has grown with particularly aggressive tree species such as the fig trees. In the recent past (1999), a shoring with hollow bricks was accomplished.

The building materials

The building materials are the local stone (calcschists), the bricks, the mortars (bedding mortars, plasters and renders). Generally, the buttress and the corners are in stone (Fig. 4) while in the overhanging wall, the bricks are more present, with different distributions depending on the sides (Fig. 5). Widespread interventions are visible on the masonry, carried out at different times. The part leaning against the eastern wall is made of bricks. The most recent Renaissance-style windows are finished in Pietra Serena sandstone (frequently used in Medici buildings), as well as two fire mouths realized in the thickness of the east and north-east perimeter walls (Fig. 6). The calcschists are the most widespread rocks of Gorgona, which from a geological point of view represents a fragment of the Western Alps. In fact, rocks referable to the Ligure-Piemontese Domain, the so-called "Schistes Lustrés", outcrop on the island [7, 8, 9]. These rocks originally constituted calcareous clayey sediments of the Ligure-Piemontese oceanic basin. During the Alpine orogeny they were involved in a subduction process with high pressure metamorphism in Blue Schists facies and a subsequent phase of low-pressure metamorphism in Green Schists facies. Compositionally, the calcschists are composed of calcite, light mica, biotite, quartz.

Figure 4 – The buttress and the corners in calcschists.

Figure 5 – In the overhanging wall the bricks are more present. Remains of the original render are visible.

Figure 6 – A fire mouth realized in Pietra Serena sandstone.

The structure is more or less schistose depending on the amount of mica and this allows an easy splitting both in slabs for roofing and in blocks for masonry. However, this schistosity is also a factor of decay because it favours the exfoliation of the rock.

The research examines in particular the composition of the artificial stone materials (bricks, bedding mortars and plasters) belonging to the most ancient phases. The results will be useful from the historical point of view (origin of the raw materials from inside or outside the island) and for the future conservation intervention. In this regard, we have to remind that the island houses a detention centre where, since the ‘80s, prisoners have been involved in various work projects with the aim to improve social reinstatement and considerably reduce recidivism [10]. Therefore, under the auspices of the former director of the jailhouse, the idea is to involve in the conservation works a group of prisoners who will also have the task of the subsequent maintenance.

Materials and methods

With the permission of the "Soprintendenza Archeologia Belle Arti e Paesaggio per le Province di Pisa e Livorno" and the Direction of the Gorgona Prison, bricks, bedding mortars and plasters were sampled and investigated through mineralogical and petrographic methodologies [11, 12, 13].

The mineralogical composition has been was determined with a PANalytical diffractometer X'PertPRO with radiation CuKα1 = 1.545 Å, operating at 40 KV, 30 mA, investigated range 2θ = 3-70°, equipped with X' Celerator multirevelator and High Score data acquisition and interpretation software; the petrgraphical study was performed on thin sections (30 microns thickness) observed at the optical microscopy in transmitted polarized light (ZEISS Axioscope.A1 equipped with a camera [resolution 5 megapixel and dedicated image analysis software [AxioVision] for evaluating the microstructural parameters).

The petrographic study of the bricks allows to understand if these materials have been realized in the island. Indeed, in the locality "Piazza d'Armi" there was a furnace that used the local earth, originated from the alteration of the local schistose rocks. It is a "lean" earthen material, rich in metamorphic rock fragments easily recognizable in the fired products. Bricks produced in the Livorno coast would display a different aspect.

Regarding the mortars (for masonries and plasters), there are many characteristics to investigate, such as the amount and type of binder, the grain size and composition of the aggregate, the type of lime lumps. This makes it possible to differentiate them, to confirm different construction phases and to identify new ones. Concerning the binder, the study of lumps will give indications on the carbonate stone that was burnt to produce the lime. Indeed, in the island there are only little outcrops of crystalline limestones suitable for producing lime otherwise clods of quicklime had to be transported to the island, as it was the case for the construction of the watchtowers of the island of Capraia [14]. Figure 7 reports the collected samples and their position in the map.

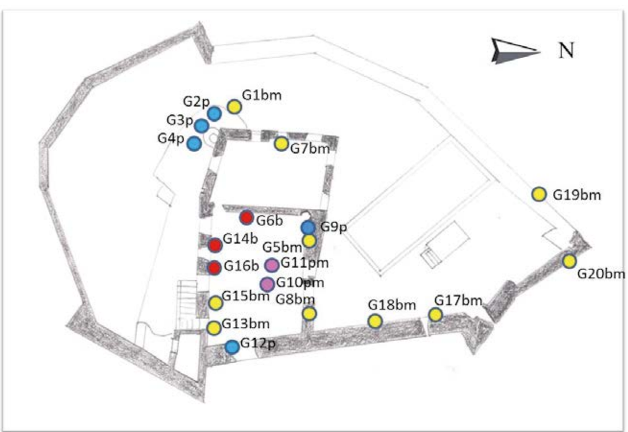

Figure 7 – The position in the map of the samples (b= bricks; p= plasters; bm= bedding mortars; pm= paving mortars).

Results

Bricks from the east room with barrel vault

There are two types of bricks, those of local origin realized from a coarse-grained earth rich in calcschists (Fig. 8) and bricks obtained from a finer earth (Fig.9). For these bricks it is possible to assume a provenance from the Tuscan coast or possibly a local selection of a fine raw material.

Bedding mortars from the east room with barrel vault

There are many typologies:

- mortar G5, characterized by an abundant binder of air hardening lime that seems to have been produced by burning crystalline limestones (presence of under burnt marble fragments) and quite fine aggregate of local origin (presence of calcschists and crushed bricks containing calcschists) (Fig. 10);
- mortar G8, characterized by an abundant binder that seems slightly hydraulic (from burning of impure marbles). The aggregate is relatively fine-grained and appears to be of local origin;
- mortar G13, characterized by an abundant binder of air hardening lime. The aggregate does not appear to be local in origin due to the presence of micritic and organogenic limestones (Fig 11);
- mortar G15, characterized by a scarce binder of air hardening lime. The aggregate is very fine, of unimodal grain size. It does not appear to be of local origin.

Paving mortars, from the east room with barrel vault

There are two typologies:

- -mortar G10, made of an abundant air hardening lime binder and an aggregate made almost exclusively by crushed bricks of local origin (containing calcschists);
- mortar G11, made of an abundant binder of mixed lime and earth. The aggregate is coarse grained, made of crushed bricks, calcschists and quartz, therefore of local origin.

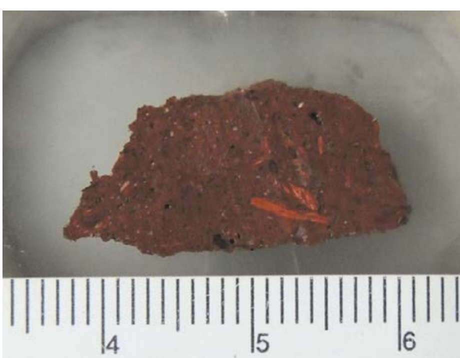

Figure 8 – Cross section of a brick realized with a coarse-grained raw material rich in calcschists.

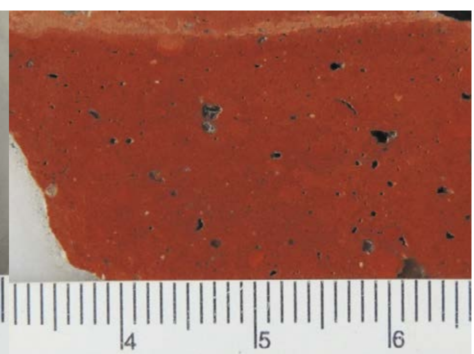

Figure 9 – Cross section of a brick realized with a fine earth.

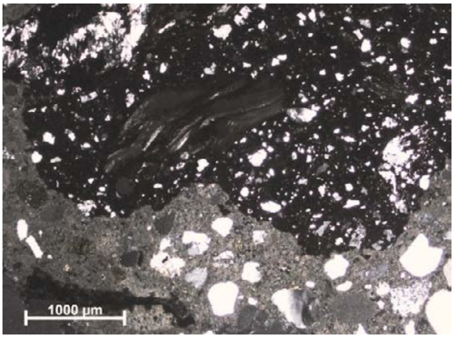

Figure 10 – Bedding mortar with a crushed brick containing a calcschist (local origin) (image at the optical microscope in thin section, XPL).

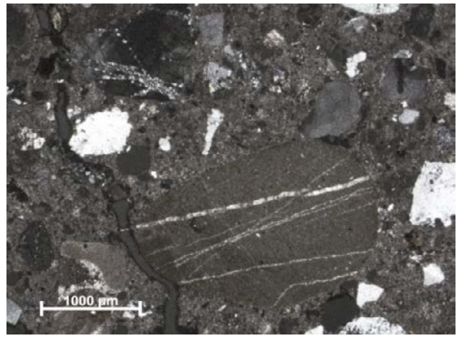

Figure 11 – Bedding mortar with a grain of aggregate made of veined micritic limestone (image at the optical microscope in thin section, XPL).

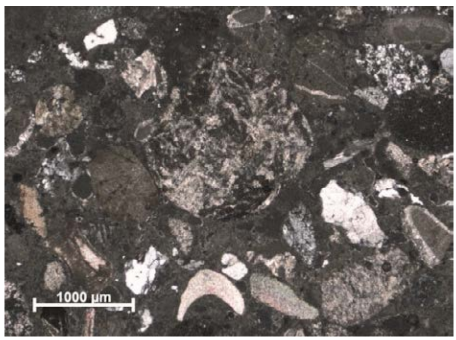

Figure 12 – Fragment of an organogenic limestone in the aggregate (image at the optical microscope in thin section, XPL).

Bedding mortar G7 from single lancet window in brick (east room)

- made of a scarce air hardening lime binder. The aggregate seems not of local origin because of the presence of organogenic limestones (Fig. 12).

Plasters

There are two typologies:

- mortar G9 (east room with barrel vault, north side), made of an abundant binder that seems slightly hydraulic (from burning of marly limestones). The aggregate is fine grained, of local origin because of the presence of calcschists;
- mortar G12 (east room with barrel vault, east side) made of a scarce binder that seems slightly hydraulic. The aggregate, of fine granulometry, seems not of local origin.

Bedding mortar of firemouth (G17) (east perimeter wall, interior)

- made of a scarce binder that seems slightly hydraulic as testified also by the presence of under burnt fragments of marly limestones (from the Tuscan coast). The aggregate, of fine granulometry, seems not of local origin.

Bedding mortar (G18) (east perimeter wall, interior)

- this mortar, similar to G17, is made of a scarce binder that seems slightly hydraulic as testified also by the presence of under burnt fragments of marly limestones (from the Tuscan coast). The aggregate, of fine granulometry, seems not of local origin.

Bedding mortar (G19) (NW perimeter wall, near the entrance)

- this mortar is made of an abundant air hardening lime binder. The aggregate is of local origin because of the presence of calcschists.

Bedding mortar (G20) (buttress, NE perimeter wall)

- this mortar is made of an abundant binder that seems slightly hydraulic as testified also by the presence of under burnt fragments of marly limestones (from the Tuscan coast). The aggregate, of fine granulometry, is of local origin because of the presence of calcschists.

Bedding mortar (G1) medieval cistern

This sample consists of two different unmixed mixtures:

- -fat mixture made of an air hardening lime binder and an aggregate of crushed bricks (800 µm - 1.5 mm) and rare quartz. Rare lumps are present;
- lean mixture made of an air hardening lime binder and an aggregate with prevailing angular quartz grains (200 – 300 µm) and rare crushed bricks. This aggregate seems of local origin.

Plasters of the medieval cistern (innermost zone)

- the external layer (G2) is made of an abundant aerial lime binder obtained from burning crystalline limestones (presence of under burnt fragments). The aggregate is made of quartz and crushed bricks and seems of local origin;
- the internal layer in contact with the masonry (G3) is made of an abundant aerial lime binder and an aggregate of quartz, crushed bricks and calcschists of local origin.

Plasters of the medieval cistern(G4) (near the mouth)

- the external layer is made of a scarce aerial lime binder. The aggregate, of bimodal grain size, is made of quartz, pozzolan and rare pyroxenes (Fig.13);
- the internal layer is made of an abundant aerial lime binder. The aggregate is made of quartz and fragments of micritic limestones.

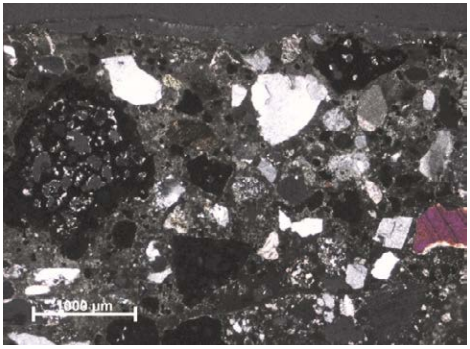

Figure 13 – Fragments of pozzolan and pyroxenes in the aggregate (image at the optical microscope in thin section, XPL).

Conclusions

The compositional analyses of the bricks and mortars used in the construction of the “Rocca vecchia” (up to the interventions of the Medici period) indicate that the origin of the raw materials is both local and from the Tuscan coast. With regard to the oldest part of the fortress (east room with barrel vault), there are bricks of local production (lean clayey raw material, rich in fragments of calcschists) but also bricks produced with a finer clayey raw material possibly selected locally or bricks imported from outside.

As for the mortars, the lime was produced both locally from the burning of crystalline limestones (particularly for the older samples), as evidenced by the presence of under burnt marble fragments but it was imported also from the Tuscan coast from the burning of marly limestones. The bedding mortars of the oldest nucleus are generally rich in binder with an aggregate of local origin (presence of calcschists) but mixtures poor in binder with an aggregate that does not seem local (presence of organogenic limestones) are also found. It is possible that these mortars should be referred to subsequent interventions. The bedding mortars of the external masonry (in the portion built in calcschists) are realised with an abundant binder and an aggregate of local origin, while the interventions of the Medici period are characterized by mixtures poor in binder with an aggregate of non-local origin. With regard to the plasters of the oldest nucleus, in analogy with the bedding mortars, there are fat mixtures with aggregate of local origin and lean mixtures with aggregate from the Tuscan coast. This information will contribute to better understand and define the different construction phases and will be useful for the future conservation intervention.

Acknowledgments

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MAKING A SITE OTHERWISE INACCESSIBLE ACCESSIBLE: 3D LASER SCANNER SCANNING OF THE GROTTA DEI CERVI DI PORTO BADISCO IN OTRANTO (LE)

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Abstract – The present paper enriches the framework of knowledge about one of the most important Neolithic caves in Europe, the Grotta dei Cervi in Porto Badisco, about 8 km south of Otranto (Le) (Italy). Its location close to the bay of Porto Badisco, overlooking the Adriatic sea, has made it a safe landing place since prehistoric times, when the populations arrived from the most disparate places of the Mediterranean and when, as evidenced by archaeological research, propitiatory and initiation rites were held inside the cave complex, often referred to as the Sanctuary of Prehistory in the Mediterranean. Currently, thanks to the 3D laser scanner survey carried out in the cave, there is a complete documentation, a digital archive that collects a database from which it is possible to extrapolate data regarding the morphology of the cave complex and the spatial location, materials and deposits present. The combination of different types of relief made it possible to relate it with the external environment, with places that were once crossed by a river. Moreover, thanks to the mapping of the extraordinary corpus of pictograms, it is possible to digitally preserve the figurative apparatus, which has been and still is being studied by numerous scholars who in recent decades have tried to grasp its true symbolic meaning.

Introduction

The extensive karst system of the Grotta dei Cervi and the Cunicoli dei Diavoli represents an archaeological site of great importance as it has been frequented by the prehistoric man since the Upper Palaeolithic. It lies below the plateau close to the inlet of Porto Badisco (Otranto), the terminal portion of a paleo-riverbed called Canalone. The cave was discovered in 1970 by some members of the "Pasquale De Lorentis" speleological group from Maglie (Le) who ventured into one of the access cavities and went down for about 14 meters before reaching the first rooms. The corridors branch off in different directions and they are variously articulated and placed at different levels. On the oldest Paleolithic levels of the Grotta dei Cervi, the archaeological layers of the Neolithic (VI-IV millennium BC) and the Metal Age (late IV-III millennium BC) are embedded, when the caves were frequented for cultural purposes, initiation and funeral rites. The important and numerous pictograms of the Grotta dei Cervi date back to the Neolithic of the V-IV millennium BC: they appear from the rocky walls of Corridor 2 and they are made of red with the use of ocher and of black with the use of bat guano.

They are strongly symbolic pictograms, which have determined the name of the karst complex as "Sanctuary of prehistory in the Mediterranean". The representations on the

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Figure 1 – Porto Badisco Otranto (Le). Zenith view of the archaeological areas under study. Integrated survey with 3D laser-photogrammetric hybrid techniques of the context and of the Grotta dei Cervi (Mitello & Muscatello, 2015).

walls of the Grotta dei Cervi refer to propitiatory scenes of deer or wild boar hunting, individual or collective anthropomorphic ritual representations, initiation and religious rites. Figures of great charm but fragile as their survival is linked to the conservation of the microclimate inside the cave.

Along the corridors, at the foot of the walls with paintings, there is evidence of religious, ritual and funerary practices of the early agricultural communities of Salento and more, represented by circles of stones, with traces of hearths inside which vases have been found; these vases contained offerings to chthonic deities and to the "Mother Earth" to gain favour with agricultural crops and to win the benevolence of the gods. Some portions of the Grotta dei Cervi have been the subject of archaeological investigations between the 70s and the 80s of the last century, with excavations that have made it possible to establish that the use of the cave began before the creation of the pictograms.

As part of the project for the enhancement of the territory promoted by the Municipality of Otranto and carried out in collaboration with the Archaeological Superintendence of Puglia, in 2015 an organic and articulated survey work was started: for the first time an integrated parametric survey of the entire Corridor 2 of the Grotta dei Cervi with its representations has been created and processed in high definition color with the 3D laser scanner technology (Figg.1-6). The survey and digitization of data still aims to know and study the morphology of the cave and the pictograms it contains; a fundamental step for digital preservation; the "*digital twin*" of the monumental cave complex can be considered as the model intended for scholars and users that allows them to see a site that would not otherwise be available for visits.

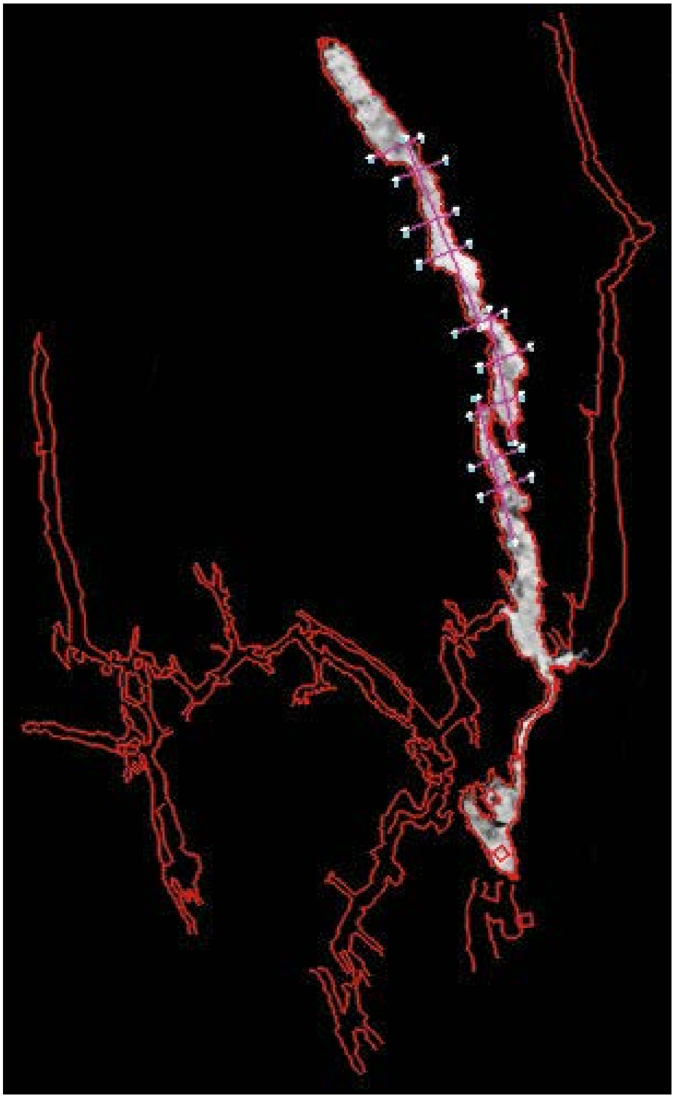

Figure 2 – Grotta dei Cervi. Relief of the rock complex. Corridor 2 detected with technologies integrated with color parametric 3D laser scanner (Mitello & Muscatello, 2015).

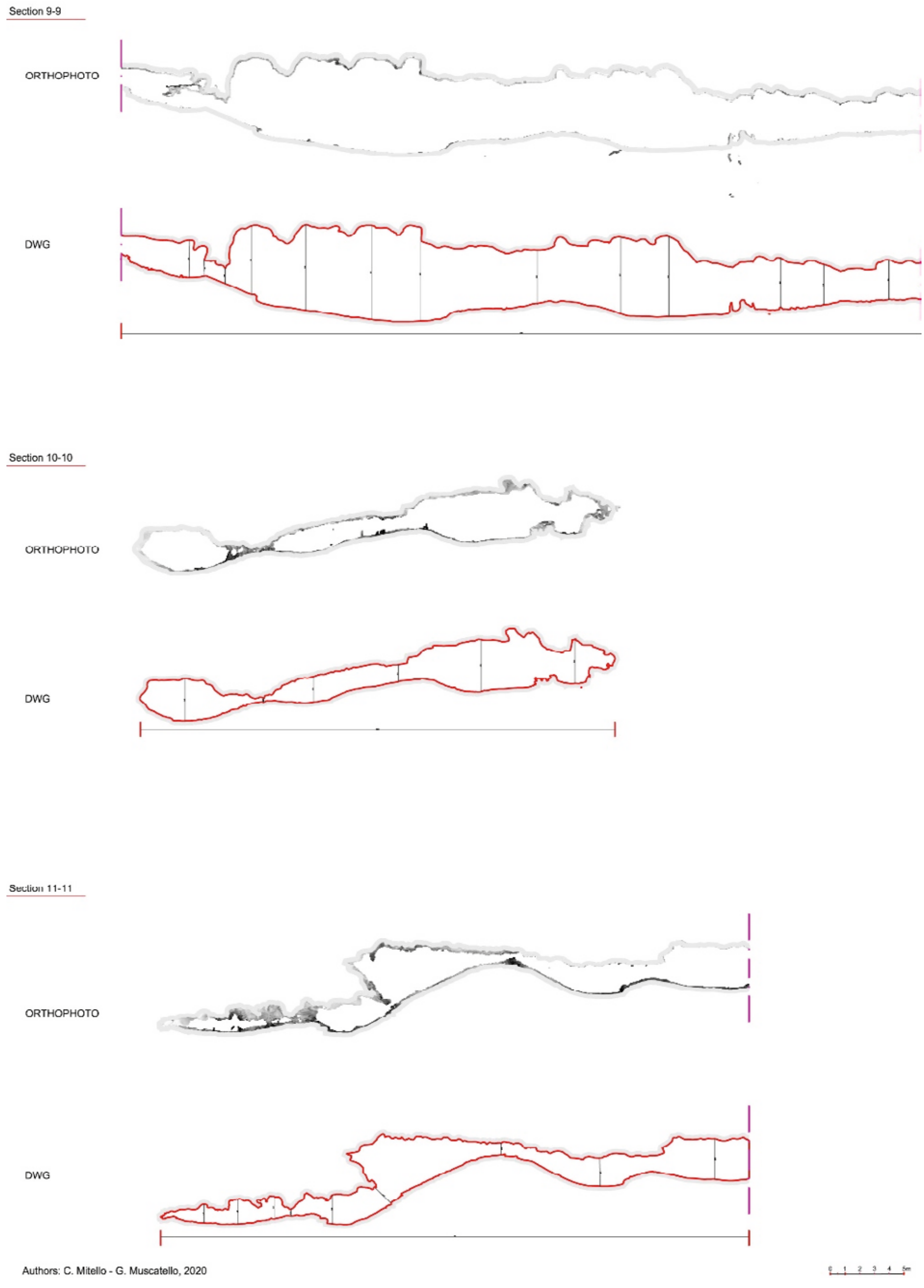

Figure 2 a – *Grotta dei Cervi*: Corridor 2 longitudinal sections.

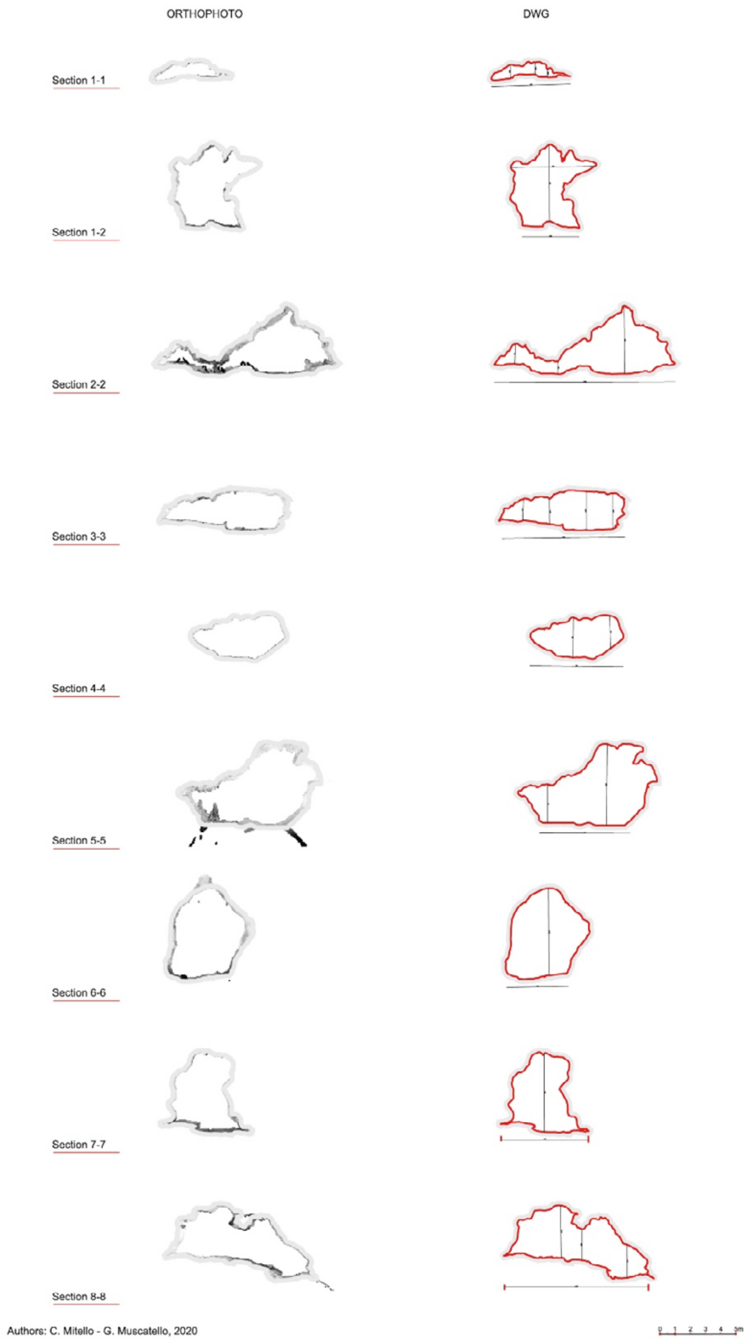

Figure 2 b – *Grotta dei Cervi*: Corridor 2 cross sections.

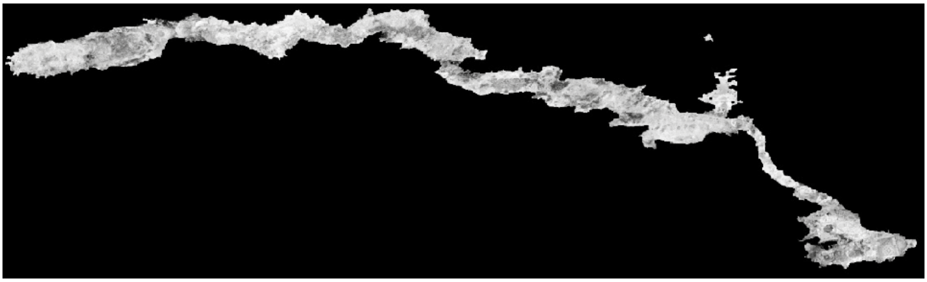

Figure 3 – Grotta dei Cervi, Corridor 2. Planimetry. 3D digital twin from dense cloud of internal volume. The morphology of the cave is highlighted (Mitello & Muscatello, 2015).

Methods: the cave and the relief as a method of knowledge.

Representing the three-dimensional space of the cave context through an overall vision was a difficult undertaking. Indeed, the cave does not constitute a single environment, it is a system that is only partially comparable to a monument or an archaeological site. Its planimetry is irregular and it is divided into rooms and alleys, where you can find distracting elements such as concretions, stalactites and stalagmites and archaeological deposits. Added to this is the irregularity of the walls, modelled in eaves and recesses, that do not allow a perfect view of the limestone surfaces. The non-conformities of the rock are constitutive elements of the painted figures; the same way, the artificial light reveals the images, giving them vibration and movement. These conditions have required a preliminary study of the context and an evaluation of the relevant procedures to be adopted.

Following the process of elaboration and creation of a dense cloud, the use of the 3D scanning technology (TLS) has offered an inspectable and measurable three-dimensional model that proposes the detected reality with a remarkable level of detail and completeness, from which it is possible to obtain not only the desired volumetric graphical representations, with global geometric information, sections and plans, but also the possibility of understanding the morphological characteristics of the site, the overall size, the abacuses of the materials, the colors and the monitoring of the cave and of the rock paintings present over the years.

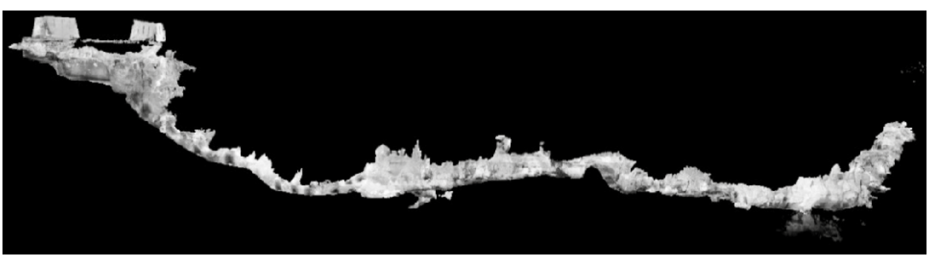

Figure 4 – Grotta dei Cervi, Corridor 2. Side view of 3D digital twin from dense cloud of internal volume. The three-dimensional model generated by the global point cloud represents the current state of the complex with all the morphological characteristics and peculiarities, including the corpus of pictograms (Mitello & Muscatello, 2015).

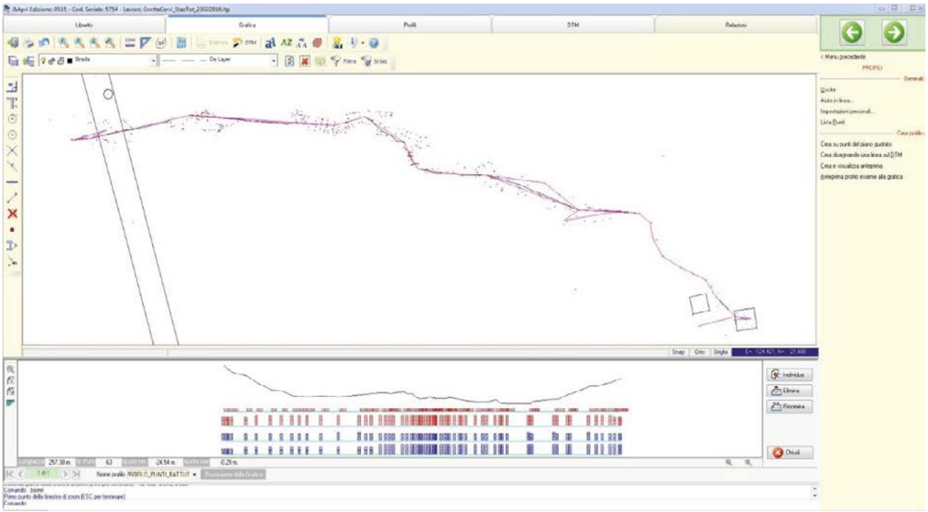

Figure 5 – Elaboration of the georeferenced integrated survey, with Gps and Total Station, of Corridor 2. Plano-altimetric development of the polygonal materialized in the cave (Mitello, 2015).

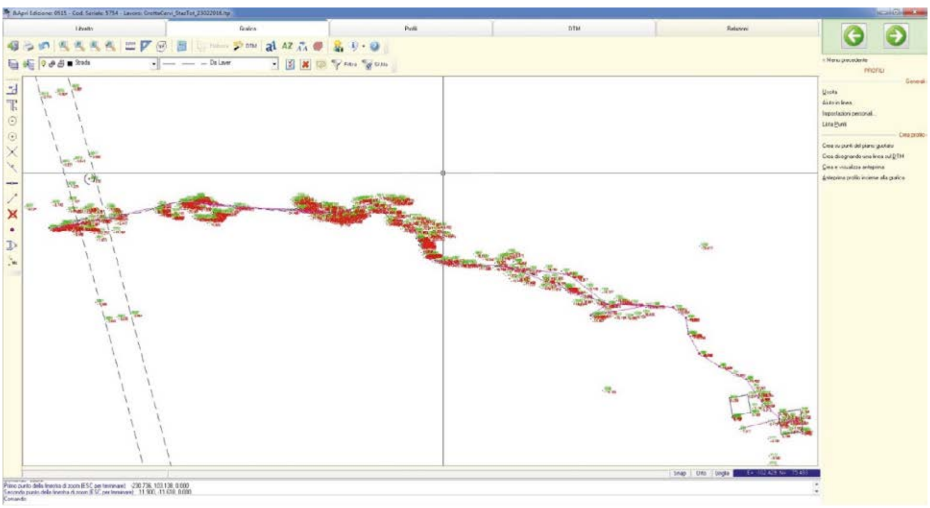

Figure 6 – Elaboration of the georeferenced integrated survey, with Gps and Total Station, of Corridor 2 of the Grotta dei Cervi. Development of the planimetric trend of the polygonal materialized in the cave (Mitello, 2015).

The laser scanner surveys in the cave, integrated with a topographic polygonal support and a GPS survey of the entire external area of Porto Badisco, made it possible to frame, reposition and orient the caves in relation to its surroundings; an important reinterpretation of the first surveys carried out in the 1970s.

The scans, compatible with the size of the geometric shapes of the site, ensured a detailed survey and were carried out from different points of view to obtain a complete coverage of the entire structure and to avoid shadow areas or gaps characterized by lack of data. The photogrammetric mapping made it possible to add further useful information, including the color of the rocks and the pigmentation of the pictograms.

The processing of the survey, the subsequent creation of a virtual tour designed within the three-dimensional model resulting from the 3D laser scanner survey, allows you to have an integral view of the geometric and morphological components of the caves excavated by an ancient underground river and later used by the man.

Digital mapping of pictograms

The Grotta dei Cervi is one of the most important monuments of post-paleolithic wall art in the Mediterranean.

Its pictograms, as already mentioned, represent a full immersion in the messages left by the people who used it thousands of years ago. The sets of pictograms on the walls, characterized by images of considerable size, were made at different times and with different pigments including ocher, bat guano and cinnabar, present in one of the corridors.

One of the most evocative sections of Corridor 2 is represented by the last section in which a pictorial composition is presented: spiral-shaped, cruciform and anthropomorphic elements and deer hunting scenes tell a suggestive story that still poses countless questions.

The pictograms represent an enormous heritage, but due to the precarious climatic conditions within the cave, they constantly risk being erased or ruined forever together with the story they tell and their meaning that is still to be examined, which is the result of experiences and thoughts of the men who lived in the Neolithic and later, who transmitted and shared, consciously or unconsciously, their lives and their habits with their representations.

The digital mapping and the consequent cataloging made it possible to definitively record the representations to make them visible to the community and available for the study of the experts in the field, without the need to physically enter the cave (Figg. 7-10).

Conclusions

Much has been written about the Grotta dei Cervi in Porto Badisco over the years, especially about the interpretation of the pictograms and about the materials found in it. This work highlights aspects that have not been thoroughly investigated such as the morphological and dimensional conformation, and the exact spatial location of the pictograms within it.

From the analysis of the data - still in progress - resulting from the work carried out with the application of modern survey technologies, a lot of elements will emerge that will help to quantify the area and the volume of the karst system where the different environments that make up the Grotta dei Cervi system are articulated.

The development of the immersive reality, the remote disclosure, the possibility of re-proposing the site, also due to the digital twin, are the aims of a probable project of enhancement and use of the cave, to make a site accessible which otherwise would be inaccessible.

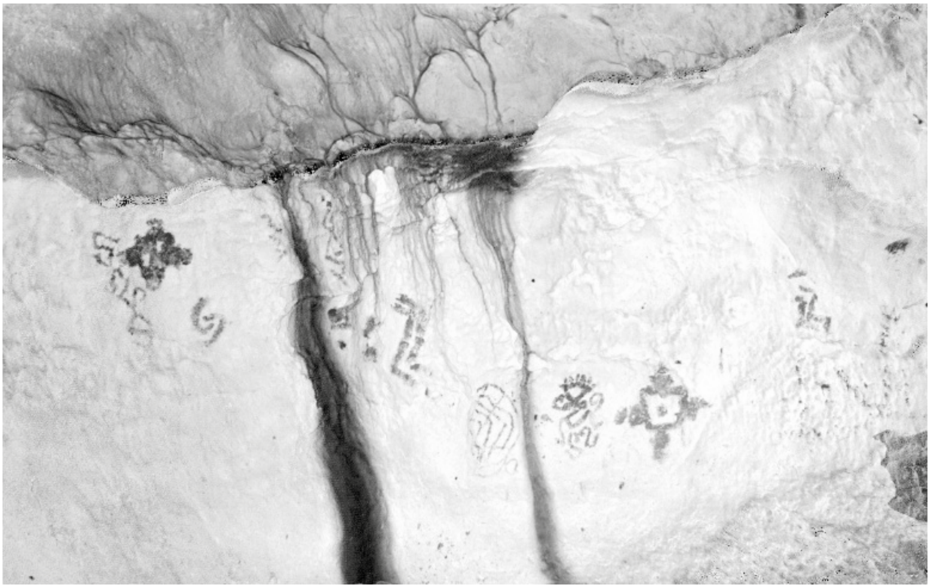

Figure 7 – Corridor 2. Digital mapping of bat guano pictograms present on the rock walls (photo by Mitello & Muscatello, 2015).

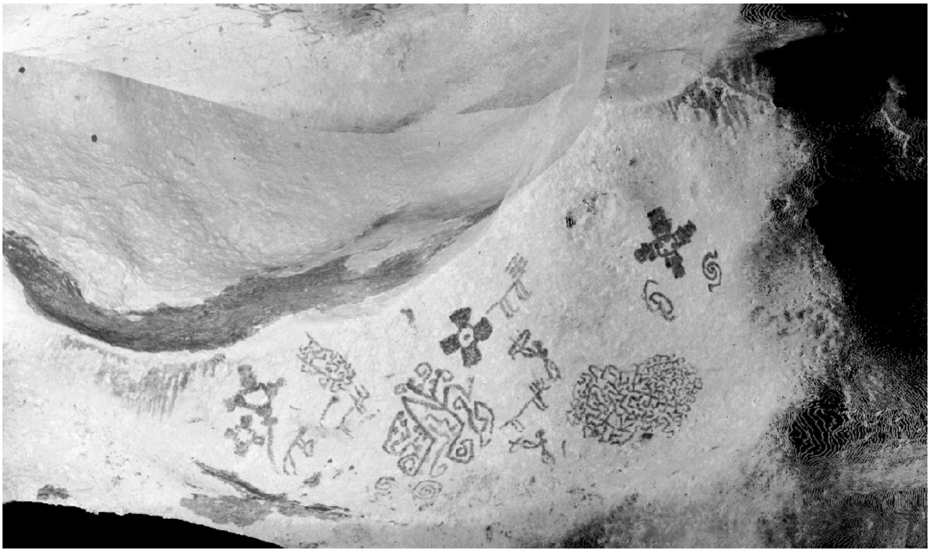

Figure 8 – Corridor 2. Digital mapping of pictograms. The symbolic representations are various, some related to the cult of Mother Earth (photo by Mitello & Muscatello,2015).

Figure 9 –Corridor 2. Processing from 3D laser scanner survey of the panoramic views of the cave for the study and virtual use of the context (photo by Mitello & Muscatello, 2017).

Figure 10 – Panoramic view processed by the parametric survey with 3D laser scanner. The vast digital archive in possession allows the analytical study of the morphology of the cave, of the pictograms and of the deposits present (photo by Mitello & Muscatello, 2017).

Notes

The direct and instrumental surveys, the two-dimensional and three-dimensional graphic elaborations were made by Carmine Mitello and Giovanna Muscatello. We thank the Municipality of Otranto and the Archaeological Superintendence of Puglia for allowing the realization of the 3D laser scanner survey inside the Grotta dei Cervi in Porto Badisco, necessary for the study of the important rock complex.

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...*IN FINIBUS LUCANIAE.* HISTORICAL CARTOGRAPHY OF THE TYRRHENIAN COAST AND DEMOGRAPHIC FLUCTUATIONS

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Abstract – Water, through rivers, lakes and seas, draws the territory, draws its boundaries: cities are born near the largest and smallest watercourses but the swamping of a stretch of coast represented the loss of population and also of markets and trade. On the maps, depopulation is highlighted with different cartographic symbols according to the period in which the map was drawn: for a long time there are two Maratea, the one above and the one below, only since 1881 the construction of the port and, therefore, the birth of a nearby village and, to the south, Castrocucco perched on a motta that was depopulated and never rebuilt. The nearby towns of Calabria such as Tortora, Aieta and Praia a mare with the Dino island and the Fiuzzi village gravitated towards Castrocucco and Maratea and are an integral part of this study. Although divided by the Noce river they are in finibus Lucaniae and up to Borgo Fiuzzi they seem to belong to the same conformation as Castrocucco with vast coasts and beaches of very large dimensions and steep rocky walls full of caves. Historical cartography reports information on these watchtowers built in the sixteenth century with the great project of militarization of the coasts of the Kingdom of Naples to defend themselves from the invasions of the Turks with the order of Pietro da Toledo of 1532 and that of Pedro Afan de Ribera del 1563. Over the centuries, on the border between Basilicata and Calabria we have witnessed very particular demographic variations and fluctuations. The city of Blanda identified in recent archaeological excavations in the territory of Tortora which disappears in the 5th century AD, the birth of Tortora and Aieta in the Apennine mountains according to that typical name of the castle of the early medieval period, the settlement in the Fiuzzi district of Praia a Mare and on its rocky pediment and full of caves, settlements of Italian-Greek monks. With the arrival of the great migrations of Albanians after the advance of the Turks, villages with the presence of these populations were born in this area too: in the territory of Praia that belonged to Aieta the village of Plaga Sclavorum was born, most likely in the area located between Torre Fortino and Fiuzzi. With the twentieth century and the mass tourism of the 60s, Aieta and Tortora begin a slow process of depopulation that leads to the birth of settlements towards the sea with Tortora marina and Praia a mare which had already become an autonomous municipality in 1928. Settlements on the coasts also take effect with the repopulation of the new Castrocucco located on the sea near the area of great tourist attraction called the Secca, in Aieta there are about 750 inhabitants and in Tortora, a town about 500 inhabitants.

Text

The title of this work was suggested to me by some memorable pages written by the Lucanian intellectual Giacomo Racioppi who, with the nickname Homunculus, in 1875

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published a booklet entitled *Paralipomeni della storia della denominazione di Basilicata*[1] . This volume specifies Racioppi's theories on the name Basilicata / Lucania with precise references to the area north of Maratea and especially to Cilento and its territory [2]. Without wishing to enter the jumble of opinions on the names Lucania and Basilicata, in this contribution we will study the countries, the populations who settled on the fleeting borders between Basilicata and Calabria in the stretch of coast between Castrocucco di Maratea, the district further south of Maratea in Basilicata, and Praia a Mare and its district Fiuzzi with the Dino island which are in Calabria. The choice of this stretch of coast to talk about demographic fluctuations stems from the awareness that in a few kilometers of coast many settlements have formed, over the centuries, some of which have depopulated and disappeared, others have transformed into the cyclical alternation that, throughout history, they have seen men prefer to live on coasts and plains or on hills and mountains. Certainly this stretch of coast has always been man-made but there have never been very large settlements, there have been many and, according to the period, one has grown more than the other almost in rotation.

"*Dal Paleolitico inferiore, attestato da uno stanziamento all'aperto rinvenuto a Tortora si passa al Paleolitico medio le cui industrie litiche sono state scoperte a Torre Talao di Scalea, ed al Paleolitico superiore del Riparo del Romito a Papasidero, che ha restituito la prima manifestazione artistica calabrese con il graffito del "bos primigenius", e della Grotta della Madonna di Praia a Mare. Il Neolitico è rappresentato dai reperti a Favella della Corte, a Cassano Ionio, a Praia a Mare. L'età dei metalli è illustrata da numerose scoperte, le più significative sono quelle che si riferiscono alla cultura appenninica, i cui resti provengono soprattutto da una grotta a Praia a Mare ed alla prima età del ferro, che vide i primi colonizzatori greci in Calabria*"[3].

The settlement choice of men has always been determined by the particular landscape beauty of this stretch of Italian coast which, even today, has a border that unites and welcomes languages and traditions from the two neighboring regions.

Even the river Noce and its mouth in the territory of Tortora which was and is considered the natural border between the two regions, today represents a watercourse super protected by the Calabrian population of Lucania and a point of strong union, especially in the last period, to prevent its waters from being polluted throughout its course that crosses territories and valleys of both regions. The Calabrian-Lucan populations united to prevent the reopening of a waste disposal plant that was closed because it was not up to standard and located in Sansago, a district in the Tortora area.

It must immediately be specified that the difference existing between the cartography produced regarding the borders is not always very precise compared to the documentation of the chancellery of the Neapolitan kings and viceroys and this dyscrasia led, for example, to moments of serious tension between the Calabrian Capuchin Friars of

[1]*Paralipomeni della storia per la denominazione di Basilicata per Homunculus* (1875), Tipografia Barbéra Roma, 58-60.

[2]IDEM. In addition to the volume of Giacomo Racioppi which remains the most anticipated and equipe with many documents of the vexata questio Lucania Basilicata, I allow myself to report V. Aversano (1983), *Il coronimo Cilento e il suo territorio (1034-1552)*, in "Studi e Ricerche di Geografia" VI-1, 78-127, still today it is an important work and comparison tool.

[3] G. GUIDA (1991), *Aieta. Pagine della sua storia civile e religiosa*, Cosenza, 11.

Mormanno and those Lucani di Maratea for the right to begging during the seventeenth century. On July 8, 1669, Father Fortunato da Cadore ordered that Aieta *per pane e vino sia solamente dei frati di Maratea, per l'olio, legumi, frutta ed ogni altra cosa sia dei frati di Mormanno…che la terra di Tortora e di Laino Borgo seguiti ad essere della Provincia di Basilicata e resti il Castello di Laino a Cosenza*[4]. It is clear that Father Fortunato followed common sense more than the real geographical divisions also inherent in the ecclesiastical Provinces, it is well known that the Franciscan families of Tortora were in the Province of Basilicata since the late sixteenth century due to the presence of the Osorio Exarque family who founded the convent of the Santissima Annunziata di Tortora after they bought the fief and were in close relations with the Franciscans of Lauria.

If I had to give a starting point to tell the evolution of this small stretch of coast, I would certainly start from the city of Blanda which no longer exists and was searched for a long time between Maratea and Cirella. It is certainly mentioned in the Tabula Peuntingeriana as a statio of the Antonine Itinerary and in many other sources but, only in 1891, Michela Lacava identified Blanda near Tortora by going to the place and bringing to light a series of important finds between the Noce and Fiumarella rivers of Tortora[5].

Since then, many reconnaissance and excavation campaigns have followed which continue today[6] and which have been able to reconstruct the evolutions of this inhabited area that from a city enotra of the sixth century BC. it became Lucanian and then a Roman municipium with the transformation of its name into Blanda Julia in honor of Augustus and its abandonment in the 5th century AD.

A new site was established near the Fiumarella di Tortora with the foundation of a diocese: the discovery of a church with a central plan and three apses with burials can be dated between the 6th and 7th centuries[7]. This is more than a thousand years of history in which Blanda was the protagonist and capital city of this stretch of territory which, with the birth of the diocesan seat, brought together Lucanian and Calabrian localities, making it clear how traditionally the communities that were born around the Noce river were united. and its tumultuous tributaries.

But it is necessary to clarify that this is the period of the great territorial and diocesan reorganizations that will result in new state and local political organizations during the eighth century and also religious upheavals that will give rise to new aggregations.

I refer to the formation of new centers of power with the settlement of the Lombards in some areas and the Byzantines in others, the always unclear dividing line between the various territorial powers led the population to decrease and to cause the loss of some inhabited centers and to the birth of others who, slowly, left the coastal plains to take refuge in hilly and mountainous areas.

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[4] G. LEONE (1986), *I Cappuccini e i loro 37 Conventi in Provincia di Cosenza*, Cosenza, vol. I, 57-58.

[5] M. LACAVA (1891), *Del sito di Blanda, Lao e Tebe Lucana*, Reale Tipografia Giannini e figli, Napoli.

[6]The bibliography is extensive but there are only a few texts with an extensive bibliography that tell the story of the important discovery and its excavations. F. Mollo (2001), *Archeologia per Tortora: frammenti del passato – Guida della Mostra di Palazzo Casapesenna,* Potenza; G.F. LA TORRE e F. MOLLO (2006), *Blanda Julia sul Palecastro di Tortora. Scavi e ricerche (1990-2005)*, in "Pelorias" 13 – Dipartimento di Civiltà antiche e moderne di Messina.

[7] New studies are hoped for in order to better understand whether it should be considered an early Christian diocese in the Lucanian or Calabrian territory.

From the many publications of local history lovers one could deduce the strong presence of Greek monasticism right in this stretch of coast, the writing production on this area by Biagio Moliterni is considered of great quality, who with great precision collects information on the origins of the communities of Aieta , Tortora and Praia a Mare[8] and that have been of great help to me for this study which aims to focus attention on coastal settlements and population cycles.

Add to this the brief but very interesting study on Castrocucco di Maratea by Luca Luongo[9] who immediately states that the territorial boundaries of the Feud of Castrocucco are only known from the 18th century land registry from which it is clear that the border with Tortora was naturally marked by the river Noce but the one with Maratea caused tensions and quarrels as it was made up of the line drawn by *Regia Torre di Caja, sita in questo territorio* [di Maratea] *sopra gli scogli del mare verso ponente* fino *alla falda del monte detto del Piscopo* towards the East[10].

Castrocucco was born in the same period in which the settlements of Aieta and Tortora were formed. Tortora is mentioned for the first time in the life of Saint Elias who lived in the 10th century [11]. Aieta, on the other hand, is mentioned in the life of San Saba di Collesano and, subsequently, in a deed of donation to the abbey of Cava dei Tirreni by Ugo and Emma d'Avena, from the monastery of San Giovanni *in loco Layta, qui est propre castro Mercury* in 1186.

Castrocucco is remembered in a document of the archbishop of Salerno Alfano of 1067 much investigated for some diplomatic contradictions that have been overcome in a study by Biagio Moliterni with many proofs to support the veracity of the document (considering the territories on the border between two administrative realities, the disappearance of the diocese of Blanda Julia, the territorial reorganization of the diocese of Cassano and many other sources linked to the birth of the towns in the area in question)[12].

But to better understand how this territory was being reorganized, it is not enough just to consider the famous phenomenon of fortification and the widespread preference of the populations of that period to settle on the hills and mountains, fortifying and militarizing these small towns.

Other documents from the 60s of the 11th century describe the situation of the Byzantine theme of Calabria which was divided into two *turmae*: one of these is mentioned since the 10th century in an hagiographic text "*con il suo centro ad Aieta; essa sicuramente a Nord si estendeva sino al Noce che costituiva la frontiera del tema di Calabria; e ad Ovest sino alla turma del Merkurion, che apparteneva al tema lucano*"[13]. In a Greek map of

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[8] B. MOLITERNI (2003), *La chiesa di San Zaccaria e l'origine del Santuario della Madonna della grotta di Praia a mare*, in "Archivio storico per la Calabria e la Lucania" LXIX, 19-26; Idem (2009), *Laos: fiume e città nella Geografia di Strabone*, in Idem LXXIV, 5-29; Idem (2010), *Laos: fiume e città negli scritti, nella cartografia e nella ricerca archeologica dal XVI al XX secolo*, in Idem LXXV, 95-128; Idem (2013), Alfano, *Pietro e la diocesi di Policastro*, LXXIX, 7-36.

[9] L. LUONGO (2019), *Il castello di Castrocucco. Note storiche*, in "*La squilla"*, 77-93.

[10] Ibidem, 80-81.

[11] V. SALETTA (1972), *Vita di S. Elia Speleota secondo il Man. Crypt. B. XVII*, in "Studi Meridionali" V, 87.

[12] B. MOLITERNI (2013), *Alfano, Pietro* cit.

[13] A. GUILLOU, *Geografia amministrativa del Katepanato bizantino d'Italia*, in *Calabria Bizantina. Vita religiosa e strutture amministrative*, Atti del primo e secondo incontro di Studi Bizantini, Reggio Calabria 1974, pp. 120-121.

1065, reference is made to a church called San Zaccaria and Sant'Elia, to the church of San Nicola de Digna and to that of Santa Venere. It is necessary to report the part of the document that is interesting for this study: *...et in valle que Mercurii nuncupatur abbatiam Sancti Petri que dicitur Marcanito, et ecclesiam Sancti Helye et Sancti Zacharie cum omnibus pertinentiis earum, et ecclesiam Sancti Nicholai de Digna cum vineis et terris et silvis et marino portu, et abbatiam Sancti Nicholai de abbate Clemente cum vineis et terri et silvis et ecclesiam Sancte Venere cum casale*[14].The toponym Digna indicates the Dino island of Praia a mare: I do not know the reason why all the literature on the subject believes that the church of San Nicola is not located on the Dino island but it is a church of the nearby San Nicola Arcella which was previously called San Nicola dei Greci. Why should they mention the Dino island in the document if the church is located in San Nicola Arcella? The same is true of the port which has been identified with that of San Nicola Arcella. It is believed that the landing on the island is a natural harbor in at least two points close to the mainland - called Capo d'Arena - and it can be assumed that the church of San Nicola was located on the rocky island of Dino.

Also as regards the church of Sant'Elia and San Zaccaria or as many write the two churches of Sant'Elia and San Zaccaria, I believe they are located in the territory of Praia a Mare. Other documents come to our aid: "*Ego Normannus et uxor mea Adeliza et Robertus privignus meus et filii mei et pro anima Goffredi de Aita et omnium parentum suorum atque meorum dono et concedo omnipotenti Deo monasterium sancti Nikolai de Tremulo cum pertinentiis suis et ecclesiam sancti Zacharie, que est iuxta mare suptus Aitam, et totam vineam, que est circa eam, una cum cripta, que est iuxta eam et tota terra, que est da Falconara usque ad Mali canale*"[15]. The second document speaks only of the church of San Zaccaria which is located near the sea below Aieta which, before 1928, the year of the birth of Praia a Mare as an autonomous municipality, included the entire territory of the current Praia a Mare. It should also be noted that there is still toponymic memory of a district of Sant'Elia which is located near a huge cave, sanctuary of the Madonna della Grotta di Praia a Mare, which around it has a series of small caves that could be the cells where the monks of the church of Sant'Elia were hospitalized.

It is agreed with the hypothesis that the church of Sant'Elia was located near the cave of the Sanctuary of the Madonna if not inside the Marian sanctuary also in consideration of another document which shows that the church and / or monastery di Sant'Elia was the same to which about a century and a half later, precisely in 1198, Giovanni Scullando, lord of Aieta, donated some funds to the Petricella, including the 15 farmers involved in their cultivation[16].

We just have to locate the church of San Zaccaria which we know was near the sea surrounded by vineyards and which was located near a cave. In a document of King Robert dated 12 March 1338 and reconfirmed on 6 February 1408 by King Ladislao, the boundaries of Scalea are described, which at the time also included San Nicola Arcella: in

[14] A. PRATESI (1958), *Carte latine di abbazie calabresi dell'archivio Albobrandini,* Città del Vaticano, 254.
[15] L. MATTEI-CERASOLI (1938), *La badia di Cava e i monasteri greci della Calabria superore*, in "Archivio Storico per la Calabria e la Lucania", VIII, 177-178.
[16] F. TRINCHERA (1865), *Syllabus graecarum membranarum*, Napoli , n. 243, 328-329.

the final part the document handed down *et exinde ad fontem de Caballarum, et ab ipso fonte vadit p. caput Mali Canalis, et a Canale ipso usque in viam turturis per Arcum Maris*[17].

To come up with a hypothesis for the location of the church of San Zaccaria, it is advisable to quote a small passage from the volume by Vincenzo Lomanaco of 1858:

"*L' aria della Praja è poco salubre da luglio ad ottobre per lo ristagno delle acque nella contrada detta Pantano, le quali, benché fossero incanalate, non cessano però nei calori estivi d'influir sulla salute di quegli abitanti. Da novembre a tutto giugno le più agiate famiglie di Ajeta vi villeggiano ne' propri casini sotto un cielo delizioso dolce e ridente. La popolazione del villaggio trovasi stremata da un fiero malore, detto il torcicollo, che nel 1841 mietè molte vittime, e spense intiere famiglie. Oggi non ascende che a 200 anime, di cui parte è addetta alla pesca, e parte alla coltura… In virtù di decreto della Ruota del Regio cedolario dei 18 Agosto 1695 D. Giovanni Francesco Cosentino marchese di Ajela soddisfece alla Regia Corte ducati 450 per ancoraggio e falangaggio. Nel relievio della terra di Ajeta del 1704 si legge la seguente tassa ducati 6 per pascoli, ducati 12 e grana 66 per decima del pesce, ancoraggio e falangaggio della Taverna dell'Arco. La prestazione annua per l'isoletta di Dina era in carlini sei. Debbo tali notizie al prefato Ch. Camillo Minieri Riccio… In questo luogo ebbe morte onorata un tal Vitigno condottiero degli Ajetani che in agosto 1639 combattè valorosamente contro t Turchi che capitaneggiati d'Amurat Rayt con sei vascelli prima assalsero Dina; di poi Scalea, onde furono respinti dal Principe Francesco Spinelli che vi lasciò miseramente la vita come narra Giannone Stor. lib. 35. cap. 1. Ciò avvenne essendo Viceré di Napoli il Conte di Lemos. La morte di Vitigno é decantata con mediocri versi dall'Abate, Molitemo (Poesie Liriche Nap. 1760 p. 166). La tradizione di questo avvenimento si conserva tuttora dai terrazzani, e si ripetono di frequente i versi che descrivono il coraggio e la pietà di quell' eroe e martire cristiano, il quale ferito letalmente, sopraffatto dall'oste che discendeva folla dai legni barbareschi, ebbe rifugio io un antro, ove si trovò poi spento intriso nel sangue col rosario in roano, ineffabile conforto dei veri credenti nell'ora solenne del supremo tragitto*"[18].

Trying to put in order the information that comes from both the documents and the literature on the subject, it is believed that San Zaccaria was located on the spur of rock that stands near the tower of Fiuzzi, in front of the island Dìno since it is close to the sea and it is located within the boundaries of the territory described in the document of 1338 which speaks of a land that starts from the Falconara tower and arrives at the Malocanale located near an Arco del Mare along the road that leads to Tortora. The reference is to that canal located immediately after the Tower of Fiuzzi which is still smelly and divides the territory of Fiuzzi from that of San Nicola.The arch of the sea is the natural arch of rock placed on the beach under the tower that allows you to continue walking on the beach without entering the water and leading up to Tortora. Near that arch there was a Taverna because it was certainly located on a busy road that connected Scalea to Tortora. In this document, the boundaries of the current Praia a Mare are well explained, at least on the marine side. Right on the spur of rock above that arch stood the monastery of San Zaccaria overlooking the sea

[17] G. CELICO (2000), *Scalea tra duchi e principi mercanti filosofi e santi*, Diamante, 22 e 64, nota 39.

[18] *Monografia sul Santuario di nostra Donna della Grotta nella Praja degli Schiavi e sul Comune di Ajeta in Provincia di Cosenza per VINCENZO LOMONACO giudice della Gran Corte Civile di Napoli e socio dell'Accademia Ercolanense, Cosentina, Pontaniana ed altre* (1858), Terza Edizione, Tipografia della Sirena, Strada Nuova de' Pellegrini n.20, Napoli, 10 e 19.20.

and with a breathtaking view (today a famous nightclub is born). Opposite the island of Digna was the church of San Nicola and between the island and the spur where the coastal tower was built, a small port was born. Even the description that Lomonaco offers us of the valiant death of Vitigno in 1639 makes us understand that it took place in a cave located near the Dino island and near the spur of rock where the monastery of San Zaccaria stood; it is unthinkable to think that gravely injured vine could have reached the Grotto of the Sanctuary of the Madonna which was located quite far from the island and at the top of a steep slope.

Furthermore, I consider very important the description of the marshy area of Praia a Mare called Pantano and which was uninhabitable until the reforms of the early twentieth century. He makes us understand that in Praia you could live high up as the Basilian monks did by locating their churches and monasteries in the caves near that of the Sanctuary of the Madonna or on the island of Dino or on the spur overlooking the sea on which San Zaccaria stood.

When a colony of Schiavoni settled in Praia it is assumed that other upheavals were taking place in this stretch of coast: we were at the turn of the fifteenth and sixteenth centuries.

In Castrocucco the site was depopulating: Luca Luongo describes this depopulation by dates making the death of this inhabited center even more bloody and truthful, the ruins of which, still today, stand on the top of a cliff overlooking the sea, noticeable even from a great distance: "*nel 1470 Re Ferrante investì Galiotto Pascale di Policastro del castello diruto e disabitato di Castrocucco in Provincia di Valle di Crati e Terra Giordana, cum eius arce juribus etc. Nel 1563 il detto castello fu venduto a Giulia De Rosa dall'incantatore del Sacro Regio Consiglio per esecuzione contro Antonio Varavalle. Nel 1573 lo stesso castello fu venduto a Giovan Cola de Giordano… Nel 1603 era possessore di Castrocucco, Fabio Giordano… Nel 1680 Domenica Giordano, Baronessa di Castrocucco, legittima moglie di D. Bonaventura Salone Caracciolo donò a D.a Francesca Greco sua figlia primogenita la Terra seu Castello di Castrocucco sito in Provincia di Basilicata*"[19].

Since then Castrocucco lost its autonomy as an independent fiefdom and after 400 years of life it disappeared from the historical scene as Blanda Julia. The few survivors who, probably, begin to settle in other small mountain villages towards Maratea, will gravitate from this period onwards towards Basilicata and completely detaching themselves from the primeval Calabrian vocation. Castrocucco still remains the gateway to Basilicata on the Tyrrhenian Sea and it would be necessary to restore the uninhabited city with a restoration, redevelop it also by illuminating it to make it a tourist destination even at night in consideration of the breathtaking landscape that can be enjoyed from that height.

While Castrocucco depopulated a colony of Schiavoni from Eastern Europe, following the advance of Turks and the fall of many cities they settled in Praia which, from this moment on, finally had a name.

"*Sulla frontiera del tenimento Calabro si vede una spiaggia popolata di bei casini, ricca di giardini fichi vigneti gelsi ed aranci, di una larga estensione che per più miglia corre in linea retta; circondata da colline coperte di alberi, e principalmente di olivi. A cavaliere della spiaggia suddetta si scorge una montagna, nella cui cavità accorre frequente popolo diverso di abili e di costumanze. Il nome del villaggio è Praja degli*

[19] L. LUONGO (2019), 86-87.

Schiavi (Plaja Sclavorum), così detto dagli Schiavi o sia Schiavoni, che molti secoli fa vi lasciarono una piccola colonia. Si ignora il commercio che esercitarono in questi lidi i legni Dalmatini, e precisamente Ragusei, i quali son chiamati anche oggidì Schiavi e Schiavoni. Il monte che siede a cavaliere del vasto lido e del delizioso paesetto, ed in gran parte lo domina contiene nel grembo un'ampia grotta incavata nel vivo sasso"[20].

The information that Lomonaco offers us makes us understand that it is a colony of the many Albanians, Greeks and Schiavoni who reached the south of Italy from the Albanian, Greek and Slavic coasts and was well received by the kings of the Kingdom of Naples. Many colonies were born that went to repopulate many depopulated centers during the demographic crisis of the fourteenth and fifteenth centuries that gripped not only Italy but the whole of Europe[21]. The colony of refugees came from Ragusa as Lomanaco tells us and it is very likely that the colony of Ragusans reached Praia a Mare in the last years of the fifteenth century [22]. Probably the first settlement of Praia a Mare was born between Località Mantinera and Fiuzzi but it is a hypothesis to be supported with other elements and will be the subject of another study.

The militarization of the coasts of the Kingdom of Naples and the construction of many coastal towers led to new forms of reorganization of these territories with the populations frightened by the landing of Turkish vessels that besieged the entire Gulf of Policastro with great vehemence. The bloody history of Vitigno is proof of this, they fought hand-to-hand on small vessels to defend the settlements that stood on the heights immediately behind the wide beaches.

Downstream of the town of Castrocucco, now almost uninhabited, the Caina tower was built which communicated with the Filocaio tower in the territory of Maratea and the Nave tower, the first defensive bulwark of the Calabrian coast. In 1566 the Nave tower was also built and the next one called the Fumarolo. Transformed into a fort in the Napoleonic age it was called Fortino; in 1935 it was restored and became the seat of the Liceo Classico of Praia.

The largest of all the towers of this stretch of coast is that of Fiuzzi which was erected on a large rock with an external staircase and a drawbridge. It is also called the Arco tower because to pass from the north to the south of this large rock, you pass under a natural stone arch that connects to another spur of rock on which the church of San Zaccaria stood. The defensive chessboard of Praia is closed by the tower of the Dino island built on the western tip of the island. All these buildings are in a fairly good state of conservation and characterize coasts and beaches in a decisive way, making the panorama even more impressive.

The geographical map (Fig. 1) that best represents what has been written in this work is the one defined as Aragonese with the indication of the ancient Iulitta which is exactly the place where the most important finds of Blanda came to light.

The stretch of coast described has not undergone excessive overbuilding and is still full of natural corners with characteristic flora and fauna, such as the sea lily.

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[20] *Monografia sul Santuario di nostra Donna della Grotta* (1858) cit., 4.

[21] On the subject I would like to point out A. PELLETTIERI (2020), *Il Mediterraneo fra le due sponde adriatiche. Le migrazioni albanesi fra i secoli XV e XVIII*, in Bravo Caro Juan Jesús, Roldán Paz, Lorena e Ybáñez Worboys, Pilar (eds.), *El Mediterráneo: sociedades y conflictos*, Madrid, 83-116.

[22] M. SPREMIC (1987), *Ragusa tra gli Aragonesi di Napoli e i Turchi,* in "Medievalia" 2 7, 187-197.

For about 50 years we have been witnessing another phenomenon that characterizes all the towns that rise on the top of hills and mountains, namely the abandonment to settle flat areas and on the seashore.

If Aieta already in 1928 had definitively freed itself from Praia a Mare which became an autonomous municipality and which had dragged on its development for about 1000 years, today the opposite must happen. Aieta, with only 750 current inhabitants, will remain the elegant and good living room of Praia that will have to drag the beautiful and characteristic mountain center towards a different development. In this period Praia a Mare can be considered the capital of this stretch of coast especially for the natural and scenic beauty of Fiuzzi and the island of Dino.

The same happened to Tortora which developed with a large settlement towards the sea for tourist reasons and only 500 inhabitants live in the historic center. Tortora country, as it is defined, is also the parlor of Tortora marina also with the creation of a very interesting museum on the excavations of Blanda which is being redeveloped and enhanced for better use.

Castrocucco is also experiencing a moment of strong enhancement due also to a project that involves the construction of a large tourist port that would create new tourist opportunities also on nearby Tortora and Praia.

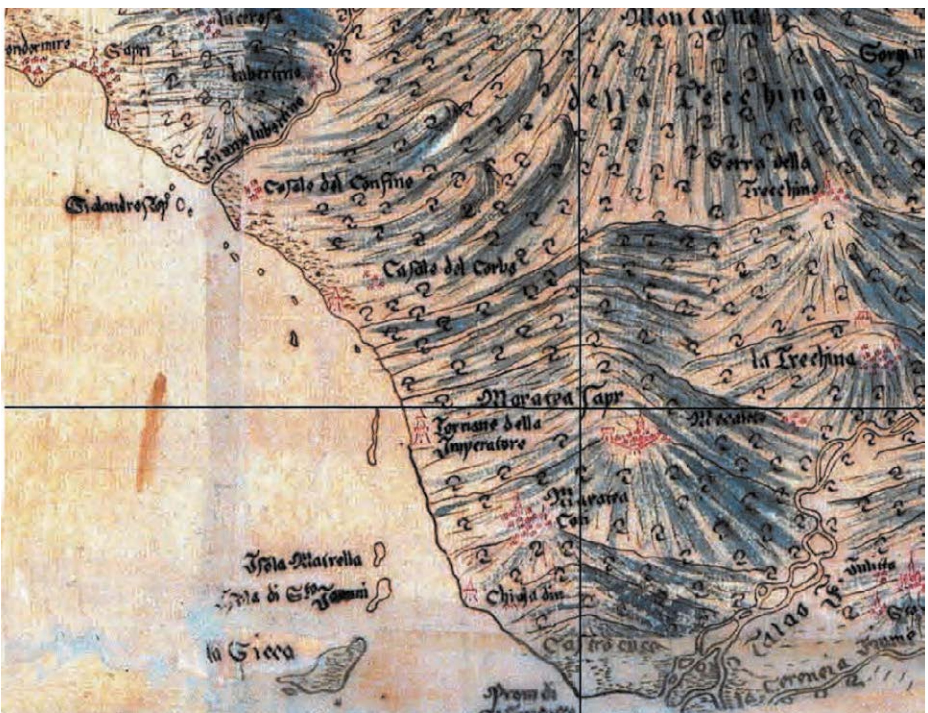

Figure 1 – *Bibliotèque Nationale de France* (BNF, *Cartes et Plans*, GE AA 1305-4).

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THE TORRE DEL MARZOCCO AND THE WIDENING OF THE ENTRY CHANNEL TO THE INDUSTRIAL PORT OF LIVORNO

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Abstract – The Torre is an ancient watchtower, dating back to the 15th century, and is subject to Italian laws for the protection of the historical and cultural heritage. Located in the heart of the port of Livorno to the north of the city, the Torre del Marzocco symbolizes the past, the present and the future of the city, rooted in port activities and its traffic.
The present contribution presents a project of the North Tyrrhenian Sea Port Network Authority aimed to redevelop and renovate the ancient marine landscape of the Marzocco Tower, through the creation of a water basin around its basement.
At the same time this project aims to widen the entry channel to the port of Livorno, as a safety measure towards the secure access of the great ships of new generation to the industrial area of Livorno's port.

Introduction - The Marzocco Tower

Since 1439 there had been increasing interest from the Florentine Republic in the refortification of the Port of Pisa, the shallow basin of water immediately north of the small settlement of Livorno, near the mouth of the Scolmatore river.

Evidence of Florentine interest was the construction of the majestic Torre Nuova also known as the Marzocco.

The outside wall, which rested on the seabed, was built in 1465. By May 1466 the construction of the Tower's foundation, at sea level, had been authorised.

The building of the magnificent Tower continued at a snail's pace for a total of 20 years until 1478/79, stretching across the Medici periods of Cosimo il Vecchio, Piero il Gottoso and Lorenzo il Magnifico.

The tower has a polygonal floor plan, reminiscent of the pre-existing towers of Porto Pisano, in particular the 12th century *e Magnturres dali*.

However, historians claim that the polygonal section and structure of the tower are of a more classical influence, citing the Athenian Tower of the Winds. Detailed historical reconstructions can be found in the publication "*L'Antico Porto Pisano e la Torre del Marzocco a Livorno*" by Giampaolo Trotta [8], commissioned by the Port Authority and edited in cooperation with the Italian *Soprintendenza (*Ministry for heritage and cultural activities)*,* the public body established for the safeguard of historical and cultural heritage.

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Enrico Pribaz, Ilaria Lotti, Raoul Raffalli, Pietro Chiavaccini, *The Torre del Marzocco and the widening of the entry channel to the industrial port of Livorno,* pp. 865-874 10.36253/979-12-215-0030-1.82

Figure 1 – View of Livorno and Porto Pisano in a 17th century copy of a 1540 drawing: detail with the towers of Porto Pisano (da *Livorno e il Mediterraneo*, 1996, p. 91)

Figure 2 – Comparison between the Marzocco Tower and the Torre dei Venti (Athens, 50 b.C.).

The tower is about 50 m high, has an octagonal floorplan and a scarp base on which the tower drums were built. The section measures about 12m and atop the tower is an octagonal spire below which is a balcony with corbels. It is clad with smooth slabs of white marble from the Monti Pisani and the name of the corresponding wind is inscribed on each of the eight corners (Mezzodì, Iscilocho, Levante, Grecho, Tramontana, Maestro, Ponente, Gherbino).

The walls are thick, have small rectangular windows, and the rooms have octagonal ogival vaults. Originally the balcony at the top of the tower was covered by the roof which bore a sphere surmounted by a gilded statue of the *leo martius;* the lion of Mars and symbol of Florence. It was from this statue that the name "Torre del Marzocco" came.

Figure 3 – Marzocco Tower "Torre Nuova" - Pennant on the Arnolfo Tower of Palazzo Vecchio, Piazza Signoria, Firenze

The historical research outlined above has evidenced that the native landscape of the Marzocco Tower was a marine setting.

Currently, the Marzocco Tower is landlocked at the southern extremity of the west bank of the Toscana Docks at the entry channel to Livorno's industrial port, as shown in the photo. The landscape of this important historical heritage is now the docks at the heart of the industrial port of Livorno.

Figure 4 – The tower's present landscape.

The Project and technical insights

The featured project concerns the works necessary for the banking of the west side of a channel which at present is the only way to access the commercial and industrial port of Livorno, as well as the creation of a new water basin around the Marzocco Tower.

Currently, the channel leading to the port is about 97 m wide with a draft of up to 14 m at the center, while alongside the banks it is just a few meters deep. The increasing size of container ships that will be using the commercial port has led to the need to widen the channel to 120 m, if trading volumes are to rise. It is also necessary to dredge the full width of the channel bed to a depth of 13.5 meters.

In order to achieve this important objective, the Port Authority requested the construction of an embankment on the Marzocco Tower side of the access channel that would make it possible to obtain a depth of 13.5 m for ship drafts.

The project provides for a breach in the embankment wall, to allow a flow of interchange between the harbour and the water basin around of the Tower.

Plans for the banking of the Marzocco area and subsequent dredging of the canal have been hindered by oil pipelines, mid-tension electricity cables and other utilities which run across the canal at a maximum depth of -15.50 m.

Indeed, in order to remove these interferences, it was necessary to excavate a new concrete tunnel under the seabed and relocate the pipelines and other utilities inside it. The tunnel, realized with a Tunnel boring machine (TBM), is a very important geotechnical achievement for its depth of -20 meters under sea level. The latter has just been completed and is essential to the future operations of the port, as outlined above, for it will allow for the widening and dredging of the channel.

Figure 5 – Widening of the entry channel to the industrial port of Livorno.

Due to the importance of these works and the proximity of the Marzocco Tower several specialistic analyses have been performed to investigate the technical aspects.

The following aspects were analyzed specifically for this project: the archeological risk, the Marzocco Tower's foundation, the subsurface, and the water basin's flow.

The archeological risk has been investigated through historical research carried out by Archeodata Cooperative Society [3]. The archeological report has been drawn up, and continuous archeological monitoring will take place during the works.

Geological diagnostic investigation was required to ascertain the geotechnical characteristics of the terrain and the type of foundation of the 15th century tower. This information was essential for the proper forecast of the impact of different construction alternatives influencing the historic tower as a result of the broadening of the industrial channel.

To investigate this aspect the Port Authority commissioned geological studies in 2008 and in 2014 on the area of the Tower. They included vertical and inclined sampling of the Tower base and geophysical investigation [4].

The geophysical survey was performed with Electrical Resistivity Tomography (ERT) and 3D Ground Penetrating Radar (GPR) by the Department of Earth Sciences of the University of Pisa and the Geostudi Astier [6].

The geophysical and geologic data have been correlated to identify the size and typology of the foundations, and to pinpoint the possible presence of buried archeological structures. Together with the survey of the Tower's foundations, adjacent areas and those within the perimeter walls were also investigated to identify additional archaeological structures in the subsoil, with regard to position, shape and extension.

The subsurface has been analysed through coring, dilatometric tests (DMT), cone penetromic test (CPTU) and downhole [7]. Investigations were also carried out from a stratigraphic and micropaleontologic point of view, to obtain a biostratigraphic and paleo-environmental characterization of the deposits.

The micropaleontologic analysis was based mainly on the species of calcareus nannofossils, ostracodes and foraminifera that were discovered in the samples examined [2].

Lastly, carbon fourteen dating has been performed on wooden elements of anthropic origins, discovered in the area of the Tower's foundations [5].

The micropalenteological study was conducted by personnel of CNR (National Research Council of Italy), a public body and largest research center in Italy.

Last of all, the Society AM3 Spin Off of the University of Florence [1] carried out a hydrodinamic and numerical model study to investigate the flow within the water basin that will be dug around the Tower. On-site measurements and analyses will be carried out in the course of the works to verify the oxygenation levels and flow of the waters, to avoid the occurrence of eutrophication.

Results

Studies conducted through historical, archeological, and other documentary material point to a very low level of archeological risk for the oldest periods examined – Etruscan and Roman periods. Such a risk is most certainly increased with regards to the structures of the Porto Pisano, built starting from the 12th century. The studies showed the native marine landscape of the Marzocco Tower (Torre Nuova).

Thanks to this geological and geophysical survey it has been possible to establish the type and extent of the Marzocco Tower's foundations, something of primary importance to ensure the stability of the tower and minimize interferences to the ground during work to reprofile the banks of the channel.

The geological and geophysical survey showed in fact that the original engineers replaced and improved the soil beneath the tower, as far down as the layers with better geotechnical characteristics, over an area far greater than the base of the tower proper, as well as creating a subsurface basement with gravel and cemented gravel and further down with lime and stone chippings to reach a depth of -6.5 m under sea level.

In the fortification area the subsurface reaches a depth of about -6 m, with layers of gravel, stone chippings, clay-brick fragments for the first 4 meters and a layer of stone chippings and slacked lime at the deepest level, as shown in the vertical and horizontal sections of tomography. Before this survey it was believed that the Marzocco tower was founded on rock outcrops.

The Ground Penetrating Radar (GPR) 3D survey of the foundations of the Tower has evidenced the possible presence of early constructions, together with materials from their collapse. However, there is no correlation between these finds and the known building phases of the tower, with the exception of those dating to the first half of the 16th century. Therefore, there is a possibility of unknown or chronologically dubious structural elements in the architectural history of the Tower.

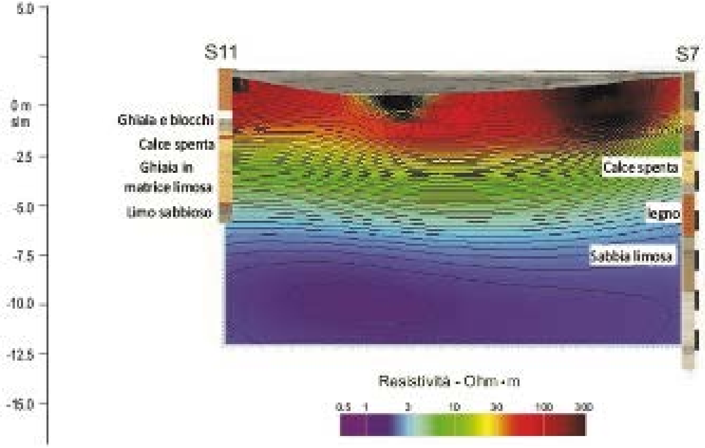

Figure 6 – Electrical resistivity Tomography - Vertical section.

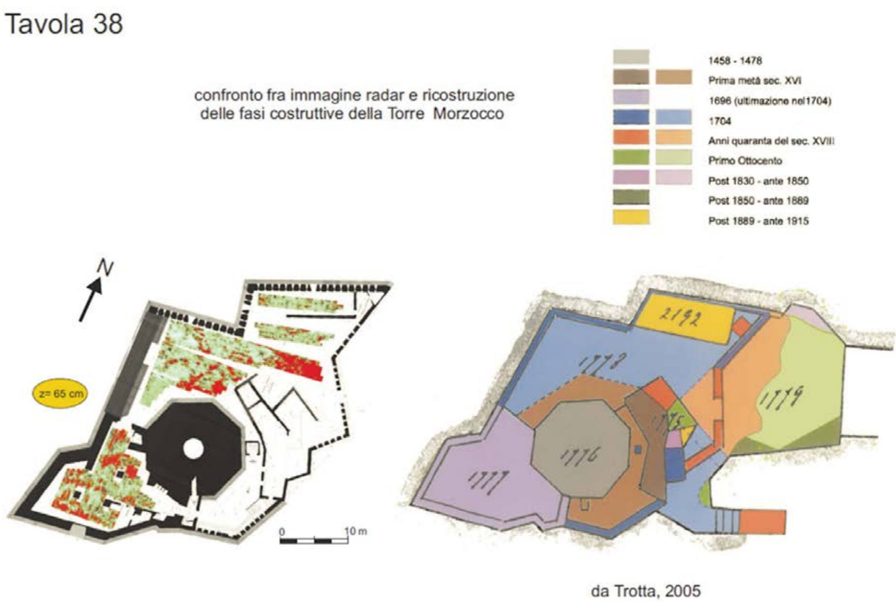

Figure 7 – Comparison between Ground Penetrating Radar (GPR) 3D and the archaeological studies on the construction phases.

The stratigraphic study, mainly based on results from micropaleontological analyses and radiometric dating, has led to the identification of four prevalent stratigraphic units of different periods and paleo environments, with a recent surface layer (Holocene) and two pre-existing ages, Pleistocene Santerniano e Pleistocene Tirreniano.

Results of the hydrodinamic study show that during the construction of the water basin around the tower it will be necessary to plan for a pumping station to track the oxygenation levels and flow of the waters until completion of the water basin.

The Marzocco tower's water basin project was submitted to the office of the "Soprintendenza for architectural and landscape assets, for historical, artistic and demo-ethno-anthropological heritage for the provinces of Pisa and Livorno", which approved the plan in 2014. It was included in the port regulatory plan with the objective of creating a new pier around the Torre del Marzocco. The shape of the water basin is shown in the picture below.

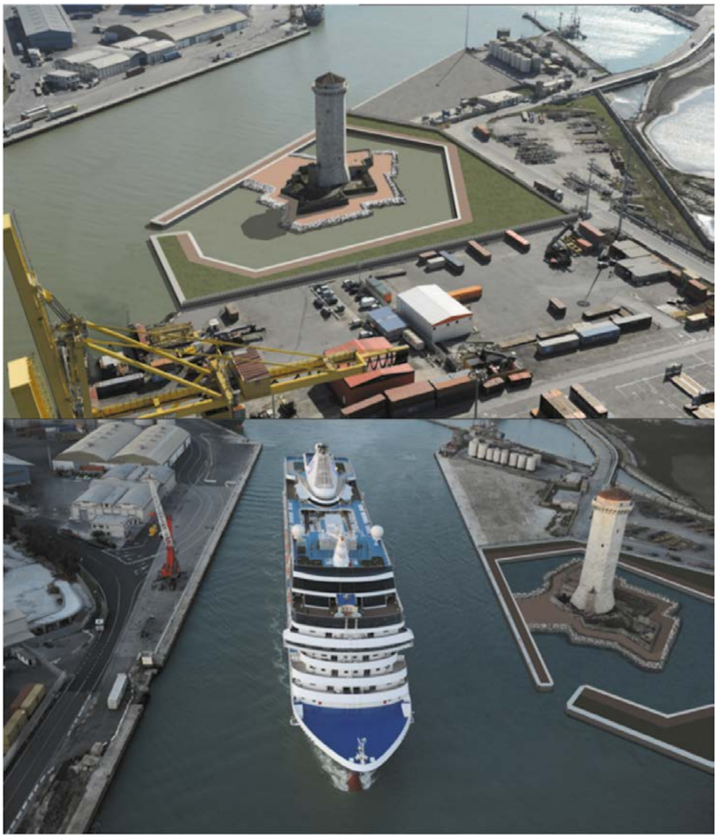

Figure 8 – Rendering of the restoration of the water basin around the Marzocco Tower.

With the completion of works on the water basin, it will be possible for craft of suitable size to sail around the tower, so that it can be seen from the sea in complete safety.

Again, and for reasons related to safety of navigation within the port and for the mooring of vessels in the Tower area, access to the internal docks was located in a position at the south end of the west bank of the Toscana Docks where there are protected berths for vessels that are too large to enter the Docks themselves. In addition, this berth will not interfere with navigability around the turning basin.

It should be pointed out that the present project covers the construction of the embankment alongside the access channel, while completion of the future tower water basin will take place at a second time, after the Conservative restoration and consolidation works on the tower foundations.

Figure 9 – Phases for the works of the water basin. (*) Conservative restoration and consolidation" of Marzocco's fortification.

This layout is in line with what the Soprintendenza stated, " ... must be implemented by the Livorno Port Authority, a project to restore the water basin around the Marzocco Tower, an octagonal monument dating to the 15^{th} century, in accordance with Law 1089/1939, to be presented to the competent Superintendence of Pisa and the General Direction for landscape, fine arts, architecture and contemporary art, in order to reconfigure the original appearance of the area and maintain the prospect on the side of the sea".

Conclusion

Several technical insights commissioned by this port Authority have allowed to examine in depth the history and structural details of the Torre del Marzocco.

Thanks to this project, the North Tyrrhenian Sea Port Network Authority has proposed a solution which includes the restoration of the water basin around the 15^{th} century tower, with approval of plans by the office of the "Soprintendenza for architectural and landscape assets, for historical, artistic and demo-ethno-anthropological heritage for the provinces of Pisa and Livorno", as well as increased safety of container ships' access and traffics of the port.

This project will allow a viewing point between the Tower (symbolising history and tradition) and the channel to today's modern Port (the present and future).

The new trend clearly shows the essential role that this heritage plays in the sustainable development of ports and in the resolution of conflicts in the port-territory relationship.

In this respect, the work planned in Livorno for the next three years involves a number of projects, such as restoring the original moat around the Old Fortress, the renovation for new functional uses of the Livorno grain silo or the restoration of the harbour defence fort. In this context, restoring the original water basin and turning Livorno's Torre del Marzocco into a museum represent one of the most important safeguarding, restoration and reuse projects.

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NATURAL RESOURCES AND COASTAL PRODUCTIVE SETTLEMENTS IN SOUTHERN PUGLIA

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Abstract – The systematic topographic research conducted for many years by the CNR and by the Ancient Topography Laboratory of the University of Salento in Puglia, in particular in the Salento peninsula and in the Tavoliere, have led to an exponential increase in the knowledge of archaeological evidence and consequently to the analysis and reconstruction of the evolution of human settlement in the territory in the different phases, from prehistoric times to the medieval phase. The data collected with a detailed survey and the use of various traditional and advanced technologies are collected in the "Territorial Information System of Cultural Heritage of the Italian territory" of the CNR. The systematic analysis also involved the coastal strip, both Adriatic and Ionian; both have an uninterrupted sequence of settlements, often with a continuity of life from the Ancient Bronze Age to the Modern Age. During the second millennium BC there is a continuous chain of large settlements often provided with fortifications, often located on promontories or reliefs in relation to deep inlets or forms of landing of different types. The few cases of regular excavations have revealed large quantities of imported materials, which attest, already in the ancient phases of the Bronze Age, continuous contacts with the Aegean world. The topographical positions of these dominant sites after nearly three millennia will be replicated by the coastal watchtower and defense system. A particular type of settlements of limited size and in the past not identified, deserves particular attention: in different points of the coast there are very consistent heaps of whole and fragmented shells belonging to different species, but mainly of murex (*Phyllonotus trunculus*); heaps, even extensive, of shells are associated with large quantities of ancient ceramic fragments: table and fire pottery, especially amphorae and various materials related to fishing (net weights, nails, bronze sheets, etc.).Evidently they are very simple preparations for the collection of molluscs and the subsequent processing for the production of purple, essentially allocations of *purpurarii*, documented by ancient sources in this sector of the territory. The obtained product, extracting the dye base from a mollusk gland, was then sent to the dry cleaners (*bafii*); that in classical and Roman times they were mainly found in Taranto; still at the end of the third century AD. C. Taranto was the production center of the imperial property purple (NOTITIA DIGNITATUM, Occ. XI, 1: *Procurator bafii Tarentini, Calabriae*). The war events of the following centuries caused the transfer of the *bafii* to Otranto but the production somehow continued until the Middle Ages; Taranto was certainly the site of settlements of *purpurarii* along the coast, then obliterated by modern urbanization; in the historical cartography an heaps of shells located on the coast of the Mar Piccolo is documented, however, still clearly visible at the end of the last century, known by the local toponym of "Monte dei Coccioli", attestation of a collection site, probably connected to the purple that various ancient sources place in this sector of the city. from the mollusk. The chronological span of the settlements recorded so far is very broad, but varies

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greatly as a result of the situation of the various sites; at last , it is possible to rely only on what is visible on the surface; mainly the materials show continuity of use of the sites from the late archaic and classical age to the late imperial age, but in at least two of the surveyed settlements the presence of Bronze Age materials is documented, always associated with murex shells and other ancient ceramic fragments of different chronology. In some cases, remains of masonry tanks with cocciopesto hydraulic coating are preserved, evidently functional to the processing of the product. The settlements detected in all cases develop in situations of small pools, always associated with the presence of fresh water, small streams, springs, including underwater springs, small lagoons; evidently the contribution of fresh water in the sea creates favorable conditions for the proliferation of molluscs and therefore favors the quantity and quality of the kept. The settlements identified to date are all on the Ionian coast, where there are many springs and wetlands. The only presence of mounds of murexes in the Adriatic is for now that of Coppa Nevigata (FG), however, dated to different phases of the Bronze Age. The study - and the protection - of the identified sites and the increase in research is important because they affect the coastal strip which is particularly at risk for seaside tourism and uncontrolled urbanization.

Introduction

The "Sistema Informativo Territoriale per i Beni Culturali (SIT) del territorio italiano", or "GIS for Cultural Heritage" (Fig. 1), has been realized by researchers at CNR and at the University of Salento. The aim is to support the research, protection, and management of cultural heritage. As a focus, it uses geographical positioned information for knowledge, preservation and to increase the value of the territorial cultural heritage. It is a very valuable and useful tool for gathering, updating, processing and consulting all available Cultural Heritage and Environmental Data from surveys, aerial monitoring, research, finalized cartography, bibliographical and archival materials.

Methods

Research developed by the Laboratory of Territorial Information Systems for Cultural Heritage (GIS) at the National Research Council (CNR) are addressed to the issues of systematic archaeological survey (to create a cadastre of the archaeological heritage) and increase in of the heritage of assets cultural properties of the national territory, in the research lines of archaeological topography, with the use of available technologies, traditional and advanced, for the identification, the documentation and evidence management; not least a correct planning of the territory.

A wide-ranging topographical analysis of archaeological areas at risk in the national territory of Italy is currently being conducted. This activity is linked to systematic aerial and terrestrial monitoring and has been developed by the author of this paper as well as Marcello Guaitoli[1] and conducted in collaboration with the Carabinieri Helicopter Groups of Pratica

[1] Ordinary Professor of Ancient Topography at University of Salento, that I thank for kindly lent me all the photographs.

di Mare and of Bari, which are coordinated by the Nucleo Tutela Patrimonio Culturale dell'Arma dei Carabinieri since 1997.

In the last thirty years, I had the opportunity to control the territory of southern Puglia thanks to the survey seminars conducted for the Institute of Ancient Topography of the Cultural Heritage Department-University of Salento, for graduate and post-graduate courses.

During the monitoring survey on the coastal land of southern Puglia, it has been possible to localize much archaeological evidence, several different kinds of coves for docking, settlements, humid areas, as well as with other colleagues following the research of the final works of academics about this subject.

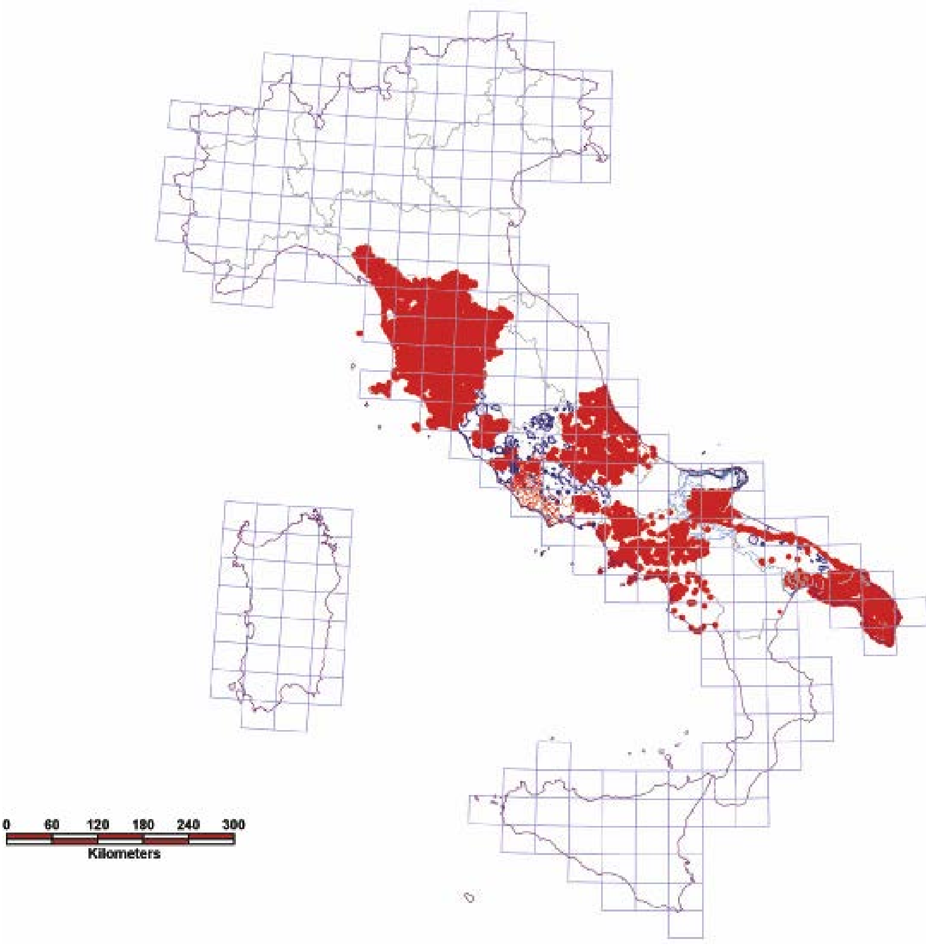

Figure 1 – Territorial Information System for Cultural Heritage (SIT BC) of the Italian territory.

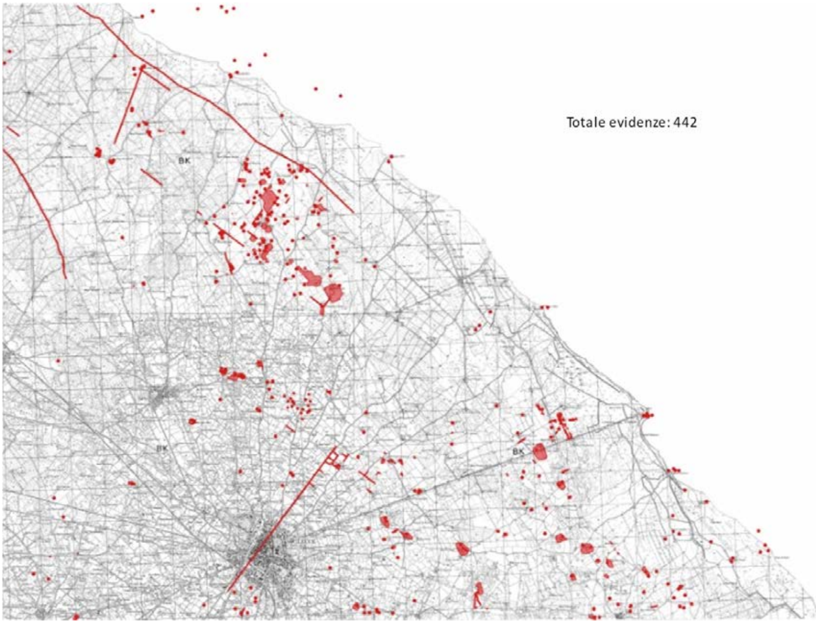

Figure 2 – Example of evidence exactly measured during the survey and restituted on map.

Results

Here will be shown only some identified settlements or areas of pottery fragments, essentially dated in the Bronze Age, sometime with fragments belonged even to the Iron Age, some others are Messapian, others are dated in Roman Age; some of them have soft water sprigs into the sea, near the seashore, or close to river.

Apart from some few ports of cities facing the coast as Egnatia, Brindisi, Otranto, Gallipoli, Taranto, many small settlements, and site of work related to fishing are present along the southern coast of Puglia. Some of the settlement facing the sea, had on their background wide humid areas, in some cases still existing or well visible on aerial photographs, both historical and recent. Humid areas were depicted even by the Arab cartographer Al Idrisi (nearly 1154) (Fig. 3), which could see them from the sea and had understood as wide long rivers and as such represented on his map[2].

[2] M. AMARI, C. SCHIAPARELLI*, L'Italia descritta nel Libro di Re Ruggero, compilato da Edrisi*, «MemLinc», s. II, VIII, 1876-77 (1883), p. 102 sgg.; cfr. R.A. SKELTON, *Meister der Kartographie*, Berlin 1963, p.74, 317, 355, tav. XXX; R. RUBINACCI, *La data della geografia di al Idrisi,* «Studi magrebini» III, 1970, p. 73 sgg.;K. MILLER, *Mappae Arabicae*, Stuttgart 1926-1931; IDEM, *Mappae Mundi. Die ältesten Welkarten*, Stuttgart 1895-1898; D. WOODWORDS, *Medieval Mappaemundi*, in HARLEY-WOODWORDS, *History of Cartography*, Chicago London 1987, p. 286 sgg. The work of Idrīsī, formed in Cordoba, then active in Africa and Asia Minor, was carried out in Palermo under the Norman Roger II, who commissioned the Arab geographer to collect all the information for a geographical description of the world, written in a manuscript in Arabic and Latin language, accompanied by a general map and 70 partial maps: the so-called Book of King Roger (or "Delight for the visit of the countries of the earth").

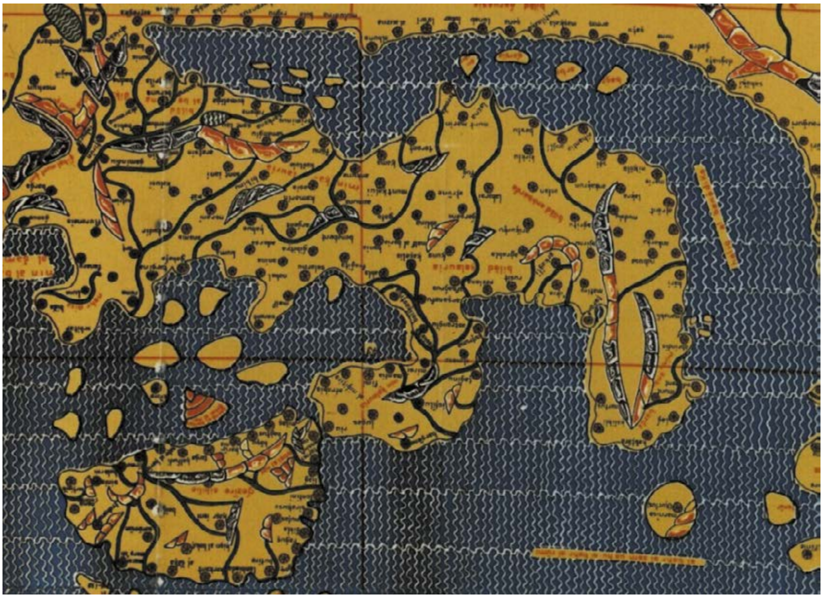

Figure 3 – Part of Idrisi maps. The map it is now shown with modern orientation (North side). Names are in reverse because in earlier times cartography was oriented South.

Figure 4 – An example of humid areas on SIT cartography: in dark blue the humid areas today, in light blue the humid areas from traces read on aerial photo (historical and recent) on maps and by survey.

Figure 5 – The humid area "Le Cesine", south of Lecce.

Figure 6 – Torre Guaceto.

Some of this site, because of their good exposition for sea control, have been later occupied by a long series of watchtowers.

Torre Guaceto is a fortified settlement (Bronze Age pottery fragments are on the site of the tower and on one of the other close little islands - Fig. 6) is on a tongue of land facing the sea and a bay, protected by the wide and now well known humid area all around.

Next is the settlement of **Torre Testa**, on a small tongue of land into the sea. On the whole surface of the site there are pottery fragments dated to Bronze Age. The modern road “litoranea” and the recent channel cut part of it.

Prehistoric material and small Bronze Age pottery fragments come from the edge of the cliff, strongly collapsed, visible along the coast of **Sant’Andrea**.

Just rather close, the prehistoric and medieval settlement of **Rocavecchia** (Melendugno, Lecce) (Fig. 7), site that plunges into the sea on a high cliff, which on the side facing the open sea is partly eroded and partly cut by various quarry sectors for extraction of blocks. The important site dated to the Bronze Age has fortunately been preserved by the medieval site overlapped it. Numerous excavation campaigns carried out by the University of Salento brought out a great portion of it and of the defensive line of *aggere* on the internal side. By the excavations It has been attacked and burned three times.

As well as the oldest settlement, even the medieval one, larger, had at least two successive lines of fortified walls; on the southern border is visible part of a third one. On the north-western side are visible traces of previous fortified lines (Fig. 8).

From the Bronze Age area of excavations comes a great number of potteries, most painted, even from Aegean area, to attest kinds of commercial routes and the importance of the site that on the southern coastal edge, facing the oldest site, has the access to a huge cave/sanctuary (actually hidden by the surface of the sea). On the walls of this site, well known as “**Grotta della Poesia**”, being used for centuries, there are thousands of inscriptions on the walls, in several languages (Greek, Messapian, Latin).

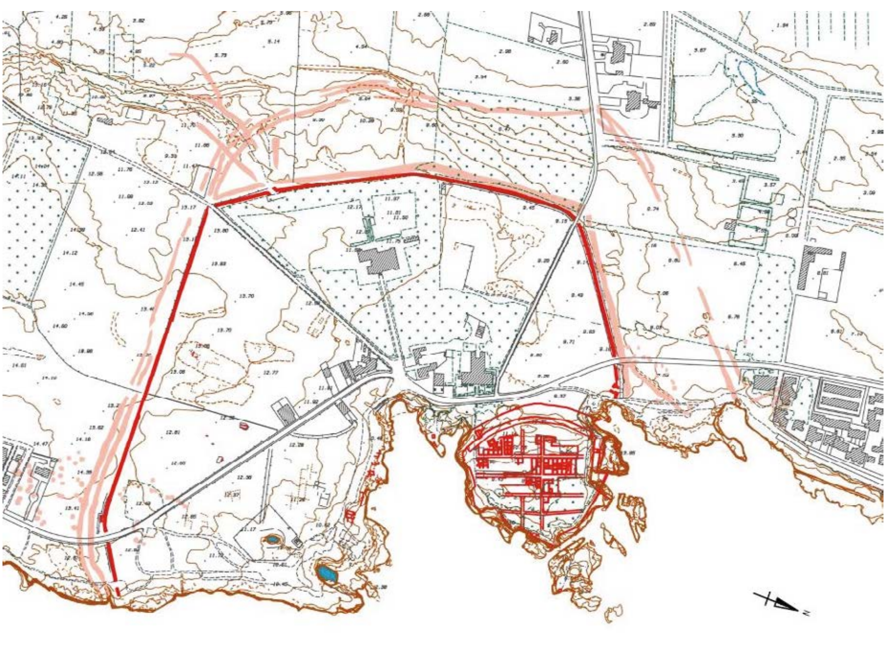

Figure 7 – Rocavecchia: restitution of traces and excavations areas on SIT map.

Figure 8 – Rocavecchia in aerial photo 2006, during a monitoring flight.

A short distance south of Otranto, a Bronze Age settlement (many fragments of pottery have been seen during survey – Fig. 9), on a flat rock platform, dominates the suggestive coast below. A watchtower marks the place (**Torre sant'Emiliano**).

Figure 9 – Torre Sant'Emiliano settlement.

Figure 10 – Porto Miggiano - a short view of the ancient quarry.

A short distance southern, another Bronze Age settlement at **Porto Badisco** is visible by the fragments of pottery and part of the *aggere*. On the nearest inland are known several little caves, some with prehistoric paintings.

Following this last one, there is a very interesting place, called **Porto Miggiano** (Fig. 10), always marked by a watchtower almost completely crashed. On the geological map it is represented by a particular sort of "calcarenite", similar to that of the whole coast, but with a finer and harder grain. It has represented, since ancient times, an important point of supply for blocks, columns of different size, likely for particular use. Unfortunately, we have not still found where all these materials were employed. By the direct survey seems possible that the carver workers could have organized a loading plan just close to the sea, immediately very deep along the quarry, thus, to allow the draft of the ships.

I omit to talk about the ancient city of **Castro**, with origins at least since the Bronze Age, also mentioned by Virgil, where during the recent excavations (by the University of Salento) of the basement of the temple and a sort of votive deposit, the statue of Athena was found, dedicated in the temple itself. Obvious commercial traffic.

On the Ionian coast of Salento are visible humid areas, as on the Adriatic side, even if in some case has been object of reclamation (for example along the coast of **Ugento**). In the area of **Torre San Giovanni** some aerial photographs I.G.M. 1943 indicate the traces of residual humidity and the coastal lagoon which has now disappeared but is recognizable in the stratification of the dune deposits.

Further along the coast a wide sea inlet where the land curves inward is marked by **Torre Pizzo** (Fig. 11) where a thick expanse of shells of "murices", fragments of pottery (from Bronze Age to Messapian Age), small bronze nails and small round clay weights for fishing nets overlap the land.

Figure 11 – Torre Pizzo.

It is along the coast that have been found several sites with layers of murices, used for the processing of purple. It is attested, even archaeologically, at least from the Classical Age; for the whole Imperial Age there are abundant documents[3].

Further on some other settlements: the **Quattro Colonne** (Santa Maria al Bagno-LE) with the remains of was a particular kind of tower; close to the right of the site there is a small river for drinking water supply. **Punta Aspide** fragments of pottery dated to Bronze Age and some to Iron Age are visible on the upper surface of the tongue of land lean forward into the sea. **Torre dell'Alto** with a Bronze Age fortified settlement (a fortification wall is visible in aerial photographs, both historical and recent). Forward north along the coastal rock are visible holes for the collection of salt. Then, at **Torre Squillace** only a few shells of Murex (because of a difficult visibility of the terrain) mark the presence of a site for purple process. Carrying on northern wards, **Porto Cesareo** (Fig. 12) with its little islands, the bay and humid areas just behind (now reclaimed), show several ancient settlements: at **Scala di**

Figure 12 – Porto Cesareo area on a map and in a recent aerial photo.

[3] In 507-511 Theodoric apologized for the inconvenience caused to the factories for the processing of the purple of Otranto (*Cassiodorus, Variae I, 2*). In the text (*Theoni V. S: Theodoricus Rex - a. 507-511*) it is specified that the work involved craftsmen, ship crews, many peasant families "*quid enim agunt tot artifices, tot nautarum catervae, tot familiae rusticorum*"; a Pers*crutatur Hydruntini maris* is in charge of collecting and shipping the dye. The dyeing business was at least partially managed in Brindisi and Taranto by the Jewish community until the 12th century.

Furno is documented since Early Bronze Age (XVIII-XVII b.C.) to Iron Age during which period it is fortified by an aggere wall; it is also documented a sacred complex in archaic period and port structures of Greek-Roman Age. At **Torre Chianca** an industrial settlement for the processing of purple active between the 1st and 6th centuries. A.D.; probable presence of a furnace for the production of amphorae; E of Torre Chianca is reported the presence of a wreck with marble columns into the sea. On the **Isola dei Conigli** (Rabbits island) levels of Bronze Age and remains of a Roman villa. Probably the emerged area should have been larger, as it seems to appear by the aerial photos. Between two islands is visible a sort of link or channel under the surface of the sea. Further on is **Punta Prosciutto** and the settlement of Bronze Age and Messapian Age; layers of Murex shells are attested. Then **Torre Castiglione** (Fig. 13 a) and the settlement dated at the Bronze Age; natural erosion has brought to light a section of the fortified wall. The red arrow shows a spring of drinking water into the sea. **Torre Ovo** has in blocks (docks ?), now visible under the surface of sea; some of the blocks have Greek letters engraved. Following northwards **Torre Castelluccia** with the settlement dated to the Bronze Age and first Iron Age; visible the embankment of the Acropoli on which some excavations were carried out. Finally, **Saturo** (Fig. 13 b): the coastal promontory between the bays of Porto Pirrone and Porto Saturo; particularly noteworthy is the area of the ancient landing (A), now buried, and the sanctuary close to the water source (B). The recent urbanization has occupied the area of the ancient lagoon.

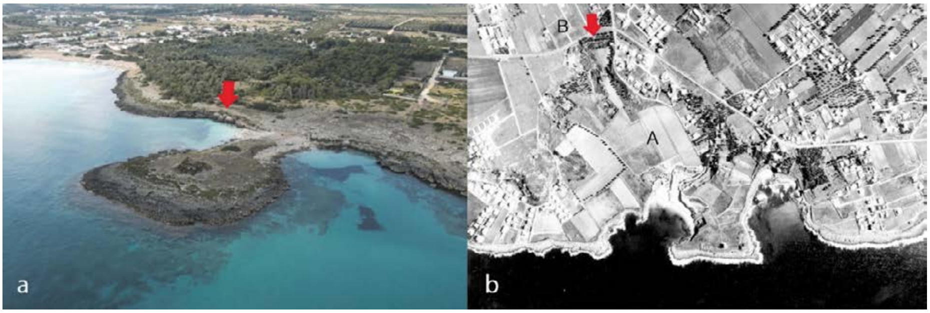

Figure 13 – a) Torre Castiglione. – b) Saturo, photo SARA Nistri 1978.

Conclusion

The result of the research is rather important for knowledge, but it will also simultaneously be the requisite basis for a correct planning of the territory. It could represent an element of collaboration with the Superintendence responsible for the territory in question and besides it is the result of a shared desire to gather as much information as possible for the reconstruction of an exhaustive historical vision of the territory being studied. That, in turn, will allow the protection at least of that which is known and consequently make possible the improvement and use of those discoveries of greater interest. But the immediate aim of this exhaustive historical vision is to prevent the progressive destruction of what evidence has been identified. New information has often been acquired in timely fashion, coming from the aerial monitoring performed by the Nucleo TPC and Helicopter Group of Carabinieri / CNR.

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[2] Scarano T. (2012) "Roca I – Le fortificazioni della media età del Bronzo – strutture, contesti, materiali", Foggia 2012, Claudio Grenzi editore, EAN 9788884314901

TUNA: UNDERWATER NATURAL AND CULTURAL HERITAGE. THE *TUNÈA* CASE STUDY, A PROJECT FOR THE RE-CONNECTION BETWEEN COASTAL COMMUNITY AND MARINE ECOSYSTEM

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Abstract – Understanding how marine nature and coastal culture intersect, and how humans and non-humans have lived and live their interdependent relationship, is a basis for sustainable coastal development. Since ancient times, the resources coming from the sea have represented a primary source of wealth for coastal regions, but also an underwater cultural heritage, which has influenced the community's lifestyle and identity, as the landscape and architectural development of territories.
Among all, the one represented by tuna fish is particularly significant, and so it is the Carloforte *tonnara* case study, one of the last fixed tuna traps in the Mediterranean Sea, located on San Pietro Island, Sardinia, along the route of passage of the Eastern Atlantic Bluefin Tuna (*Thunnus thynnus*). During the decades the *tonnara* practice has strongly linked the history, the culture and the architecture of this little island to the submerged nature of its sea: since until about thirty years ago the life of Carloforte inhabitants was closely linked to the fishing activities, but the evolution of the fish market at a global scale has radically changed this relationship. Nowadays the private part of the buildings complex is still in part active, while the public one is abandoned, and the ancient connection between the community and its *tonnara* is now interrupted.
In 2021 the author of this contribution created *Tunèa*[1], a trans-disciplinary, arts-based, research in action project developed in the frame of her PhD research at the University of Cagliari and within the U-BOOT Lab cultural association, which the author is co-founder. Aim of *Tunèa* is to study the dis-connection between Carloforte community and its *tonnara* through the activation of cultural actions that involve the community, the Municipality, the *tonnara* property and the *ciurma*[2], together with a group of artists and researchers, in order to understand if it is possible to re-create the lost relationship and, eventually, in which forms.

Introduction

Since the ancient times the resources coming from the sea have represented an important source of wealth for the coastal communities. Among all the one represented by

[1] *Tunèa*, *tonnara* in italian language, means tuna fishery in tabarchino, the dialect spoken by the community of San Pietro Island. However, this term has several meanings: it identifies the system of nets used to capture bluefin tuna (Thunnus Thinnus), but also the set of buildings where fish are processed and stored [1].
[2] Sea and ground staff of the tuna fishery, led in all preparation and fishing operations by the *Rais*, the crew chief.

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tuna fish deeply influenced the community's lifestyle and identity, the landscape and the architecture, becoming, along time, a proper cultural heritage, strongly linking non-human underwater life to human territorial life. The depiction of some tuna fishes in the graffiti inside Grotta dei Genovesi in Levanzo testifies that the fishing of this species was practiced in Sicily already in Neolithic times; later on, the Phoenician navigation routes that followed the tuna routes to the extreme coastal regions of the Atlantic made men and fish somehow 'travel companions', linking the Mediterranean and Atlantic regions in a cultural continuum until the threshold of the Roman age and beyond [1].

In this context, the Carloforte case study is particularly significant.

Carloforte is a small village located on San Pietro Island, Sardinia. The history, the culture and the physical conformation of the architecture on this little island are strongly linked to the submerged nature of its sea [2]: San Pietro is in fact located along the route of passage of the Eastern Atlantic Bluefin Tuna (*Thunnus thynnus*), that at the beginning of each summer enters the Mediterranean to reproduce.

The Carloforte *tonnara*[3] is one of the last places in the Mediterranean Sea that still uses the fixed tuna trap, a traditional eco-sustainable fishing system which, by selecting only adult fishes, contributes to the repopulation of this endangered species. Until about thirty years ago, the life of Carloforte inhabitants was closely linked to the fishing activities, but then the evolution of the fish market has radically changed this relationship. In the last decades the Japanese demand, fueled by the worldwide boom in the consumption of quality sushi and sashimi, has pushed the turnover of bluefin tuna fishing on a global scale to a very high level: a large percentage of the catch is towed alive to Malta, where it is fattened and then exported to Japan. The processing of bluefin tuna on the island of San Pietro has therefore drastically reduced, and so are the ancillary works in which a large part of the population has been employed for more than two centuries doesn't exist anymore. And if the private part of the buildings complex of the tuna fishery is still in part active, the public one is abandoned, and the ancient connection between the community and its *tonnara* is now interrupted.

In 2021 the author of this contribution created *Tunèa*[4], a trans-disciplinary, arts-based, research in action project developed in the frame of her PhD research at the University of Cagliari and within the U-BOOT Lab cultural association, which the author is co-founder.

Aim of *Tunèa* is to study the dis-connection between Carloforte community and its *tonnara* through cultural actions that actively involve the community, the Municipality, the *tonnara* property, the *Rais* and its *ciurma*[5], in order to understand if it is possible to re-create the lost relationship and, eventually, in which forms.

In October of the same year the project won the Creative Living Lab call, promoted by the General Direction for Contemporary Creativity of the Italian Ministry of Culture to support multidisciplinary social innovation projects, focused on the regeneration of proximity spaces within peripheral territorial areas, through the active involvement of local communities.

Tunèa it's a cultural-based territorial regeneration project, aimed at the gradual reopening of the *tonnara* to public use, through the active involvement of the community in

[3] *Tonnara* in italian language has several meanings: it identifies the system of nets used to capture bluefin tuna (*Thunnus Thinnus*), but also the set of buildings where fish are processed and stored [1].
[4] Tuna fishery in *tabarchino*, the dialect spoken by the community of San Pietro Island.
[5] The ciurma is the sea and ground staff of the tuna fishery, led in all preparation and fishing operations by the *Rais*, the crew chief.

all its phases. The project has the objective of getting the Carloforte inhabitants to develop a new vision on the possible future of the former tuna fishery spaces, designing new forms of connections to the identity cultural heritage represented by the Bluefin Tuna, with a renovated ecological approach.

Methods: the arts-based research in action approach and the re-opening of the *tonnara*

The *Tunèa* project started in 2021 on the personal initiative of the author of this contribution.[6]

The context in which the project is developed, Carloforte, is located on San Pietro island, Sardinia, a coastal zone characterized by a high level of complexity due to the interactions between global and local phenomena, in which social and cultural dynamics are influenced by pressing economic interests that affect the environment, exacerbating the Climate Change effects.

The method chosen to address this complexity is based on the *arts-based* research in action approach [3, 4], within the paradigm of the landscape planning. This method gave me the opportunity to involve artists and researchers coming from a wide range of different disciplines, in a transdisciplinary process that actively involved the coastal community and the stakeholders [5].

Starting in February 2021, the project was personally curated and developed involving Alessandro Toscano, photographer and visual artist, with the contribution of the landscape architect Mirko Melis and the maritime anthropologist and dancer Ambra Zambernardi, engaged in artistic residencies on the island. All the activities carried out by the researchers involved the Carloforte community in collecting historical and photographic material, written documents and oral storytelling. This phase was useful to discover and understand the local maritime culture linked to the tuna fishing tradition.

The results of this first phase were presented to the public in July through some actions which were themselves useful in triggering the later phases: thanks to the collaboration with the owners of the active tuna fishery, the workspaces were opened to the public for the first time to host guided tours, readings, a sound performance, and a talk between the artists and researchers involved in the project, together with the Carloforte inhabitants, the visitors and the *Rais* (the tuna fishery crew chief). Then two artist's notebooks were produced between August and October: the first contains the mock-up of a relational artwork for the involvement of the Carloforte community in a first action of reconnection to the tuna fishery, the second one a project for the creation of a tuna fishery herbarium, as a basis for the landscape recovery of the open areas around the *tonnara*.

In October Tunèa won the Creative Living Lab 3rd edition tender, promoted by the General Directorate for Contemporary Creativity - Italian Ministry of Culture, thanks to which it was possible to start the second phase of the project, dedicated to the reorganization

[6] A clarification on the stylistic choice in the following narrative is necessary: for consistency with the methodological nature of the work done, the author considers it appropriate to use the first person. This choice, generally not recommended in the context of traditional research, is considered legitimate in the context of epistemological processes located within the research-action paradigm.

of some unused areas of the *tonnara* and to their reopening as cultural spaces, made accessible through activities that involved the community, the local administration and associations and the stakeholders. In this second phase the working group was expanded to include the architects Patrizia Di Monte and Fiorella Rizzo, and several artists, researchers and communication experts, which spent long periods on the island in order to continue the dialogue with the population, institutions and stakeholders through formal and informal meetings.

In April we organized three workshops dedicated to active involve the community:

- a visual storytelling workshop led by Alessandro Toscano, involving the village children in the construction of a story suspended between legend and reality linked to the maritime history of the island;
- a dance workshop led by the anthropologist and dancer Ambra Zambernardi dedicated to the creation of a choreography reinterpreting the gestures of tuna fishing tradition;
- a co-design workshop led by the architects Patrizia Di Monte and Fiorella Teresa Rizzo aimed to design temporary architectural solutions to be realized inside the tuna fishery open spaces re-using fishing materials.

Results: the re-opening of the *tonnara* as a public space connecting coastal community and marine ecosystem

In June 2022, after cleaning and securing some of the open spaces of the abandoned tuna fishery in cooperation with the municipality, we made them temporarily accessible to the community and visitors, transforming them into public spaces by carrying out some light interventions, results of the three workshops led in the previous months.

The principal interventions were three:

- *La Camera del Mare (The Sea Room)* a human-sized *camera obscura* created by Alessandro Toscano as the final point of the visual storytelling realized with the children: a site-specific art installation co-built together with some young people from Carloforte, inside which the visitors could immerse themselves in an upside-down vision marine ecosystem;
- a temporary structure for access to the area entitled *Sotto un cielo di reti* (*Under nets sky*), a gallery suggesting the tuna fishes' feelings while entering in the tonnara, result of the co-design workshop curated by Patrizia di Monte with the tutorship of Fiorella Teresa Rizzo; yje installation was realised by a group of Isola workers and surmounted by fishing nets donated by the Rais, who led the net-laying operations;
- a participatory dance choreography entitled *Calar Tonnara – Studio#01,* realized by Ambra Zambernardi which animated the spaces for three days, involving visitors and the community in a shared choreography based on the gestures of fishermen, the movements of tuna and their relationship.

During the first weekend of June those creations were accompanied by talks, cinema, a music performance and guided tours of both the disused and active tuna fishery.

All the projects and activities had the same common objective: make possible to live again the *tonnara* as a public space, where coastal community could find new ways of connection to the marine ecosystem.

Discussion and conclusion: the overturning of a vision

The initial idea of the project was to try to understand whether the disconnection created over the years between the community and the tuna fishery, intended both as a productive activity and as a physical place in which the community used to share collective activities, could be mended. For this reason, the working group's initial focus was on active tuna fisheries.

The adopted non-linear and trans-disciplinary method, represented by the approach of artistic research in action, made it possible to address the problem through the continuous hybridisation between different disciplinary approaches, while at the same time deepening knowledge on site with the active involvement of the community.

The researchers' artistic residencies carried out during the first phase of the project and the workshops implemented in the second phase revealed the possibility of mending the relationship between the community and the active tuna fishery through the reactivation of shared practices related to tuna fishing. In fact, reversing the course of local economic dynamics linked to tuna fishing and dependent on global market phenomena appears difficult to achieve in the short term.

The presence of the disused tuna fishery then became an opportunity.

Opening up the disused spaces of the abandoned tuna fishery as public spaces, even if only temporarily, and realising small projects within them that would invite visitors to turn their gaze upside down on the relationship between coastal culture and the marine ecosystem, represented a reversal of the point of view on the reflection that the Municipality of Carloforte is developing to identify new functions for the former tuna fishery.

The project actions are in fact intended to be preparatory to the elaboration of an innovative planning strategy, developed through a process of informal involvement of citizens and therefore capable of opening up unexpected scenarios.

This approach has emphasised several aspects of this project pathway:

- the possibility of the reuse of the coastal maritime heritage which, although it has lost its original function linked to the tuna industry, maintains its meaning of common good and material and immaterial cultural heritage, capable of transmitting the identity bearing still alive in the direct and indirect memory of the Carloforte community;
- the awareness that the reuse, even gradual, of the disused coastal maritime heritage can become an opportunity to open shared dialogues between communities, municipalities and stakeholders, useful to elaborate innovative project visions for the re-connection between coastal communities and marine ecosystems, with a view to sustainable development from an environmental, social and economic point of view.

Acknowledgements

The project *Tunèa* was created by the author of this contribution in 2020 and has been developed since 2021 as a trans-disciplinary, *arts-based* research in action project, in the frame of her PhD research at the University of Cagliari and within the U-BOOT Lab cultural association, which the author is co-founder.

During the evolution of the project, the author involved various artists and researchers in its development. Among them, heartfelt thanks go to: Alessandro Toscano, Maria Fanari, Ambra Zambernardi, Mirko Melis, Patrizia Di Monte, Teresa Fiorella Rizzo, Luca Spano, Maurizio Lai, Alessia Usai, Paul Carlile, Simone Petrucci, Maria Vittoria Durante, Nicolo Capriata, Stefano Rombi, Francesco Rosso.

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The 9th International Symposium *Monitoring of Mediterranean Coastal Areas: Problems and Measurements Techniques* was organized by CNR-IBE in collaboration with *Italian Society of Silviculture and Forest Ecology*, and *Natural History Museum of the Mediterranean* and under the patronage of *University of Florence, Accademia dei Lincei, Accademia dei Georgofili, Tuscany Region, The North Tyrrhenian Sea Ports System Authority, Livorno Municipality* and *Livorno Province*. In the Symposium Scholars had illustrated their activities and exchanged innovative proposals, with common aims to promote actions to preserve coastal marine environment. Despite the COVID 19 pandemic, the success of this edition is attested by the 170 contributions selected by the Scientific Committee from among those received. Participation involved all the thematic lines envisaged by the sessions, involving many countries of the Mediterranean Sea. A big endeavor for a costal environment of paramount importance but threatened by global changes. The importance of this Proceedings is attested by the fact that this volume is the first issue of a new FUP Series.

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