ECOLOGICAL STATUS OF THE TUSCAN ARCHIPELAGO ROCKY HABITATS ASSESSED BY THE *MEDSENS* INDEX

Eva Turicchia[1,2,3,4], Carlo Cerrano[4,5], Matteo Ghetta[6], Francesca Giannini[7], Marco Abbiati[2,3,8], Massimo Ponti[1,3,4]

[1]BiGeA – Dipartimento di Scienze Biologiche, Geologiche ed Ambientali, Università di Bologna, Via Sant'Alberto 163, 48123 Ravenna (Italy), e-mail: eva.turicchia2@unibo.it

[2]DBC – Dipartimento di Beni Culturali, Università di Bologna, Ravenna (Italy)

[3]CoNISMa – Consorzio Nazionale Interuniversitario per le Scienze del Mare, Roma (Italy)

[4]RCI – Reef Check Italia onlus, Ancona (Italy)

[5]DISVA – Dipartimento di Science della Vita e dell'Ambiente, Università Politecnica delle Marche, Ancona (Italy)

[6]Faunalia, Pontedera (PI) (Italy)

[7]PNAT – Parco Nazionale Arcipelago Toscano, Portoferraio (LI) (Italy)

[8]CNR – Consiglio Nazionale delle Ricerche, Istituto Scienze del Mare, Bologna (Italy)

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

Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
Eva Turicchia, Carlo Cerrano, Matteo Ghetta, Francesca Giannini, Marco Abbiati, Massimo Ponti, *Ecological status of the Tuscan Archipelago rocky habitats assessed by the MedSens index,* pp. 785-793 © 2022 Author(s), CC BY-NC-SA 4.0, 10.36253/979-12-215-0030-1.75

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).

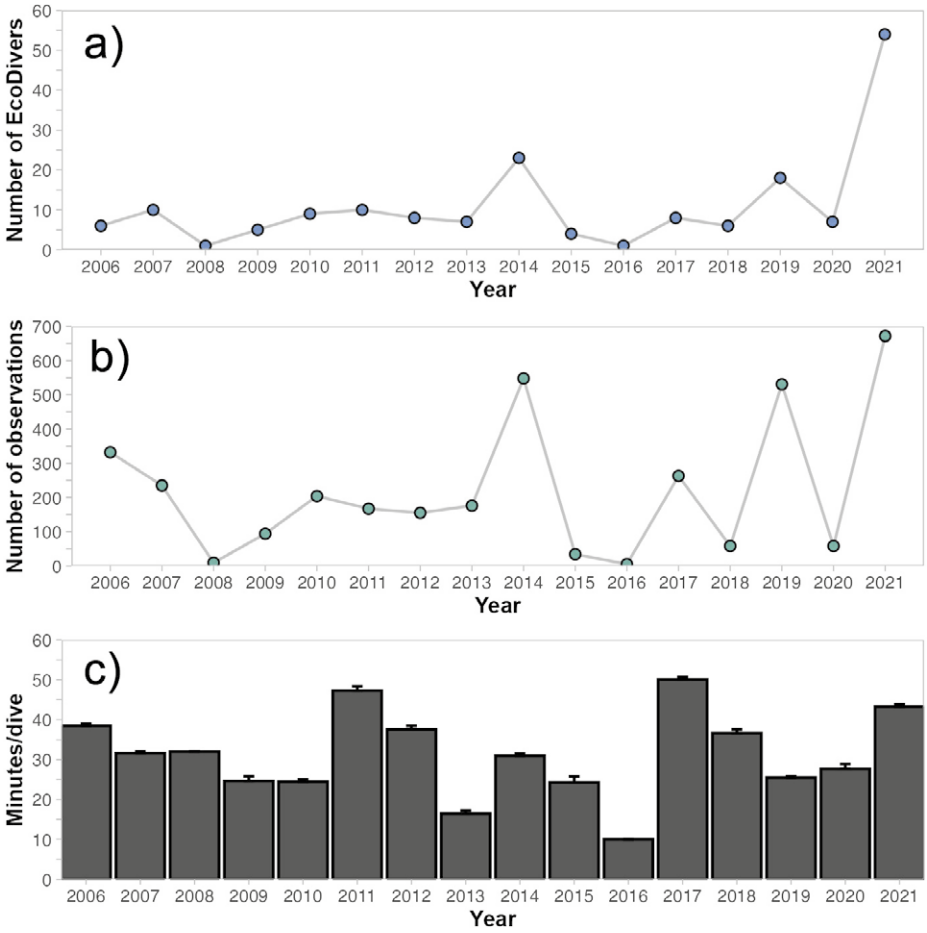

Figure 2 – In the Tuscan Archipelago National Park from 2006 to 2021, applying RCMed U-CEM protocol: a) number of EcoDivers per year; b) number of observations per year; c) mean (+ standard error) time spent searching for species by dive per year.

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).

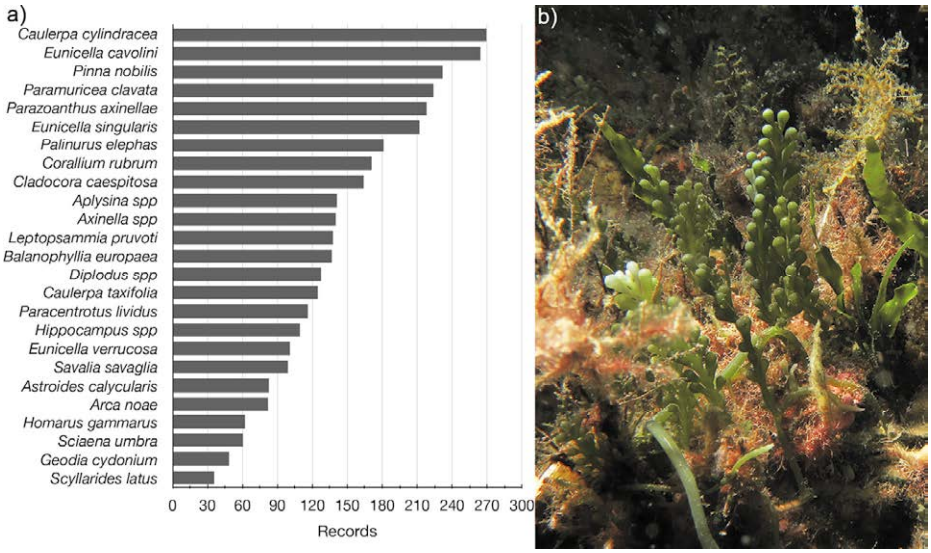

Figure 3 – a) Number of records (including absences) for each target species searched in the Tuscan Archipelago National Park from 2006 to 2021; b) *Caulerpa cylindracea*, Punta San Francesco, Giannutri Island, 2021 (photo courtesy Eva Turicchia)

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).

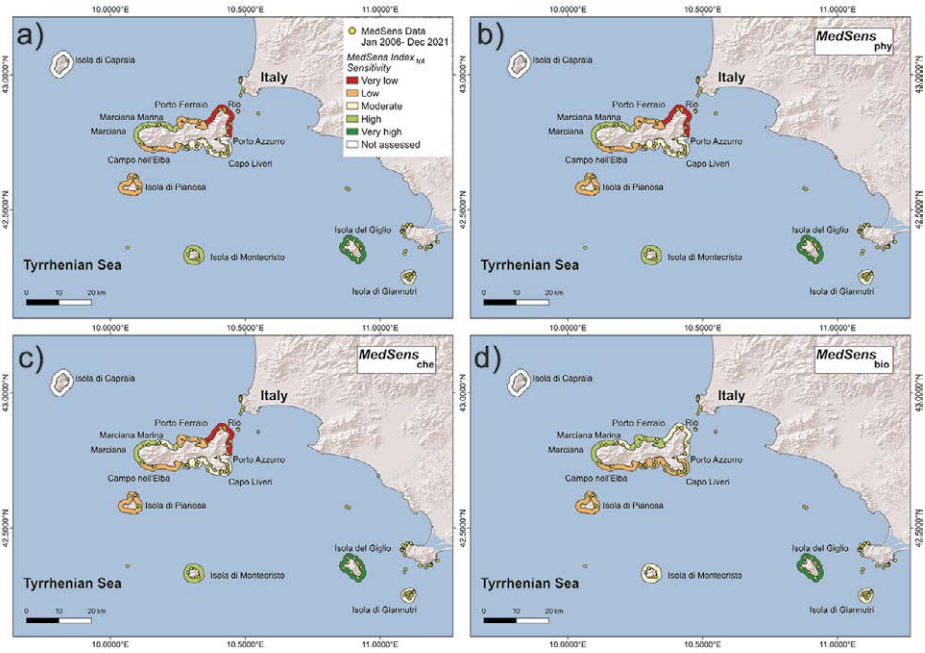

Figure 4 – Sensitivity assessments in the Tuscan Archipelago National Park from 2006 to 2021: a) overall assessment (*MedSens*$_{tot}$) and physical pressures (*MedSens*$_{phy}$), b) chemical pressures (*MedSens*$_{che}$), and c) biological pressures (*MedSens*$_{bio}$). Yellow dots display Reef Check 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.

Acknowledgemnts

We thank all the EcoDivers and their trainers, especially the Tuscan Archipelago Park guides, who provided and continue to provide new data, and the dive centres participating to the "ISLEPARK Divers Monitoring Network". This study and the monitoring network were supported by 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 Italy France Maritime 2014 -2020.

References

[1] Cerrano C., Milanese M., Ponti M. (2017) - *Diving for science - science for diving: Volunteer scuba divers support science and conservation in the Mediterranean Sea*, Aquat. Conserv. 27 (2): 303-323.

[2] Deter J., Descamp P., Ballesta L., Boissery P., Holon F. (2012) - *A preliminary study toward an index based on coralligenous assemblages for the ecological status assessment of Mediterranean French coastal waters*, Ecol. Indic. 20 (0): 345-352.

[3] Gatti G., Bianchi C. N., Morri C., Montefalcone M., Sartoretto S. (2015) - *Coralligenous reefs state along anthropized coasts: Application and validation of the COARSE index, based on a rapid visual assessment (RVA) approach*, Ecol. Indic. 52: 567-576.

[4] Hill J., Wilkinson C. (2004) - *Methods for ecological monitoring of coral reefs. A resource for managers*, Australian Institute for Marine Science, Townsville, AU.

[5] Kelly R., Fleming A., Pecl G. T., von Gönner J., Bonn A. (2020) - *Citizen science and marine conservation: a global review*, Philos. Trans. R. Soc. B-Biol. Sci. 375 (1814): 20190461.

[6] Micheli F., Halpern B. S., Walbridge S., Ciriaco S., Ferretti F., Fraschetti S., et al. (2013) - *Cumulative human impacts on Mediterranean and Black Sea marine ecosystems: Assessing current pressures and opportunities*, PLoS ONE. 8 (12): e79889.

[7] Piazzi L., Acunto S., Cinelli F. (2000) - *Mapping of Posidonia oceanica beds around Elba Island (western Mediterranean) with integration of direct and indirect methods*, Oceanologica Acta. 23 (3): 339-346.

[8] Piazzi L., Gennaro P., Cecchi E., Serena F., Bianchi C. N., Morri C., et al. (2017) - *Integration of ESCA index through the use of sessile invertebrates*, Sci. Mar. 81 (2): 283-290.

[9] Piazzi L., Gennaro P., Montefalcone M., Bianchi C. N., Cecchi E., Morri C., et al. (2019) - *STAR: An integrated and standardized procedure to evaluate the ecological status of coralligenous reefs*, Aquat. Conserv. 29: 189-201.

[10] Sartoretto S., Schohn T., Bianchi C. N., Morri C., Garrabou J., Ballesteros E., et al. (2017) - *An integrated method to evaluate and monitor the conservation state of coralligenous habitats: The INDEX-COR approach*, Mar. Pollut. Bull. 120 (1-2): 222-231.

[11] Turicchia E., Abbiati M., Sweet M., Ponti M. (2018) - *Mass mortality hits gorgonian forests at Montecristo Island*, Dis. Aquat. Org. 131 (1): 79-85.

[12] Turicchia E., Cerrano C., Ghetta M., Abbiati M., Ponti M. (2021) - *MedSens index: The bridge between marine citizen science and coastal management*, Ecol. Indic. 122: 107296.

[13] Turicchia E., Ponti M., Rossi G., Cerrano C. (2021) - *The Reef Check Med Dataset on Key Mediterranean Marine Species 2001–2020*, Front. Mar. Sci. 8 (1714).

[14] Turicchia E., Ponti M., Rossi G., Milanese M., Di Camillo C. G., Cerrano C. (2021) - *The Reef Check Mediterranean Underwater Coastal Environment Monitoring protocol*, Front. Mar. Sci. 8 (8): 620368.

[15] Tyler-Walters H., Tillin H. M., d'Avack E. A. S., Perry F., Stamp T. (2018) - *Marine Evidence-based Sensitivity Assessment (MarESA) – A Guide*, Marine Biological Association of the UK, Plymouth (UK).

[16] Valisano L., Palma M., Pantaleo U., Calcinai B., Cerrano C. (2019) - *Characterization of North–Western Mediterranean coralligenous assemblages by video surveys and evaluation of their structural complexity*, Mar. Pollut. Bull. 148: 134-148.

[17] Volpi C., Benvenuti D., Borri M., Cannicci S., Lazzara L., Santoni G., et al. (2009) - *BioMarT Atlante della Biodiveristà - Individuazione di biocenosi vulnerabili e hotspot di biodiversità in ambiente costiero di substrato duro e censimento di specie rare nel mare della Toscana*, Regione Toscana and Museo di Storia Naturale Firenze, Giunta Regione Toscana.

[18] Wilkinson M. D., Dumontier M., Aalbersberg I. J., Appleton G., Axton M., Baak A., et al. (2016) - *The FAIR Guiding Principles for scientific data management and stewardship*, Scientific Data. 3 (1): 160018.