Sustainable Management of Mediterranean Coastal Fresh and Transitional Water Bodies: a Socio-Economic and Environmental Analysis of Changes and Trends to Enhance and Sustain Stakeholders Benefits

Proceedings of the International Conference held at the End of the WADI Project (INCO-CT2005 –015226) at the University of Malta, the 5-8 November 2008

Edited by

Felicita Scapini, Jean-Marc Boffa, Louis F. Cassar, Elisabeth Conrad and Mariella Nardi

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INTRODUCTION

SUSTAINABLE MANAGEMENT OF MEDITERRANEAN COASTAL FRESH AND TRANSITIONAL WATER BODIES: A SOCIO-ECONOMIC AND ENVIRONMENTAL ANALYSIS OF CHANGES AND TRENDS TO ENHANCE AND SUSTAIN STAKEHOLDER BENEFITS

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Mediterranean coastal environments, particularly low coasts (river plains, deltas, sandy beaches), are subject to increasing pressures of urbanization, pollution and exploitation of natural resources. The origin of many such pressures is inland; rivers are generally the main vehicles of stress factors such as floods, sediment (sand, stones and mud) and waste (solid and liquid urban waste, industrial pollutants, agriculture discharge). From the sea, there is the threat of increasing sea level. As a consequence, coastal environments are increasingly squeezed between land and sea (Defeo *et al.*, 2009). Nevertheless, the most beautiful cities around the Mediterranean are coastal cities, located near a river mouth or a lagoon, e.g. Venice, Alexandria, Tunis, etc. In addition, mass seaside tourism has developed mainly on low coasts with sandy beaches and coastal plains. The spatial scale of the pressures is very important, i.e. where they originate and from what distance they might affect the system. The whole Mediterranean basin may be affected by pollution discharged into the sea or by invasive species introduced by human actions and currently out of control (Gherardi, 2008). Despite the cultural and political diversity, the Mediterranean is a unit (Braudel, 1985) and negative pressures can affect neighbouring countries. Natural and cultural diversity around the Mediterranean is a value, but it is increasingly being lost and substituted by a homogenization of urban and sub-urban environments subject to rapid overall development.

Two international projects were focused on the ecology of sandy beaches and rivers connecting inland areas with the sea: MECO "Baseline research for the sustainable management of Mediterranean sensitive coastal ecosystems" (4^{th} framework program, IC18-CT98-0270, 1998-2001) and MEDCORE "From river catchment areas to the sea: a comparative and integrated approach to the ecology of Mediterranean coastal zones for sustainable management" (5^{th} framework program, ICA-3-CT2002-10003, 2002-2005). The values of and threats to these

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environments by human activities were highlighted and guidelines for sustainable management of the environments were produced (Scapini, 2002; Scapini, 2006; Bayed & Scapini, 2006; Bayed & Ater, 2008).

The human component of the systems and human activities in general are considered negative factors to the health of ecosystems. However, humans have been important components of Mediterranean coastal environments since historical times and have been involved in shaping the landscapes, including those that we now consider "natural", e.g. pine woods. Human populations are rapidly expanding in the coastal areas and their needs have to be addressed, particularly where local people are threatened by an escalating process of increasing population → decreasing environmental quality → increasing poverty.

Freshwater bodies are environmental resources of paramount importance for local people, but they are seriously threatened by human activities. Water bodies in Mediterranean coastal areas may be collectors of sediments and pollutants, and their very existence is constantly threatened. This is aggravated by unpredictable rainfall and changing climate in the region, which may lead to a period of drought or unpredictable storms. When there is sudden strong rainfall following a period of drought, sediments originating in the mountains and transported by floods may fill lagoons, first causing diminished water circulation and increased concentrations of salts and pollutants, and then the disappearance of the lagoons. In low plains, these natural threats to freshwater bodies are often aggravated by land reclamation. Land-use conflicts may arise among agriculture, fisheries, urbanization and natural protection. Both agriculture and cities have a strong and ever increasing demand for fresh water; both produce polluting waste that is discharged into rivers, lagoons or coastal waters. As a consequence, the water supply becomes increasingly scarce and of bad quality (polluted and saline). With a scarce water supply, increasing freshwater demand may escalate into "water wars" among different stakeholders. In the short term, such "wars" or conflicts would likely end with the victory of the most (economically or politically) powerful stakeholders and the beginning of an (apparently) rational use of the resource. However, the losers would remain poor, i.e. the local population and the social components with no voice in the debates (women and children). In the medium and long term, ecosystem components would also be losers, e.g. when biodiversity is eroded. Biodiversity is rarely included in the economic costs/benefits analysis and is often considered a value only when already lost. When environmental resources are of concern, long-term sustainability should be taken into account in any management plans.

The WADI project "Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socio-economic and environmental analysis of changes and trends to enhance and sustain stakeholder benefits"

(INCO-CT2005-015226, 6th framework program, 2006-2008), financially supported by the European Union, had the objective of encouraging a rational and sustainable use of freshwater resources in Mediterranean coastal areas experiencing freshwater scarcity, through participatory approaches. To achieve this aim, a large international consortium of eleven partners from seven countries (Italy, Spain, Portugal, Malta, Morocco, Tunisia and Egypt) conducted interdisciplinary research on the status, dynamics, pressures and trends of a set of water bodies located in coastal areas of the Mediterranean region experiencing water scarcity or unpredictable water supply. The WADI project based its research activities on the stakeholders, those who use/exploit or manage the water body of interest. The research focused on the issues and system components highlighted during meetings with the stakeholders, with a bottom-up approach. A study site approach allowed for better understanding of what was going on around freshwater bodies in Mediterranean coastal areas, while the international collaboration favoured comparisons among case studies, so as to suggest general guidelines for sustainable management of water bodies.

Generalizations have high heuristic power but rarely reflect reality. In contrast, a consideration of the context, including small scales, i.e. the scales of the particular issues of concern, can teach a lot about real relationships. According to Beck (1986), when decisions are taken centrally (at a national level), issues are generally oversimplified and the solutions proposed may not be the best ones for the people actually affected; on the other hand, when decisions are taken locally (at a sub-political level), the decision makers are well aware of the complexity of the problem, which receives due consideration, reducing possible risks. At this level, various indicators can be perceived and management can be adaptive. This was one of the main lessons learnt from the WADI experience based on a study site approach.

Each component of the system has its own spatial and temporal scales and these must be the scales of both the research and the management. The landscape scale is an intermediate unit perceived as such by humans, but landscapes can only be understood if the historical changes are taken into account. At the other extreme are the biological scales, those of biological changes and cycles that are diurnal, seasonal or annual, related to the life cycles of the organisms. Some human activities also have seasonal cycles, e.g. agriculture and tourism, and may impact in various ways on each other (agriculture and tourism need freshwater supplies at the same time of the year) and on the ecosystems.

This volume collects a number of original papers presented by WADI researchers at the International Conference held at the end of the project in November 2008. The papers were subjected to scientific review by experts. The diversity of subjects reflects the multidisciplinary expertise of the consortium, which conducted research focused on case studies. Abstracts of papers not yet ready for publication can be found at the end of the volume. These Proceedings provide an idea of the multidisciplinary and international nature of the WADI project, and also represent a baseline for future studies dealing with the same or similar water bodies. The volume targets the following readers: researchers who can carry on the WADI experience around the Mediterranean, particularly students who intend to participate in international higher education programs (ERASMUS, TEMPUS and similar programs); managers responsible for water and coastal management, to show them the complexity of these kinds of systems and their value; national and international decision makers, to highlight the value and ecological and socio-economic importance of Mediterranean coastal water bodies and the need of an integrated management.

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We wish to thank all the participants in the WADI project, who contributed with their enthusiasm and labour to the success of the project; the European Commission, which supported it financially within the INCO-MED framework of the 6th FP; the project officers Dr. Cornelia Nauen, Dr. Marialuisa Tamborra and Dr. Armand Beuf, who followed with interest and competence the progress of the project with their constructive criticisms of the interim reports. We acknowledge the contribution of the late Dr Fatilia Bou-Salah, who encouraged the gender integration in the socio-economic analysis of the project WADI.

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THE SPANISH STUDY SITE

CONSTRUCTING AN INTEGRATED EL HONDO CASE ACCORDING TO WADI AIMS: REFLECTIONS ON METHODOLOGICAL ISSUES AND REACHING THE SOCIAL OBJECTIVES OF THE WADI PROJECT

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Abstract: The final objective of the WADI project was to produce a certain kind of integrated scientific knowledge on Mediterranean water systems in order to enhance stakeholders benefits and the sustainability of these complex and conflictive systems. According to this objective, WADI has adopted three main methodological approaches: a case study approach, a participative approach, and a scenarios building approach. We summarize the diversity of qualitative and quantitative research carried out at the study site of El Hondo wetlands Nature Park (SE Spain), and in particular, we discuss, by means of specific examples, the apparent environmental learning induced on local stakeholders by this integrative, participative research in contraposition to the management problems and social conflicts caused by the inflexible application of a reductionist, although well-intentioned and scientifically sound, ecological advice.

Preliminary considerations

The general (and certainly ambitious) objectives of WADI are clear from the very meaning of its acronym (Water Demand *Integration*) and from the subtitle of the project: "a socio-economic and environmental analysis of changes and trends *to enhance and sustain stakeholders benefits*". So, WADI deals with integration of different water demands and services, and tries to obtain this scientific integration, not for the sake of mere intellectual understanding, but mainly for social benefits. Accordingly, the success of the project should be measured against these main questions: has this proposed cognitive integration been attained? And has this better integrated understanding benefited local stakeholders in some way?

The discussion on WADI results should be related to a more basic discussion on the role that research and scientific recommendations could play in favoring a more sustainable environmental management policy, and thus on the factors that promote or hinder the real efficiency of environmental scientific research for confronting the environmental crisis (Martín-Cantarino, 1999). This discussion, taking as a base the learning generated through WADI, is the general objective of the present paper.

In order to discuss the degree of success of our project according to their proclaimed ambitions, and specifically in the case of El Hondo study

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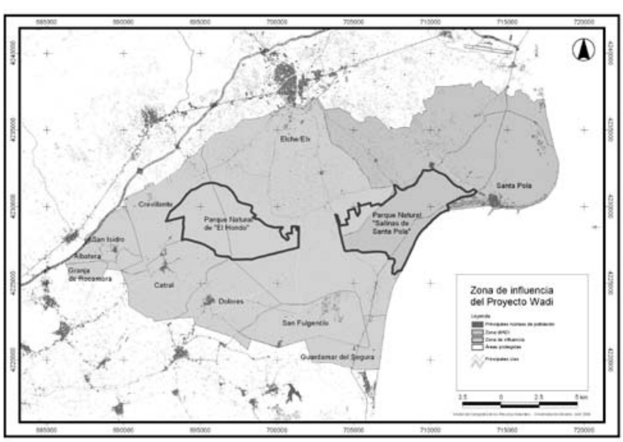
site, we think it is important to recall the basic rationale of the project and the methodological approaches designed from the beginning to cope with their challenges.

- *Complexity: our basic challenge*

Real socio-eco-systems, selected as WADI study sites, are complex. Traditionally, the scientific way of dealing with reality has been its reduction to well-defined, tractable problems, at the expense, of course, of loosing comprehensiveness. For WADI, complexity is not solvable this way, because it had to deal with complex sites in an integrated, not a reductionist, manner. WADI has announced that it will produce, not a juxtaposition of well-defined, sectorial studies on various aspects of the research sites, but integrated assessments of the whole socio-ecological system. And this is not an easy task.

In the case of El Hondo, complexity is considerable (Fig. 1). Physically, the water system is of an enormous complexity, partly as a result of its long history of gradual human control of water fluxes in the area. The El Hondo water system mainly comprises two large ponds of fresh irrigation water taken from the mouth of river Segura and five drainage canals, about ten smaller hunting/fishing ponds (with brackish water of different characteristics, since the provenance of these waters is very diverse), four ponds dedicated to ecological conservation (three owned by the environmental administration and the fourth by a conservationist NGO), the salines of Santa Pola (connected to the sea) and thousands of kilometers of drainage and irrigation canals, of very different water quality, connecting all above-mentioned ponds and water reservoirs. The system is naturally and inextricably connected to another Nature Park (the Salines of Santa Pola), which is also very complex.

Figure 1. The study area of El Hondo.



In relation to social aspects, the situation is no less complicated. Many different administrations, from the national (i.e. Water Administration) to the regional (i.e. Environmental administration) and local levels (10 town councils directly involved) have some degree of responsibility on the system's management. Every level of management involves multiple actors. For instance, El Hondo falls within two national Water Administrations, that of the Segura river (Confederación Hidrográfica del Segura) and that of the Vinalopó River (corresponding to the Confederación Hidrográfica del Júcar). At the local level, 20 communities of irrigating farmers have the direct responsibility for the day-to-day operation of the water system. There are also many agricultural associations, civic platforms and conservationist groups, cultural associations, etc. with relevant influence on the social system. Any research at El Hondo aiming to provide a comprehensive picture of the system faces the problem of complexity. Perhaps this is the reason why such a comprehensive picture has been never drawn.

Complexity is an important issue in ecology, and has recently generated a certain amount of innovative and controversial proposals (Allen *et al.*, 2001; Carpenter, 2002; Zellmer *et al.*, 2006). Certainly, as remarked by Carpenter (2002), the success in dealing with complexity will determine the real social relevance of ecology during the next years. And it is important to note that the methodological approaches under discussion are the same than the WADI project has tried to develop in its study sites.

Figure 2. Partial aerial vision of El Hondo ponds at daybreak (Photo by J.A. Sánchez).

- *The WADI methodological approach*

Methodologically, WADI involves three main approaches: case studies, participatory research, and future scenario development for each study site.

First, WADI was designed as a *case study* research project. It is important to note that this methodological choice fits perfectly, and perhaps unavoidably, with the declared aims and ambitions of the project. Case studies have a long tradition in many fields of knowledge, especially in social sciences, and have generated a large body of methodological thinking. We cannot give here a review of this enormous literature, but it is important to remark that case studies are generally considered to be an efficient tool for obtaining a comprehensive understanding of complex, real situations. For Stake (1977), one of the leading experts in this methodological approach, "a case is a study of complexity, in real terms". As such, case studies are especially useful for testing the real efficacy of general or abstract ideas and policies when applied to the real world (U.S. General Accounting Office, 1990). For example, the study by Keough & Blahna (2006) on the possibility of achieving integrated, collaborative environmental management, which in certain aspects resembles our present approach, is based on an analysis of four real cases.

For the purpose of WADI, a suggested definition of case studies is: "a method for learning about a complex instance, based on a comprehensive understanding of that instance, obtained by extensive description and analysis of the instance, taken as a whole and in its context" (U.S. General Accounting Office, 1990). In order to generate this "learning", case studies can (and must) use a variety of methodologies, and both qualitative and quantitative data. The combined use of several methods is imposed, not only by the diversity of subjects, but also by the need to guarantee accuracy of qualitative information and validate facts by means of triangulation, i.e., the comparison of results obtained by different methods or researchers or from different sources (U.S. General Accounting Office, 1990; Yin, 1999; Walker *et al*., 2001; Gibbert *et al*., 2003)

WADI conducts *participatory research*, as case studies normally do. The final objective of integrating demands and enhancing stakeholders' benefits means in our case that WADI should produce some kind of learning (integrated learning) among stakeholders. This is the only way by which these social benefits could be achieved, since it is obvious that WADI cannot benefit stakeholders through financial investments, or other kinds of direct beneficial measures. But it is also clear that such "social learning" is hardly attainable through top-down dissemination approaches, for example through the ex-post dissemination of results from three years of research (Ison & Watson, 1999). Lack of participation and top-down approaches are mentioned as frequent causes for the low impact of development interventions. WADI, on the contrary, should be a collaborative research. People, according to this approach, should not only be "consulted" but integrated in the very research process if we aim to obtain real learning. Even issues studied should not be completely defined until having obtained substantial inputs from stakeholders, as we shall explain below.

WADI is also a *scenario development exercise*. Scenarios are coherent pictures of possible future situations. This means that the construction of WADI cases should not be simply a comprehensive understanding of study sites, but also an exercise in projection. This is evident also from the very title of the project: "a socio-economic and environmental analysis of changes and *trends*". Contrary to formal models, scenarios, as case studies can (or must) include both qualitative and quantitative information (Carpenter, 2002), and should take a collaborative, participatory approach. In the same manner as cases, scenarios are intended to favor mutual learning among participants in the process.

- *Narratives as necessary results of WADI*

How can different data, both quantitative and qualitative, originate from different disciplines and sources of information be merged into a coherent image? Which format should WADI reports take in order to offer, not a hotchpotch of different, unrelated issues, but an integrated case analysis? The ultimate instrument for addressing complexity is narratives (Allen *et al.*, 2001; Zelmer *et al.*, 2006). Narratives are not irrelevant and inconsistent tales, but stories telling the meaning of acquired knowledge. Stories combine both quantitative and qualitative data and explain them. The aim of case studies is to produce good, well-founded narratives (U.S. General Accounting Office, 1990). Scenarios, the ultimate aim of WADI, are also a method for producing plausible narratives – narratives of possible futures (Carpenter, 2002).

Narratives not only allow a meaningful treatment of complexity, they are also the necessary channel for communicating it to different readers, due to their capacity for promoting shared meanings of exposed facts. And this is so because stories, if properly built, generate commensurate experience amongst independent listeners (Zelmer *et al.*, 2006). Independently of its scientific quality, a typical research report does not help people to change their behaviour, since it normally does not reach them at a deep level of understanding (Probst, 2002). Since the final purpose of WADI is not to obtain information, but to enhance stakeholder benefits, our final written product should not be a document containing data, but a well-constructed narrative offering the reader access to the case at different levels, and thus promoting social learning.

Methods

Our first problem, after preliminary prospection of the systems, was to decide how to efficiently guide research taking into account limitations of time and resources. This implied to decide on the issues our research efforts should be centered around in order to obtain the information needed to construct the El Hondo case according to WADI premises, and taking into account that one of these premises is that research issues should be selected in a participatory manner.

Since the first project meeting in February 2006, WADI activities at El Hondo site have aimed to obtain from stakeholders the most complete set of information in order to identify the key elements necessary for constructing the El Hondo case. As normally required by case study methods, several different qualitative techniques have been used during these contacts with stakeholders, ranging from semi-structured interviews to participant observation (Table 1). For example, the Conference organized as an homage to Nuevos Riegos El Progreso (one of the historical water companies operating in the El Hondo area of influence) in November 2006 was planned not only as a dissemination activity, but also an opportunity for developing participant observation with the agricultural and education groups operating in the area. The same can be said of other conferences, courses, etc. Later, when research priorities were at least preliminarily defined according to the results of qualitative research with stakeholders, quantitative sampling techniques were of course employed in order to investigate ecological issues (fauna and vegetation sampling, chemical analysis of water and soil, etc.). In Table 1, qualitative techniques used for obtaining information in each research field are schematically shown.

Table 1. Qualitative methods used during WADI work at El Hondo study site.

	Soil	Water	Veg.	Fauna	Ethno Biol.	Cult. Herit.	Land. Perc.	Env. Man.	Env. Educ.	Hist.	Oral Hist.
Documentation analysis		X	X	X	X	X		X	X	X	
Semi-structured interviews	X	X	X	X	X	X		X	X		X
Structured interviews							X				
Participant observation			X	X	X	X	X		X		
Cooperative writing						X		X	X		X
Group discussion					X			X	X		X

During the analysis of preliminary qualitative results, the following criteria were used for selecting specific priority research subjects:

1) The issue appears to be widely recognized as a significant (bio)indicator of environmental quality. Local people recognize it as a real and evident symptom of environmental change. In the case of biological aspects, we have centered our efforts in those aspects that spontaneously have emerged as widely accepted indicators of environmental (and life) quality.
2) The issue is related to important cultural aspects. In a sense, our intention, in line with the WADI philosophy, was to preferably select aspects that were not only "objectively" ("scientifically") important, but also socially important, i.e, that were the base of local cultural values. We accept that proper attention to these cultural features (from recreational to culinary interests or handicraft skills) could greatly contribute to enhance social support for the ecosystem and, thus, generate more sustainable scenarios (Infield, 2001; Jacobson & McDuff, 1998).
3) The issue has been historically important. Through historical analysis a given aspect has been demonstrated as a determinant factor of the present state of the system, and its present values and services.
4) The issue shows realistic potential as a catalyst for (future) socioeconomic development under present socio-cultural conditions (and thus of alternative future scenarios). If adequately valued, the issue could promote social initiatives. Documentation of other comparable cases has been essential here.
5) The importance of the issue has not been obvious to the moment. It is clear that priority goes to issues not investigated before and to considering outstanding issues in a different, more integrated perspective. However, it is not easy to know what has been investigated at El Hondo, because results of previous research efforts have never been compiled, and even less made accessible to interested stakeholders. Many findings generated by previous research programs have never been shared with stakeholders (including environmental managers, and even decision makers). Since the very beginning of the project several stakeholders requested WADI to compile and make this fragmented information accessible and this has indeed been one of the most engaging tasks during the first months of WADI work. It is evident that in order to design alternative future scenarios, we should analyze alternative factors which, if adequately valued and promoted, would create new stakeholders benefits.

The five above criteria were not arbitrarily chosen, but were selected after an analysis of the abundant literature existing on the social relevance of science. Specially important for our purposes have been the five principles of practical relevance proposed by Thomas & Tymon (1982):

1) Descriptive relevance, or the accuracy of the research in capturing phenomena encountered by the practitioner (stakeholder) in his organizational setting. Our criteria number 1 and 2 are somehow derived from this requirement, because they try to measure social interest toward that issue.
2) Goal relevance, or the correspondence of the variable to issues the practitioner wishes to influence. Since our objective is to build alternative future scenarios with the involvement of stakeholders, and simultaneously to influence their behavior, this principle is directly related to our criterion number 4.
3) Operational validity, or the ability of practitioners to implement actions resulting from the project's findings by manipulating causal variables. It is included in our criterion number 4 because the potential of generating new future scenarios under the WADI rationale is not considered a mere theoretical exercise, but a realistic one. For example, the "great problem" of water scarcity per se was excluded because this problem exceeds the capacity of all stakeholders, except perhaps the Water Administration (Confederación Hidrográfica del Segura). However, recent history shows that even the CHS has not been able to solve this problem. So, a re-framing of the problem in a new context rather than a specific research is needed.
4) Non-obviousness or the degree to which a theory meets or exceeds the complexity of common sense already used by practitioners. This requirement fits our criterion number 5, if we take the information included in present documents, reports, management plans, etc., as analyzed during the first phases of WADI as an indicator of the "common sense already used by practitioners".
5) Timeliness concerns the requirement that a finding or explanation be available to practitioners in time to use it to deal with problems. Obviously, it is included also in the requirement of realism expressed in criterion number 4.

Results and discussion: learning from a real story and three examples of WADI work at El Hondo

Issues selected for WADI research seen through the above-mentioned criteria comprise a wide range of interests. They include issues such as available resources for eco-tourism, landscape changes over time, relationships between given biological communities and human management patterns or the man-made water infrastructures, etc. We present here only three cases among selected research issues, as examples of our critical analysis of the evolution of El Hondo during project years (the kind of information used for constructing the El Hondo case). We have selected these examples because we think they best exemplify relations between scientific research and environmental policy in our area.

- *Analyzing a conflict: the case of malvasia (White-headed Duck: Oxyura leucocephala)*

The relevance of the White-headed Duck (*malvasia*, in Spanish) for the El Hondo Nature Park is undeniable. From a conservationist point of view, it is perhaps, along with the Marbled Duck (*Marmaronetta angustirostris*), one the most important animal species – and undoubtedly the most widely known, and has almost become the symbol of the Nature Park. El Hondo is an essential site for the conservation of the species in the Iberian Peninsula and the western Mediterranean area. Data are conclusive. In 2002, for example, 70% of the Spanish population of White-headed Duck inhabited El Hondo. Objectively, thus, the maintenance of *malvasia* populations is a management priority. The *malvasia* is internationally protected by the Bern Convention, the Bonn Convention, the Ramsar Convention and the European Directive 79/409/ECC. Also it is considered as an endangered and strictly protected species by Spanish national and Valencian regional legislation. In January 29th 2008 a National Strategy for the conservation of the wWhite-headed Duck was officially launched.

Contrary to other examples, a lot of scientific information is available on this species. In fact, a specific LIFE project was carried out from 1st January 2001 to 1st January 2005 on *malvasia*'s ecology, populational status and present risks in order to prepare the Management Plan for the species in the Valencian Region. The total budget of this LIFE project was € 565,592 (75% funded by the EC and 25% by the Valencian administration).

The *malvasia* is a duck which needs deep waters, so the water level of El Hondo ponds of are of great importance for its conservation. Moreover, rapid changes in water levels can cause the destruction of nests and broods. Additionally, the report recommended the prohibition or limitation of hunting and fishing, due to the deaths of adult *malvasia* ducks caused by these activities.

Here environmental decision-makers paid close attention to the results of this well-funded and rigorous research project. The decree 93/2005 of the Regional Government (popularly known as the *malvasia*'s Decree) endorsed all these considerations. In fact, the decree has a very ecological style, even considering its vocabulary and richness of scientific details. Hunting and fishing were prohibited or seriously limited. And especially no "sudden" variation in the water level was permitted during the breeding period of the white-headed duck, from 1st February to the end of August. This includes the prohibition of any important discharge of water from the ponds or any introduction of water into them during this period.

In the very dry summer 2005, in order to save crops the executive assembly of Riegos de Levante decided to release water from the ponds in order to irrigate fields, despite the legal prohibition imposed by the *malvasia*'s Decree. Green groups immediately denounced this transgression of the *malvasia*'s Decree and damages caused to protected fauna of the Nature Park in court. As a consequence, the executive manager of Riegos de Levante was legally charged with environmental crime and a lawsuit was brought against him. An official report by the Environmental administration, requested by the legal court, which documented the loss of *malvasia*'s broods, was used as the main incriminating evidence. The tension between Riegos de Levante and the Environmental Administration reached its peak during the formal start of WADI project (January 2006). However, the project, whose approach and aims, and especially its participatory character, had been extensively presented to all parties during the previous year, was apparently felt as providing new possibilities for each position. In fact, despite the tension, all contacted parties attended the official presentation meeting of WADI in February 2006, and participated actively, offering their collaboration for the development of the project.

The situation remained stationary during following months. Evidently, given legal consequences, Riegos de Levante did not release any more water from the ponds during the periods in which such discharges are prohibited by the *malvasia*'s Decree. The feeling of grievance grew among irrigators and generally among rural sectors of the area. Political aspects were also present, creating a quite explosive situation. The presentation by the environmental administration during the last months of 2006 of the drafts of new management plans for the Nature Park, which endorse a series of use limitations, and barely contain any proactive or compensatory measure for affected sectors was felt as another cause of resentment, as manifested angrily during the WADI general meeting with stakeholders held in February 2007. During the summer of 2007, and after complaining several times that agricultural fields had not been irrigated due to the *malvasia*'s decree, Riegos de Levante also denounced that they could not even pump up to the ponds of El Hondo the much-needed and relatively good water that, thanks to some strong rains, were available in the Segura river at the end of summer, and which ended up running into the sea. In the context of the local traditional water culture, this loss of water is radically incomprehensible, and thus a very sensitive popular argument against the administration's decisions.

As a result of this conflict, in order to manifest its feeling of grievance, in January 2008 Riegos de Levante took the decision to close the entrance to their property and thus, to impede access of the general public, environmental managers and of researchers to the most important part of the Nature Park (the two large ponds owned by Riegos de Levante). Despite the importance of the decision, no public declaration was made by the Environmental Administration, and no measure was taken against this situation by any other institution. Moreover, no repercussion was noted in the social environment of the area, even after months had passed and the closing of the ponds was maintained.

In August 2008 Riegos de Levante denounced an outbreak of botulism and a massive mortality of waterfowl due to immobilization of poor quality waters, and publicly demanded from the Environmental Administration the drainage of the two ponds for sanitary and environmental reasons. After some reluctance (extraction of water in spring and summer was precisely the cause of the conflict, due to its interdiction by the *malvasia*'s Decree), the environmental administration, when the epizootic outbreak was confirmed by its technicians, finally authorized the drainage of the ponds. Once dried, Riegos de Levante publicly declared that they would not pump up new water into the ponds until the *malvasia*'s Decree was derogated or drastically changed according to irrigator's demands.

Despite the fact that the most important part of the Nature Park was not only closed, but had also dried out, no public declaration was made during these months neither by the Environmental Administration nor by any other stakeholder, except, as usual, by green groups. After months of inactivity, Riegos de Levante took up the initiative again. On 19th December 2008, a large public demonstration organized by Riegos de Levante, in collaboration with other local agricultural associations, marched through the streets of Elche in order to reclaim irrigation rights in El Hondo and the derogation of the *malvasia*'s Decree. Riegos de Levante succeeded at mobilising, not only agrarian associations, but also other Elche's civic organizations and even town authorities. Their capacity to mobilise local forces was confirmed by the fact that all political parties represented in the town council, including the political party heading the Regional Administration (and thus the Environmental Administration) supported the demonstration more or less enthusiastically.

This demonstration was the final catalyst which obliged the Environmental Administration to call for a dialog. Apparently the success in mobilising such a range of very disparate local forces (except green groups), including groups not normally sympathetic to the positions of Riegos de Levante, surprised and preoccupied the political decision makers showing they had lost control of the situation. The way in which administration normally ignores how things go at local levels, and specifically in the rural or agricultural world, i.e., the emotional charge in discourses, the importance of informal relations, the more-or-less generalized sense of grievance (which acts always as a common ground against administration), etc. is a typical example of what sociologists have pointed out regarding similar environmental conflicts (Pedreño-Canovas & Cid Cid, 1998).

At this moment (January 2009), the environmental regional minister and the chiefs of Riegos de Levante have formally initiated negotiations in order to put an end to the conflict. The final form of the agreement is not yet known, but it is clear that this story will not go without serious consequences for El Hondo, affecting not only the ponds of Riegos de Levante, but potentially the whole system. Some data indicate that recent events have probably strengthened moves towards a sub-optimal future scenario.

In our opinion, the *malvasia* lesson is that even an ideal situation from a researcher point of view where scientific findings have successfully influenced management decisions can generate unexpected, dramatic consequences. In this case, scientific research was of good quality and gave a clear counsel to decision makers, this counsel was endorsed by decision makers to the extent that a protection law was passed and a considerable economic effort was made through campaigns and environmental education activities, as recommended, in order to raise public awareness about the white-headed duck and the soundness of protection decisions.

What has gone wrong then? One could simplistically think that the failure of the *malvasia* story cannot be attributed to scientific research, and that the complex mixture of social, political and cultural problems responsible for such a turbulent situation has more strictly to do with managerial (or political) problems than with scientific questions. According to this, scientists have done their job giving decision makers clear recommendations, based on objective and scientifically sound argumentation. The rest, could we think, is a question of the "savoir-faire" of managers.

For us, the question is more complex. In relation to the *malvasia*'s case, it is probably appropriate to recall the affirmation of Boehmer-Christiansen (1994): "Science is often more comfortable in providing advice on what ought to be done and why, rather than practical advice on how it might be achieved". It is obvious that in our case, researchers have clearly said what ought to be done in order to conserve *malvasia*'s populations and why. In fact, a considerable part of written reports, published materials and even legal documents was dedicated to explaining the importance of the white-headed duck and, thus maintaining certain water levels and ruling out traditional activities that might endanger *malvasia*'s wellbeing. Given the objectivity of scientific evidence and measures proposed, the Administration simply adopted and legally ratified them integrally. At face value, this may constitue a perfect success story for scientific research and the rarely attained dream of environmental researchers.

In our opinion, this case perfectly illustrates what Herrick (2004) calls the futility of policies trying to ensure above all the "objectivity" of data and information used for policy decisions, or even the consequences of "excessive objectivity" denounced by Sarewitz (2000). The quest for objectivity in data usable by environmental management is not, of course, reprehensible. But the problem arises when the supposed "objectivity" of facts obscures public and policy debate (Herrick & Jamieson, 2001). Has the objectivity and the scientific excellence of research on *malvasi*a's ecology obscured public debate? The question is very important because the LIFE project was mainly funded by the EC, and requirements for the true protection of the white-headed duck and its habitats find their source in EC Directives.

The Environmental administration not only needs to know how the *malvasia* can be preserved, but also how the socio-ecosystem should be influenced or handled in order to guarantee the conservation of the *malvasia*. In other words, it is not so much a matter of managing the *malvasia* that a matter of working with stakeholders upon whom the survival of *malvasia* depends. And this kind of information has not been provided to managers by current scientific research, because it needs a comprehensive approach encompassing rather than reducing complexity. Thus, a specific effort of integration of social and environmental, quantitative and qualitative, formal and informal information is absolutely needed.

For Walker *et al.* (2001), this activity of integration is distinctly different from those of managers, planners or researchers, and not one that sits appropriately within the strict boundaries of any of these categories, but one that could evolve from any of these starting points. The usual opinion that scientists should provide data and information, and that managers must find the ways of implementing recommendations resulting from this information is too simplistic. Managers do not need pure scientific information, obtained through normal disciplinary constraints, but rather the integration of data into their real context where they find practical sense. Being also a research activity, WADI tries to take research as a starting point for advancing towards the so badly needed integration in the management of our systems, as the case of the *malvasia* at El Hondo dramatically documents.

- *Fish and traditional fishing*

The study of fish and fishing was identified from the very beginning of our contacts with local stakeholders as a relevant research issue for WADI. When local people tried to emphasize the environmental degradation of the area, time and again they alluded to the past abundance and quality of fish fauna, the satisfaction they obtained from traditional fishing activities, and how all this richness had been lost. References to fish as a popular indicator of environmental quality (including a clear sense of quality of life) have been registered from many independent informants and by means of different qualitative techniques including interviews, group discussions, participatory observation, etc.

Also through these techniques we have documented the importance of traditional ecological knowledge related to fish and fishing. Moreover, many present features of the water system are a direct consequence of the local desire of managing fish favorably ever since medieval times. However, despite this key role of fish and fishing, no study has been developed on this subject until now.

Our collaborative work has had the positive result of making fishermen conscious of the value of their activity not only as a personal, much-appreciated traditional amusement, but also as a driver of potential developments. For example, activities such as traditional fishing exhibitions and *in situ* tasting of traditional fish cooking, as a part of a formal strategic program of eco-tourism and local development, have been proposed by the Community of Riegos de Carrizales and the Association of Private Owners of El Hondo to the Environmental Administration.

- *Ethnobotany and traditional agriculture*

The same reasons for selecting traditional fishing led us to select the case of botanical traditional knowledge, including cultivated species as a relevant WADI issue. In fact, it is obvious that traditional agriculture has been the main historical factor in the construction of the present landscape. Our work was focused on studying local varieties of agricultural crops, trying to ascertain the potential development of these crops and their cultural values.

Among others, several agricultural and ethno-botanical products were identified as capable of promoting social benefits including the local high-quality variety of melon, local traditional pomegranates, some vine varieties for the production of white wine, several textile plants grown in relation to irrigation infrastructures and used for handicrafts (mainly *Imperata cylindrica* and hemp, *Cannabis sativa*) and a series of uncommon vegetables, including spontaneous plants traditionally eaten in the area (*Sonchus tenerrimus*, *Cichoria intybus*, *Beta vulgaris*). The possible use of common reed (*Phragmites communis*) as a source of biomass or construction material is being studied. Also historic and cultural reasons support the plausibility of developing crops of halophilous plants formerly used for making soap.

As a result of the WADI meeting of November 15th 2008, when experiences from another WADI site (Parco della Maremma, Italy) and from other Spanish protected areas were very adequately shown to El Hondo stakeholders, and taking advantage of the findings of the collaborative WADI work on local ethno-botanical and agricultural values, the Community of Riegos de Carrizales has devised a strategic plan for promoting these agro-ecological potential enterprises. Although the initiative is yet embryonary, it has been officially supported by the environmental and agricultural administration. It is important to note that the name selected by the farmers for this initiative: "Agrarian Nature Park of Carrizales" (which has obtained support also from the Environmental and Land Planning Administration) aim to integrate both natural and (agri) cultural values.

- *Cultural Heritage*

The objective importance of cultural heritage related to the use of natural resources and specifically water seems clear in a such a historically rich land use system which displays some of the most refined human control of water fluxes among WADI study sites and, perhaps in the entire Mediterranean basin. However, and surprisingly, no comprehensive information on that subject is presently available in a formal manner. At the same time, the social relevance of the issue is clear, and social interest towards this issue has been tested in several occasions during WADI activities. From the field of environmental management, several authors have advocated the use and promotion of cultural issues in order to strengthen the affective implication of local people with protected areas (Infield, 2001). Thus, the promotion of a wider recognition of the importance of cultural heritage could be a strategic tool for engaging larger sectors in the protection of environmental values.

Our work has resulted in a catalogue of more than 200 physical items mainly related to traditional use of water, ranging from ancient water reservoirs to water wheels, ancient machinery, canals and other relevant infrastructures, etc., with a technical description of each object, and information useful for management purposes. But, as explained, our aim was not only to produce data, but also to set social potentialities in motion. We present below two examples of results obtained with local cultural institutions.

In 2007, an agreement of collaboration within the framework of WADI project was signed between the direction of the Ethnological Museum of the Elche Countryside and the University of Alicante. The objectives were 1) to review and catalogue existent, but not studied, ethnological materials in the Museum's collection (tapes, photographs, written reports, etc.) related to the traditional use and management of natural resources, 2) to identify the gaps in this collection according to previous experience of the Museum's personnel and that of WADI researchers, and 3) to develop a plan for filling gaps by means of a well-planned field work and documentation effort.

For WADI purposes, the agreement was useful in order to conduct participant observation with the Museum's personnel, collaborating with them in their daily tasks. Also cooperative writing (the joint preparation of written proposal and reports) has offered important research opportunities, and has resulted in mutual learning. An apparent sign of this advance has been the development of a research project aimed at studying traditional knowledge related to irrigation and water management devised jointly by the Museum's personnel and WADI researchers. The proposal has been presented to the Regional Ministry of Culture, and its funding approved in 2008.

A similar approach guided the signature in 2008 of a contract with FUNDESCED, a local cultural foundation from Almoradí, a small town South of El Hondo. The contract tried to analyze the importance of local cultural heritage for local development, through their value addition within specific touristic integrated programs combining ecological, landscape and cultural issues, and specially the connection with El Hondo Nature Park. As a result, a catalogue with 55 cultural elements and several proposals of touristic/interpretative routes have been produced. The town council has endorsed the project and it is expected that the program will be officially launched during 2009.

Some final conclusions

We think that the combination of different qualitative methodologies (complemented with quantitative work when feasible) has allowed a more integrative perspective, as requested by WADI objectives. Participant observation, i.e., obtaining information during and through active collaboration with stakeholders, although very time-consuming, was especially useful in two ways. First, thanks to this approach we have been able to obtain a deeper understanding of the very complex relations existing between environmental and social aspects, with access to key data not easily accessible from the outside, as shown by the paradigmatic case of *malvasia*. Thus, the research team has experienced a kind of comprehensive scientific learning of the real socio-eco-system that would be very difficult (or impossible) to obtain through conventional environmental research methods. Second, we have been able to influence, to a certain degree, the evolution of the situation through social learning of involved stakeholders, as testified by initiatives launched by the Community of Riegos de Carrizales, the Ethnological Museum of the Elche Countryside and the FUNDESCED foundation, all of them based on the potential of integrating ecological and socio-cultural values as advocated by WADI.

Also in their analysis of factors that promote effective integrated and collaborative environmental management, Keough & Blahna (2006) identify the following key drivers among others: establishment of integrated goals, promotion of inclusive public involvement, use of multidisciplinary data and the existence of economic incentives. In our case, the unfoldment of the *malvasia* affair as well as additional above-mentioned examples illustrate the different kinds of integrated scientific research conducted. In the first case scientific advice based in good disciplinary research unleashed (unconsciously, of course) an acrimonious environmental conflict, with serious consequences for the future of the area. In the other examples, scientific support, collaboration and advice have led some local stakeholders to devise and develop creative and seemingly sustainable activities with an important environmental component. For achieving this, scientific work should be not only driven by the need of guaranteeing internal scientific validity (which normally is based in disciplinary constraints), but also by the requirement of attaining external validity, i.e. social relevance (Thomas & Tymon, 1982). In our case, cultural and ecological aspects must be combined to produce engaging and realistic recommendations with clear perspectives of socio-economic benefits for stakeholders involved.

Although the plausibility of obtaining economic incentives is necessary for social engagement, it is simplistic to think only in terms of mere economic profits, as noted by Keough & Blahna (2006). The temptation of taking subsidies as a way of solving conflicts is certainly important for many environmental administrations. But subsidies alone, without proper consideration to the real social concerns (and this implies again the generation of truly integrated information) are rarely effective. The fact is also illustrated by the *malvasia* affair. Although Riegos de Levante has been generously subsidized by the Regional Administration during past years (amounts close to €100,000-120,000 were annually paid to the Community), this did not prevent the outburst of the conflict to the surprise and irritation of the subsidizing Administration. All the initiatives presented above include an economic facet, but socio-cultural questions have also been taken seriously into account.

Despite the enormous complexity of the El Hondo socio-ecosystem, and despite the magnitude of the problems it faces, including the conflicting situation inherent to its structure, we think that the usefulness of WADI approach has been positively tested, to a relatively satisfactory degree, in the demanding laboratory of the real world. From merely scientific considerations, we do think that it has also offered important lessons. Specifically, it has shown the importance of integrated, participatory socio-ecological research in order to provide decision makers and stakeholders with the appropriate scientific advice they need for the sustainable management of this system.

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associations, and irrigating farmers communities). It would be impossible to give here the list of all of them, but we feel that they should be recognized as co-authors of this paper.

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LONG-TERM (1883 TO 2008) HISTORICAL CHANGES IN AGRICULTURAL LANDSCAPE PATTERNS IN A TRADITIONAL IRRIGATED SYSTEM OF ALICANTE PROVINCE, SPAIN: THE CASE OF LO CONTADOR PROPERTY (CARRIZALES OF ELCHE)

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Abstract: This case study of a cultural landscape in a traditional irrigated system of Alicante Province was conducted to develop appropriate techniques for quantifying and analyzing the landscape change since 1883. Methods were derived from landscape structure change analysis, based on old maps and aerial photographs, and were rendered at a high scale level using GIS tools. The created database for the diachronic GIS analysis is a key piece in order to obtain a clear view of land uses evolution in the study area. The main objective of this study is to emphasize that an approach based on a land plot level and using GIS technologies provides valuable results for planning conservation programs in cultural landscapes at local scale.

Introduction

Landscapes are an anthropic creation resulting from the historical performance of people on the territory and the influence of different socioeconomic models of human intervention. At a particular point in time, some of their larger or more persistent elements must be regarded as a historical heritage and only can historical analysis explain their presence in the landscape (Turri, 2002). In this way, as stated González-Bernáldez (1981), the combination of historical documentation and remote sensing can be very useful for understanding a particular landscape as we see it today.

The spatial unit of human activity on the countryside has traditionally been the estate or property. Their spatial configuration responds to a determined strategy, guided and constrained by socio-historical or biophysical conditions at a higher level of organization or analysis. An exact knowledge of historical changes in the landscape structure could facilitate and improve interpretations about the current and future state of the landscape (Bender *et al.*, 2003). This is particularly valuable for more effective landscape planning at the local level, where landscape changes are important relative to conservation planning.

Felicita Scapini, Jean-Marc Boffa, Elisabeth Conrad, Louis F. Cassar and Mariella Nardi (editors), *Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socio-economic and environmental analysis of changes and trends to enhance and sustain stakeholder benefits*, ISBN 978-88-6453-015-4 (online)

Historical studies of rural landscapes have been based largely on the rich information contained in the cartographic sources of collective farms and private domains. Suffice it to recall the classic works of Bloch (1931) on the French countryside, of Sereni (1961) in Italy, or of Rackham (1986) on the British lands. Studies of this kind have often resorted to levels of survey driven by the need to define limits of individually owned lands, as well as cadastral mapping, and so on. The resolution of these maps can be considered too high, and may contain very detailed information, not only on the boundaries of the farms, but also on the spatial configuration of cropped plots and uncultivated land (Faus Prieto, 1995).

Other studies such as those of Mometto (1992) or Turri (2002) focus on the diachronic analysis of individual farms and have clarified the current configuration of Mediterranean landscapes. As a consequence of socio-politic processes in the Alicante Province, have had a great tradition the creation of new landscapes of agricultural colonization. In this case, the new landscape structure, resulting from drainage of ancient marshlands. Thus it is possible to find an important quantity of cartographic documentation that shows the initiation of reclamation works and also disputes over property rights arising from the changes then taking place in the traditional tenure and management of such a rural space.

Subsequent to this long tradition of landscape studies in the field of history or geography, the development of techniques in landscape ecology especially since the 1980s, permitted a richer set of possible documentation approaches. This paper presents preliminary results that the integration of ecological and historical analyses has generated, and discusses methodological problems and opportunities of using spatial information from such a diversity of backgrounds and approaches.

"Lo Contador" property, bordering the southern boundary of El Hondo Nature Park, and sharing the same origins as the Carrizales foundation in Elche has been an important part of the new agricultural territory reclaimed from the old marshlands. This property owes its name to the fact that was the property of the assistant or "contador" (Spanish term) of the Duke of Arcos and Maqueda, Marquis of Elche, feudal lord and promoter of the drainage and reclamation of this ancient marshland in the first half of the 18th century. The existence of a rich historical documentation on this property, including old cartography, permits a diachronic study of landscape structure.

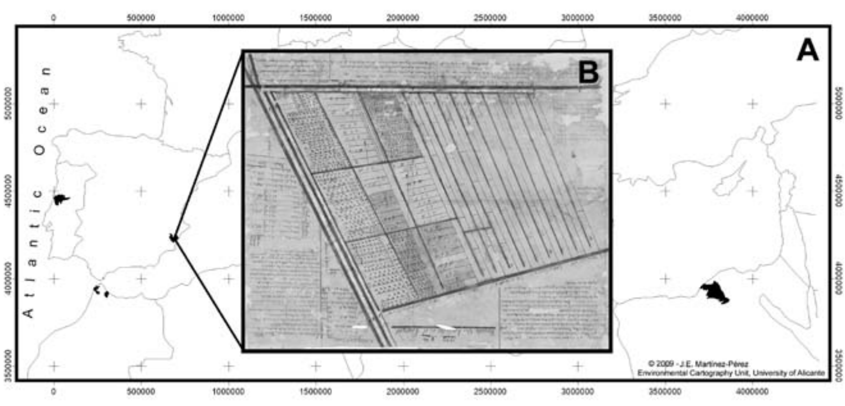
Therefore, the study consisted in analyzing the evolution of this landscape from the date of its creation with the bonification of the old marshes, as a significant example of the Carrizales area, which is currently designated as wetlands and incorporated in the protected buffer zone of El Hondo and Salinas de Santa Pola Nature Parks.

This study presents the analysis of one traditional irrigated system (Lo Contador property, Elche), considering historical land use changes. This project started with the agreement between the University of Alicante and the Carrizales Community of Irrigating farmers (Elche) in 2007, in the framework of the WADI Project.

Study area

The study area is located in the Bajo Vinalopó region, Alicante province in Southeastern Spain (UTM 30N: 697000, 4191000; 699200, 4225400). The area is characterized by a semiarid and dry Mediterranean climate, with 18 °C of annual average temperature and an annual rainfall lower than 350 mm. Traditionally, land uses in the region include irrigated groves and industrial activities with a high diversity of agricultural products, resulting in a rich cultural landscape. Recent landscape changes, derived from a loss of productivity, have led to a loss of landscape diversity due to a landscape homogenization process, which can be supposing many negative repercussions on ecological balance.

Figure 1. (A) "Lo Contador" property location in Southeastern Spain, into El Hondo study area. (B) Historic map boundaries of "Lo Contador" (1883).



Materials and methods

Analyses were carried out using GIS. The analysis of landscape change is based on a variety of sources, including historical maps and aerial photographs. A historic source (historical map), which represents the traditional landscape structure, should be the starting point for the change analysis of landscape. Likewise, the continuity of the graphic sources is of great importance. It is necessary to consider several time periods which representing the evolution of landscape structure.

Land use maps were prepared by digitizing aerial photographs and old maps. We obtained land uses for the area from 1883 (historical map), 1956, 2002 and 2008 years. Cartalinx® and ArcView® software was used to make these maps. Using Crosstab module (Eastman, 2006) in Idrisi system, temporal changes in the landscape structure can be established with the Kappa Index (Rosenfield & Fitzpatric-Lins, 1986).

Cartographic sources included the following:

- A 1883 hand map of "Hacienda del Contador en el Carrizal", a typical land surveyor map coloured with aquarelles (Faus Prieto, 1995). It shows the farm borders, the irrigation and drainage network and surface areas of different crops in great detail.
- A 1956 aerial photography (American flight). It is a national aerial photographic reference, being the first photogrammetric flight that covered all of the Spanish State.
- A 2002 orthophotograph. Orthophotographs of the Valencian Region were made by the Cartographic Valencian Institute (ICV) in digital format in 2002.
- A 2008 orthophotograph. Orthophotographs of the Valencian Region were made by the Cartographic Valencian Institute (ICV) in digital format in 2008.

Results

Figure 2 presents the views of the study area at the four dates used to analyse land use changes. Specific geometric pattern are consistently used to map similar land use categories at the four dates.

Visual analysis of temporal layer maps illustrated a high degree of landscape change in the period under investigation (Fig. 2). Within this period, olive tree and vineyard in particular have transformed to abandoned lands, while areas with vineyard have been transformed into barley and abandoned land. The biggest loss in agricultural land was in the alfalfa plots because in the last decades the use of draught animals in all farming activities has ceased. Thus, this category has disappeared of traditional agricultural landscape. By the other hand, new elements, such as palm trees, have appeared in the scenario. This new type of production responds to new demands of ornamental Mediterranean plants.

Table 1 shows land use changes between 1883 and 2008, quantifying the change in surface area (m^2) in the 15 land use categories identified over the period of study. Rows provide long-term (1883-2008) historical changes in agricultural landscape pattern in the study area.

Figure 2. Left column: Temporal layer maps of the distribution of land use categories and plot structure in "Lo Contador" property: 1883 (A), 1956 (B), 2002 (C) and 2008 (D). Right column: Distribution of land uses after dissolve plots in a simple GIS process.

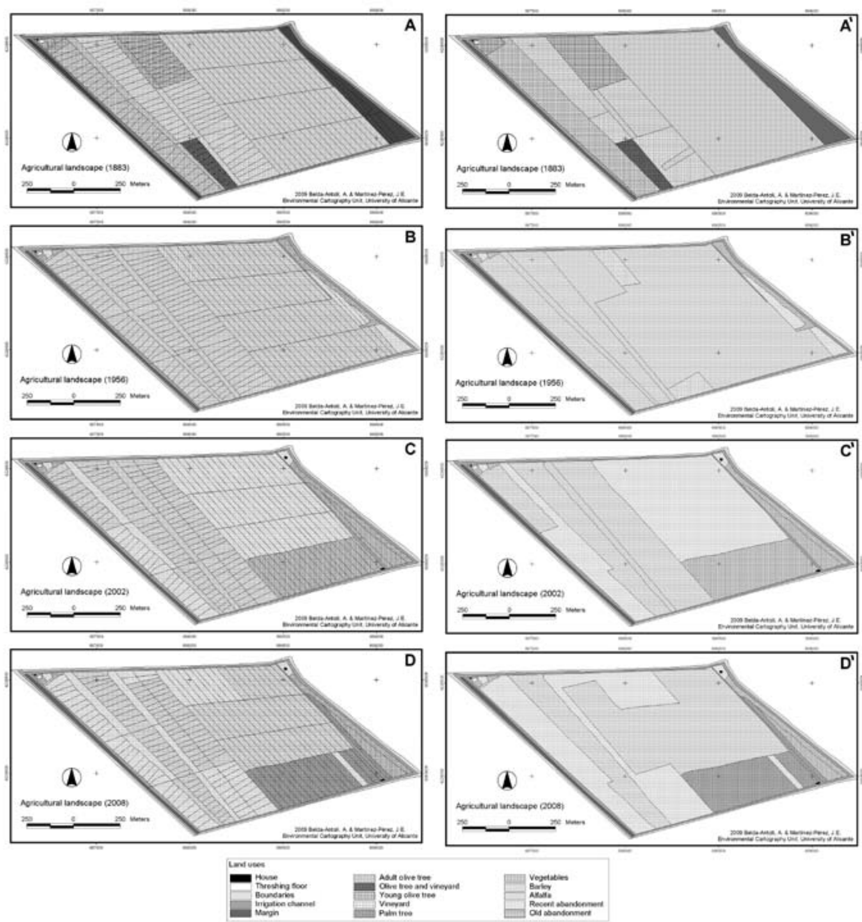


Table 1. Categories of change in the study area (1883–2008).

Land use (m^2)	1883	1956	2002	2008
House	69.96	69.96	446.71	446.71
Adult olive tree	149033.36	0.00	0.00	0.00
Olive tree and vineyard	25216.65	0.00	0.00	0.00
Young olive tree	76646.62	0.00	0.00	0.00

Vineyard	84609.30	40530.73	0.00	0.00
Barley	137902.58	811887.11	343201.29	499889.33
Alfalfa	490093.00	117302.36	35499.75	0.00
Vegetables	0.00	0.00	168511.80	21193.88
Threshing floor	335.05	335.05	335.05	335.05
Boundaries	48946.71	48946.71	48946.71	48946.71
Irrigation channel	66098.08	66098.08	71115.91	71115.91
Margin	75924.75	17574.33	17574.33	17574.33
Recent abandonment	0.00	29145.55	445166.26	331448.25
Old abandonment	0.00	22986.19	24078.25	24078.25
Palm tree	0.00	0.00	0.00	139847.65
TOTAL	1154876.06	1154876.06	1154876.06	1154876.06

Conclusions

Despite considerable differences of these data sources, the comparative analysis between old cartographic documents and modern aerial photography at a fine scale permitted a temporal analysis of spatial changes in land use which highlighted some interesting features to understand the current landscape. Furthermore, land plots based analysis of historical landscape structure and landscape development data can be directly integrated into new strategies of landscape planning.

To overcome the difficulty in the photointerpretation process of using old maps without a modern geographic reference system, a geographical correction was applied generating corrected orthophotos that permitted an adequate interpretation of land uses at landscape levels. This graphical source also provides information concerning economic, social and cultural factors, which can be used to develop explanations of changes in landscape patterns and to create futures scenarios.

The land use change analysis, based diachronic GIS, has proven to be advantageous, especially for the quantification and description of landscape structure change at the local level. The quantitative GIS approach, used to explain historical landscape change, is an essential component for the prediction of future landscape changes.

The preliminary analysis between 1883 and 2008 shows the long-term stability of landscape structure metrics in “Lo Contador”. Thus, this property can be considered as a relic fragment of the territory (along with other spatial structures in this study area) linked to the drying of the old marshlands in the eighteenth century.

This absence of changes in the agricultural landscape seems to primarily originate from the constraints imposed by the irrigation and drainage networks, which act as a durable frame on landscape features. Changes introduced (water distribution, pumping water, etc.) over time have been implemented within the traditional irrigation system, whose spatial configuration has dictated water flows and irrigation patterns since the time the marshlands were drained and reclaimed.

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INFLUENCE OF CHARACTERISTICS OF IRRIGATION CHANNELS ON THE BREEDING BIRD COMMUNITY OF A WETLAND ZONE IN SOUTHEAST OF SPAIN

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Abstract: The "El Hondo Natural Park" is mainly composed of a series of irrigation channels and water reservoirs, subjected to various regimes of management as well as reed and vegetation control, thus creating a great variety of habitats and situations. To determine the influence of these habitats and management regimes on the local bird community, a set of characteristics of these channels and their surrounding area were analysed with a Correspondence Analysis (CA). The degree of reed development in channels and the presence in the surroundings of orchards and other reed formations were the most decisive factors to explain the probability of occurrence of reed birds and waterbirds, as well as bird species richness and abundance. Other bird species were not directly influenced by channel variables, but only by those of surrounding land uses.

Introduction

During the last decades, agriculture in the El Hondo region has experienced an important shift from traditional dry crops to irrigated crops, driven by market pressure and opportunities for greater profitability (Leal, 1969). As a result, a set of water transport and storage systems in the form of channels and ponds have been developed to cater for the increasing water demand of these new irrigated crops. Irrigation channels come in different forms, either closed or open-air, and are made of concrete or ground. These differences influence the types of habitats created and their similarity to natural fluvial systems. Previous research shows that such changes in agricultural environments may have a deep impact on biodiversity and on landscape structure (Pimm *et al.*, 1995; Donald *et al.*, 2001; Brotons *et al.*, 2004).

Channels are managed by private individuals, enterprises or regional government, who all work to attain highest efficiency and profit. Accordingly, the vegetation on the banks of watercourses is cut and sprayed, and sediments are dredged at varying frequency and intensity. Irrigation channels are semi-anthropised ecosystems that change over time with evolving requirements of agriculture. Effects of management on local fauna are not well known but probably depend both on the spe-

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cific characteristics of irrigation channels and their interaction with surrounding habitats.

In wetlands, birds are a flagship group of animal species that respond quickly to environmental changes. Therefore their study can provide a test of the ecological value of this type of constructed ecosystems. The paper's objectives are 1) to evaluate the influence of irrigation channels and land use in their surroundings on the probability of occurrence of selected bird species, and 2) to identify characteristics of irrigation channels that influence bird species richness and abundance.

Materials and methods

Study area

The study was located in Carrizales, an area between two important wetlands in Alicante (Southeast of Spain), Hondo Natural Park and Salinas de Santa Pola Natural Park. The study area is within the coordinates NW X:697104, Y:4226507; SW X:700991,Y:4222517; NE X:705182,Y:4228218; and SE X:705297,Y:4227084 (Fig. 1).

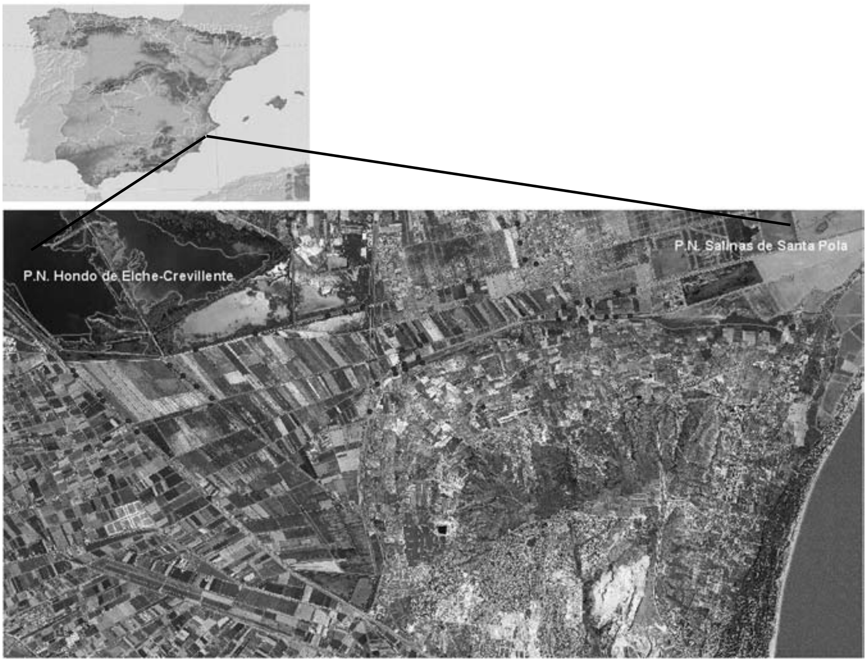
This area is included in the "Catálogo de zonas húmedas de la Comunidad Valenciana" because of its importance as a natural corridor between the aforementioned wetlands. Three hundred years ago, this area was an extensive wetland that was drained for agriculture and malaria eradication, and irrigation channels were built to maintain a flow of water for agriculture.

Currently, the traditional land use in the area which extends over approximately 1,649 ha is a mix of vegetable and arboreal crops (palm and pomegranate trees). The complex network of irrigation channels with their associated vegetation within the agricultural matrix and patches of natural vegetation creates a heterogeneous mosaic of land uses.

Bird counts

To study the bird community associated with irrigation channels, 45 sampling points were selected, representing the various combinations of channel features (ground or cement, with or without vegetation and with or without reed). Each sampling point includes a plot which was 100m long and 6.5m wide on each side of the channel. Counting was done at the center of this plot, for five minutes in each sampling point. Countings were done always from sunrise within the 3 subsequent hours. Only birds seen within the established limits of sampling plots were recorded. In order to ensure that birds surveyed were indeed breeding, only birds which appeared in at least four of the total sampling points were included into the analysis. The point counting was carried out twice in the breeding season, in May and June of 2007.

Figure 1. Study area map. Points are bird counting points. Source: Unidad de Cartografía de los Recursos Naturales - U.A. Instituto Cartográfico Valenciano.



Environmental variables

In order to characterize the sampling points the following group of variables was recorded:

- *Physical variables*: Building material (concrete (0) or ground (1)), Channel width (m) and Distance of the counting point to the nearest wetland (m).
- *Vegetation cover*: In each sampling point, ten 6.5 m-long transects were laid out perpendicular to channel edge, five on each side of the channel and spaced 25 m apart. The occurrence of plant species or bare soil along transects was measured and its percentage of cover estimated. The maximum height of each element was also measured. Species were grouped according to functional and morphological groups.
- *Vegetation height categories*: Vegetation height data obtained from the aforementioned vegetation transects were used to group the vegetation in 5 height categories. Without vegetation (0), from 0 to 0.3m (1), from 0.3 to 1m (2), from 1 to 2m (3) and taller to 2m (4).

- *Reed variables*: At each sampling point, we took 20 measures of reed density, 16 in the band of vegetation that borders the channels and 4 inside these channels. We used 33 cm x 33 cm squares to record the number of reed stems, their diameter and height and their condition (dead or live). Squares on the edge of channels were distributed at 0, 0.75, 1.50 and 2.25m along two perpendicular transects located 50m apart, on each side of the channel. Reeds inside the channels were counted and measured in four 33cm x 33cm squares located 25m apart. Using these data we estimated the reed basal area and calculated a measure of reed heterogeneity as the difference in reed density between both shores of the channel at each sampling point.
- *Channel surroundings variables*: Using an official on-line GIS service (<http://orto.cth.gva.es/website/urbanismo/viewer.htm>) 50m radius circles were delimited around each sampling point. Within these circles we estimated the percentage of area occupied by the different kind of crops, semi-natural vegetation and buildings.

Statistical analysis

To reduce the high number of variables, a Correspondence Analysis (CA) was performed for each group of variables (except physical variables). Resulting factors, representing environmental gradients, were used as predictors in regression models. In each CA, we selected the number of factors that explained at least 80% of variance.

To model bird species occurrence, we used logistic regressions. The relation of species richness and total bird abundance to environmental gradients were analysed by means of linear regressions. In both cases we used Akaike Information Criterion (AIC) to select variables for use in the models. Models were fitted independently for each group of environmental variables, in order to detect which type of variables had a greater influence on birds. AIC was used to compare models for the same dependent variable fitted to different environmental predictors. The model with the lower AIC was considered the best model unless AIC differences between some models were less than 2, in which case they were considered equal alternative models.

Results

Environmental variables

A synthesis of Correspondence Analysis results is presented in Table 1. For simplicity, only variables with correlation coefficients greater than 0.5 are shown. The number of axes that explained 80% of variance ranged between 3 for vegetation height variables and reed variables and 6 for vegetation cover and surroundings variables.

Table 1. List of correlated factors identified in correspondence analysis of channel characteristics.

Variable	Code	Negative correlation (r < -0.5)	Positive correlation (r >0.5)
Surrounding area	SA1	Halophyte plant formations	Grassy crops
	SA2	Reed formations	Palm tree and pomegranate farming
	SA3	Grasses crops	Ground irrigation channels and reed formations
	SA4	Houses	Herbaceous crops
	SA5	Palm tree farming	Fallow land
	SA6		Roads
Vegetation height categories	VH1	Height of vegetation between 0 and 0.3m	Height of vegetation higher than 2m
	VH2	Without vegetation and height of vegetation between 1 and 2m	Height of vegetation between 0.3 and 1m
	VH3	Height of vegetation between 1 and 2m	Height of vegetation between 0 and 0.3m
Vegetation cover	VC1	Roads and low size grasses	Other channels and reed formations
	VC2	Other channels and reed formations	Halophyte plant formations
	VC3	Herbaceous crops	Tree farming
	VC4	Halophyte plant formations and creeping plants	Tree farming
	VC5		Bare soil
	VC6	Medium and high size herbaceous plants	
Reed development	RD1	Reed's density heterogeneous in the two sides of the channel	Height of alive reeds, diameter both of alive and dead reeds and basal area both of alive and dead reeds
	RD2	Presence of reed inside the channel and density of dead reeds	Number of channel edges with reed
	RD3	Presence of reed inside the channel	Difference in reed density between the two sides of the channel

Bird species model

Altogether 496 birds were detected in point counts, belonging to 38 different species. The most abundant species were Common moorhen (*Gallinula chloropus*) with 79 contacts, Zitting cisticola (*Cisticola juncidis*) with 68 contacts, Barn swallow (*Hirundo rustica*) with 45 contacts, Reed warbler (*Acrocephalus scirpaceus*) with 43 contacts and Little egret (*Egretta garzetta*) with 28 contacts. Only 16 of total bird species were included in the analyses, because they appeared in at least four of the total point counts. Alternative models for species occurrence are shown in Tables 2 to 4.

Table 2. Logistic regression models relating species occurrence to reed development variables. Regression coefficients are shown for reed gradients selected in the models. N=45; <0.1 n.s. (not significant), ⋆ <0.05, ⋆⋆ <0.01, ⋆⋆⋆ <0.005; R^2 Explained variability percentage; AIC: Akaike Information Criterion of the final model. Models considered the best for a species (minimum AIC) are typed in bold. Models with difference AIC<2 with respect to the best model appear underlined.

Reed development	RD1	RD2	RD3	R^2	AIC
Ardeidae					
Ardea purpurea				0	33.395
Ardeola ralloides				0	28.996
Egretta garzetta		-0.869 ⋆		0.115	48.278
Nycticorax nycticorax	4.807 ⋆		-1.851 ⋆	0.435	23.736
Rallidae					
Gallinula chloropus			-1.354 ⋆	0.116	55.754
Laridae					
Larus ridibundus				0	28.996
Sternidae					
Chlydonias hybridus				0	33.395
Hirundinidae					
Delichron urbica				0	28.996
Hirundo rustica				0	54.192
Turdidae					
Turdus merula	1.298 ⋆			0.127	49.571
Sylvidae					
Acrocephalus scirpaceus	**3.575 ⋆⋆**	**-1.949 ⋆**		**0.496**	**32.284**
Cettia cetti	1.043 •			0.082	42.658
Cisticola juncidis			<u>0.730 •</u>	<u>0.073</u>	<u>57.078</u>
Sylvia melanocephala				0	49.674
Fringilidae					
Carduelis chloris				0	47.036
Serinus serinus				0	33.395

Table 3. Logistic regression models relating species ocurrence to vegetation height categories and vegetation cover variables. N=45; <0.1 n.s. (not significant), ⋆ <0.05, ⋆⋆ <0.01, ⋆⋆⋆ <0.005. R^2: Explained variability percentage; AIC: Akaike Information Criterion of the final model. Models considered the best for a species (minimum AIC) are typed in bold. Models with difference AIC<2 with respect to the best model appear underlined.

	Vegetation height categories					Vegetation cover							
	VH1	VH2	VH3	R^2	AIC	VC1	VC2	VC3	VC4	VC5	VC6	R^2	AIC
Ardeidae													
Ardea purpurea				0	33.395			2.900 •				0.191	29.386
Ardeola ralloides				0	28.996		**1.813**				**-2.338 ⋆**	**0.337**	**23.887**
Egretta garzetta	-1.344 •			0.085	49.779	**-0.796**			**-3.781 ⋆**	**-1.067**	**3.711 ⋆**	**0.419**	**39.06**
Nycticorax nycticorax	**0.069**	**0.094 •**		**0.762**	**13.480**	0.097 ⋆⋆	0.037 ⋆					0.501	21.663
Rallidae													
Gallinula chloropus				0	60.574			1.460 ⋆⋆				0.154	53.558
Laridae													
Larus ridibundus			-2.151 •	0.129	27.524						2.417 •	0.142	27.151
Sternidae													
Chlydonias hybridus	-3.743	-3.035 •		0.589	18.906	-2.097						0.353	24.317
Hirundinidae													
Delichron urbica				0	28.996	2.323					3.270 •	0.219	27.062
Hirundo rustica	**1.155**	**1.882 •**	**-3.019 ⋆**	**0.219**	**48.766**				1.541 ⋆			0.140	48.883
Turdidae													
Turdus merula	1.539 ⋆⋆			0.198	45.873			**2.689 ⋆**	**1.583 ⋆**			**0.379**	**38.381**
Sylvidae													
Acrocephalus scirpaceus	2.354 ⋆⋆	1.595		0.334	40.771	3.247 ⋆			-1.441 •			0.281	43.500
Cettia cetti	0.816 •			0.069	43.230	2.180 ⋆						**0.159**	**39.432**
Cisticola juncidis				0	59.286	0.978 •		-0.895				0.122	56.274
Sylvia melanocephala				0	49.674	-0.668			-0.945			0.108	48.523
Fringilidae													
Carduelis chloris				0	47.036							0	47.036
Serinus serinus				0	33.395				**1.313 •**			**0.105**	**32.093**

Table 4. Logistic regression models relating species ocurrence to physical and surrounding area variables. N=45; <0.1 n.s. (not significant), ★ <0.05, ★★ <0.01, ★★★ <0.005, R^2: Explained variability percentage; AIC: Akaike Information Criterion of the final model. Models considered the best for a species (minimum AIC) are typed in bold. Models with difference AIC<2 with respect to the best model appear underlined.

	Physical variables					Surrounding area							
	Width	Material	Distance	R2	AIC	SA1	SA2	SA3	SA4	SA5	SA6	R2	AIC
Ardeidae													
Ardea purpurea	**-0.947 •**		**0.003 ★**	**0.257**	**29.317**							0	33.395
Ardeola ralloides				0	28.996				-1.669			0.112	27.985
Egretta garzetta				0	52.053	-0.795 •		0.781				0.099	51.067
Nycticorax nycticorax				0	33.395	-0.015 •	-0.037 ★★					0.343	26.616
Rallidae													
Gallinula chloropus	0.530 ★			0.132	54.842		**1.729 ★★**		**-0.799**			**0.208**	**52.396**
Laridae													
Larus ridibundus			-0.001	0.092	28.512			**2.075 ★**		**1.434**		**0.357**	**23.351**
Sternidae													
Chlydonias hybridus			**-0.016**	**0.799**	**10.288**							0	33.395
Hirundinidae													
Delichron urbica	**2.150 ★**			**0.459**	**18.589**				0.998 •	1.479 •		0.195	27.394
Hirundo rustica				0	54.192		0.985 ★					0.102	50.874
Turdidae													
Turdus merula				0	54.192		0.772 •				-1.653	0.128	51.503
Sylvidae													
Acrocephalus scirpaceus	-0.342 •			0.059	53.061		-1.309 ★				-1.112	0.173	49.166
Cettia cetti		-1.504 •		0.084	42.6	0.976		0.754				0.113	43.366
Cisticola juncidis				0	59.286			**-1.043 ★**	**1.357 •**			**0.142**	**55.18**
Sylvia melanocephala			-0.001 •	0.065	48.578	**-0.735**		**1.089 •**				**0.113**	**48.295**
Fringilidae													
Carduelis chloris	-0.319			0.051	46.741		0.714	1.358 ★			-2.829 ★	0.258	41.4
Serinus serinus				0	33.395	1.129						0.073	33.089

Groups of bird species with similar ecology and habitat requirements tended to share environmental variables selected in their models. Within the reed passerines found in the study area, the Reed warbler (*Acrocephalus scirpaceus*) is the most closely associated to wetlands and its probability of occurrence increases with higher development of both dead and live reeds (height, diameter and basal area) and the density of reeds inside the channels. For this species it is also possible to construct a significant model with vegetation height or vegetation cover variables, but these alternative models are clearly worse than the lowest AIC model, which suggests that specific characteristics of reed vegetation play a role in the habitat selection of the Reed warbler within channels. The Cetti's warbler (*Cettia cetti*) is not so much a reed specialist and the best model for this species includes a gradient of vegetation cover that ranges from concrete-paved ground and low grasses (negative side) to reed cover (positive). The next models in AIC explain clearly less variance but are also significant and they include channel material, with greater presence of this species in concrete channels, or a positive association with reed development. Thus this species appears where vegetation cover around channels is high and this situation is attained mainly when reeds are well developed.

In the case of waterbirds, habitat selection is more varied and models differ more among species. The best model for Moorhen (*Gallinula chloropus*) includes variables from the surrounding area, which is a bit surprising at first glance. According to this model, the probability of occurrence of this species increases with cover of tree orchards (palm and pomegranate trees) and decreases with reed cover and vegetable farming. A model of slightly lower significance may be constructed with a negative relationship to cover of herbaceous farming (including vegetables) for this species. Thus, short crop farming around channels negatively affects its use by the Moorhen, while at least some types of tree farming favour the species. During the study Moorhens were observed many times walking and looking for food in tree farms close to the channels, where they may get invertebrates in the wet ground or fallen fruits.

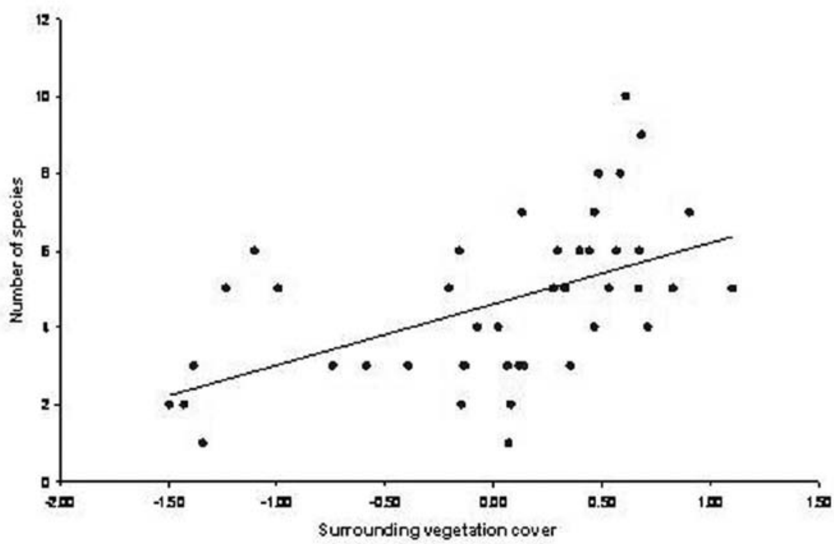
Four species of herons used the channels frequently enough to be modelled, but the variables influencing their use differed among species. Little egret (*Egretta garzetta*) and Squacco heron (*Ardeola ralloides*) preferred channels with low halophyte woody formations, well developed herbaceous formations and narrow channels. Except Black-crowned night-herons (*Nycticorax nycticorax*), that preferred reed formations (the only species occurring in reed taller than 2 meters) as well as vegetation of 0.3 to 1m height. In this study, Purple Heron (*Ardea purpurea*) preferred low deep, narrow channels with low vegetation, built in the ground that are distant to wetlands, due to their ability for long movements in search of food.

Some generalist species, widely distributed in many habitats, were found using the channels, i.e. Serin (*Serinus serinus*) and Blackbird (*Turdus merula*). These use irrigation channels as a complementary habitat, as demonstrated in the models by the fact that they were influenced only by surrounding variables.

Community models

Models for species richness are shown in Table 5. Two alternative models with identical percentages of variance explained may be fitted to our data. In one of these models species richness related positively to tree farming and reeds, and negatively to herbaceous farming, low grasses and concrete pavement of channels (Fig. 2). In the other model, species richness related positively to reed development and reed density inside the channels (Fig. 3).

Figure 2. Relation between species richness and surrounding habitat type (ranging from herbaceous crops to tree farming) represented by composite variable VC3. N=45.



Models for total abundance are shown in Table 6. The model with variables related to the area surrounding channels was the best one. Reed formations and pomegranate farming were the most influential environments. Roads and herbaceous crops had a negative influence on total bird abundance. The highest performance model is shown in Figure 4.

Table 5. Linear regression models relating species richness to each set of variables independently. N=45; <0.1 n.s. (not significant), * <0.05, ** <0.01, *** <0.005, R^2: Explained variability percentage; AIC: Akaike Information Criterion of the final model. Models considered the best for a species (minimum AIC) are typed in bold. Models with difference AIC<2 with respect to the best model appear underlined.

Physical variables	Width	Building	Distance				R^2	AIC
							0	192.37
CA gradients	Axis1	Axis2	Axis3	Axis4	Axis5	Axis6	R^2	AIC
Surrounding area			0.224 *			-0.209	0.199	188.05
Vegetation height	0.292 ***						0.279	182.68
Vegetation cover	**0.174**		**0.375 *****				**0.366**	**181.07**
Reed development	**0.337 *****	**-0.115**					**0.365**	**181.10**

Figure 3. Relation between species richness and reed development (gradient of height of live reeds, diameter both of live and dead reeds, basal area both of live and dead reeds and symmetry degree of reed density between the two sides of the channel) represented by the composite variable RD1. N=45.

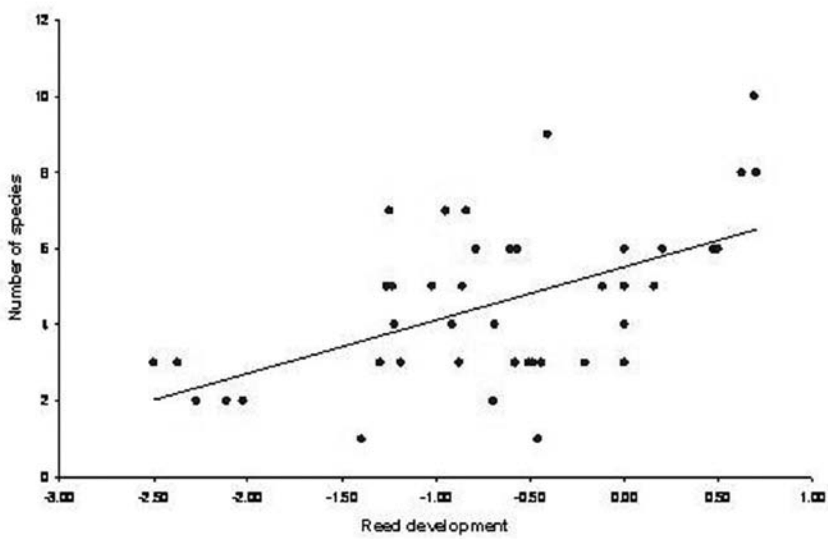
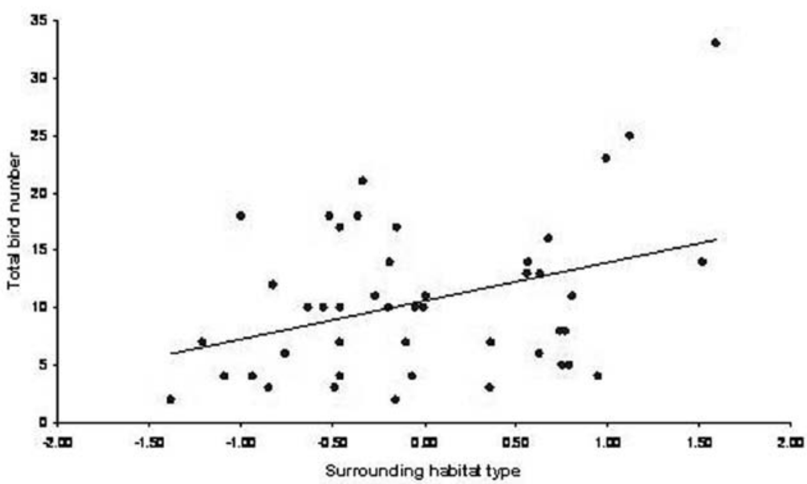


Table 6. Linear regression models relating total bird abundance to each set of variables independently. N=45; <0.1 n.s. (not significant), ★ <0.05, ★★ <0.01, ★★★ <0.005, R^2: Explained variability percentage; AIC: Akaike Information Criterion of the final model. Models considered the best for a species (minimum AIC) are typed in bold. Models with difference AIC<2 with respect to the best model appear underlined.

Physical variables	Width	Building	Distance				R^2	AIC
			-0.033 ★★				0.04	356.63
CA gradients	Axis1	Axis2	Axis3	Axis4	Axis5	Axis6	R^2	AIC
Surround-ing area	**0.001 •**		**0.006 ★★★**	**-0.001**		**-0.002 ★**	**0.349**	**307.27**
Vegetation height	0.003 ★★★	0.003 ★★	-0.002				0.157	339.64
Vegetation cover	0.001	-0.003 ★★★			-0.003 ★★	-0.003 ★	0.202	333.6
Reed de-velopment	0.003 ★★★						0.153	336.50

Figure 4. Relation between total bird abundance and surrounding habitat type (+ Ground irrigation channels and reed formations; - Grassy crops) represented by the composite SA3. N=45.



Discussion

The study collected enough data for the probability of bird species occurrence to be modelled in relation to the characteristics of irrigation channels for all bird species, and for some species several significant alternative models were identified. Thus, bird species use of the irrigation channels is affected by sets of channel variables which in turn depend on their management.

As would be expected, different groups of bird species use irrigation channels and respond to channel characteristics differently. Some reed and aquatic birds breed and live in channels while other species use wetlands as an expansion of their typical habitats in search of food. Channels are also used by generalist species in a temporary fashion.

The models identified the channel characteristics with strongest influence on bird species richness. As indicated by their equally high predictive power, two groups of variables are worth noting. On one hand variables related to reed development, including the presence of reeds within channels affected not only species richness, but also the presence of reed specialists such as the Reed warbler. Vegetation cover variables also had an important effect on species richness, where tree farming close to the channels influenced species richness positively while herbaceous farming tended to reduce it. Thus, bird species is not only influenced by the characteristics of typical wetland vegetation that colonizes channels, but also by the type of farming in their proximity. The most appropriate model for total bird abundance included variables characterizing the area surrounding the channels and the materials they are built in. The presence of channels built in the ground and reed formations favoured highest abundance.

In the study area, the diversity of managers and their management practices on channels and their associated vegetation confers a high landscape heterogeneity to the study area. This is accentuated by the important diversity of cropping patterns (herbaceous, arboreal, old fields, fallow land), the presence of salt marshes and different types of reed formations, as well as residential and farm buildings.

This study shows that recommendations for bird conservation to farmers and institutions managing irrigation channels and especially reed formations should be geared toward the specific habitat needs of groups of species. For the conservation of reed specialist species, a selective and staggered winter cut of reeds in irrigation channels is highly preferable to their complete removal on an annual basis, as it allows an appropriate development with different reed ages in the breeding season. For generalist bird species the maintenance of a heterogeneous landscape with tree and cereal crops, halophilous scrubs and reed formations could be the best conservation action.

Acknowledgements

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PARTICIPATORY ASSESSMENT OF FISH DIVERSITY AND GIS MAPPING OF WATER RESOURCES IN THE BAJO VINALOPÓ AND THE VEGA BAJA OF SEGURA RIVER

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Abstract: A participatory Geographical Information System on fish diversity at El Hondo study site has been developed incorporating the rich local knowledge on fish ecology and canal water quality. Local stakeholders, as depositaries of a long-time direct knowledge of the system, have provided important information, not easily obtainable otherwise, on fish populations and their dependence on local water conditions. The potentialities of GIS for integrating geographical data and the incorporation of both normal science and local traditional knowledge allow a richer understanding of this complex water systems and its associated fish fauna.

Introduction

The WADI project, funded by the European Commission, conducted a comparative analysis of the ecological and socio-cultural aspects of a number of Mediterranean wetlands, with a view to elaborating more sustainable scenarios for their future development. In Spain, the site chosen to conduct the study was the Nature Park of El Hondo of Elche-Crevillente and its catchment area, which covers a good portion of the water system in the southern region of Bajo Vinalopó and the district of Vega Baja del Segura.

One of the main objectives of this work was to offer a multidisciplinary view of an aspect of the site's management, based on dialogue with local stakeholders, and identifying possible areas of special relevance linked to the territory. The ecological knowledge of local fishing communities, including in freshwater or transition water bodies, has been reflected in numerous studies (Eythorson, 1993; Johannes, 2001; Baird, 2007), with several authors documenting spatial aspects associated with fish resource use problems (Flichman, 1997; Le Grusse *et al.*, 2006). For instance, Ibarra (1895) documented historical conflicts over the exploitation of fish resources in the study area, which was an important source of income (up to 10% of total revenue) for the lords of Elche.

There has been much interest concerning the biodiversity associated with irrigation channels. Translating biodiversity information into the optimum management of irrigation structures within their wider terri-

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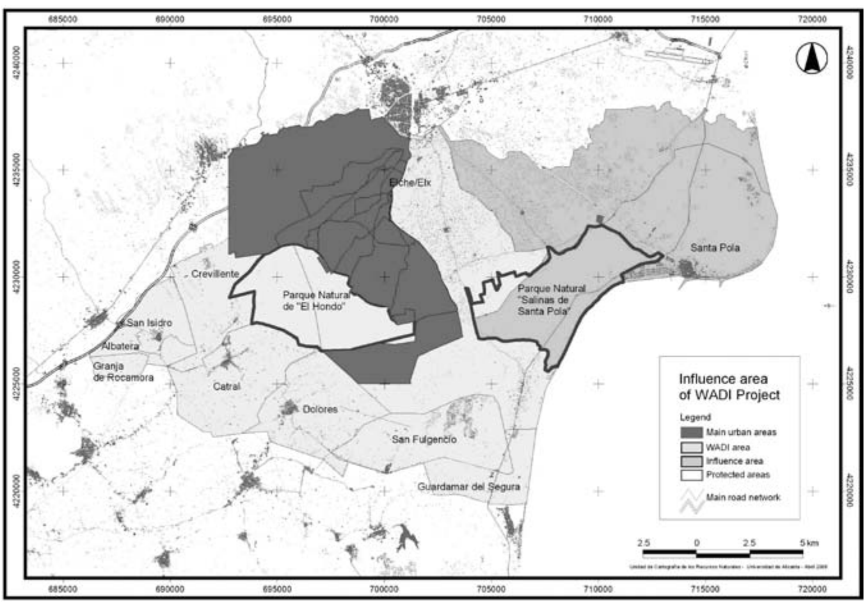
tory presents methodological challenges. This study intended to gather local knowledge related to fish diversity and traditional fishing methods and integrate it into its spatial context using a participatory GIS approach (McCall & Minang, 2005).

Study area

The study area is situated in the southern part of the geographical region known as the Bajo Vinalopó Region in its transition to the Bajo Segura, south of the province of Alicante and in the catchment area of the Nature Parks of El Hondo and the Salinas de Santa Pola, bound by UTM coordinates 30N: 667000, 4191000; 781000, 4321000.

Figure 1. Study area of WADI Project in Alicante Province (Spain).



The water system, which hosts the fish populations under study, is composed of an intricate network of man-made channels, ponds and reservoirs, and natural water bodies which have been profoundly changed by man. In the area leading to the Vinalopó and Segura rivers, the operation of the water system is made possible only through a high degree of human intervention. Remarkable energy levels are required, both for pumping water that feed certain portions of the system, as well as for the continued care that the extensive series of dams and canals require. This area of high ecological value is suffering severe degradation processes that seriously threaten its future, in addition to being one of the areas of greatest social conflict on the Iberian Peninsula.

The ombrotype of the study area is semiarid Mediterranean (Rivas-Martínez, 1983), with an average annual temperature of 18 °C, presenting two distinct periods, with strong rainfall in the autumn-winter season and very dry weather in summer, with average annual rainfall of 350 mm. The index indicates that within the thermal bioclimates of the xeric Mediterranean ocean, this area belongs to the Thermo-Mediterranean thermotype (Pérez, 1994).

Methodology

For the construction of the GIS database, we used the 2000 year cartographic base of the Valencian Cartographic Institute (ICV), focusing on the layer linked to the water network and water bodies. Toponymic information provided by informants was incorporated in this layer to reflect current field realities. Another key image, also from the ICV, is the orthoimage mosaic covering the study area. Water sampling points (n=22) were randomly selected as a representative sample of the network of channels and ponds in the study area (Figures 2 and 3). For each water sample, a measurement of conductivity, as an indicator of water salinity, was taken directly in the field using a portable conductivity meter, CON 110, Eutech Instruments ®, to avoid any disruption that may occur by transport of samples. Water sampling points were geo-referenced using Trimble GPS ® and subsequently exported to ArcView ® format (*. shp).

Figure 2. Sampling points in the study area.

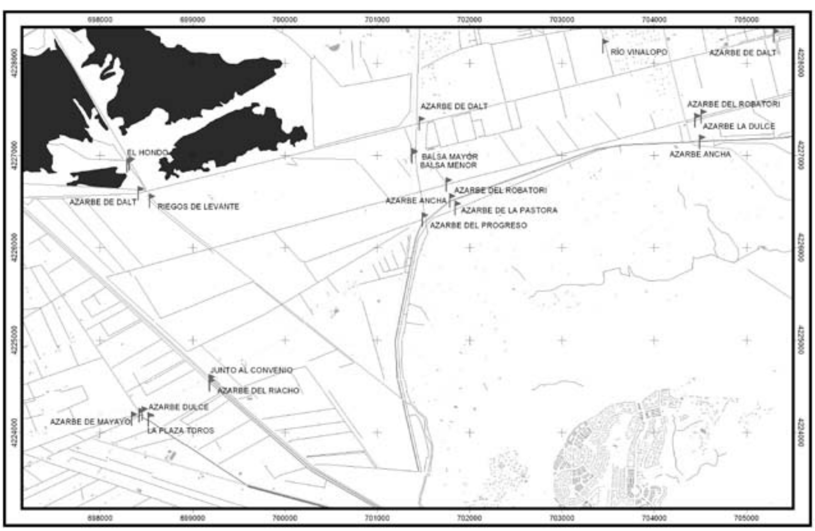
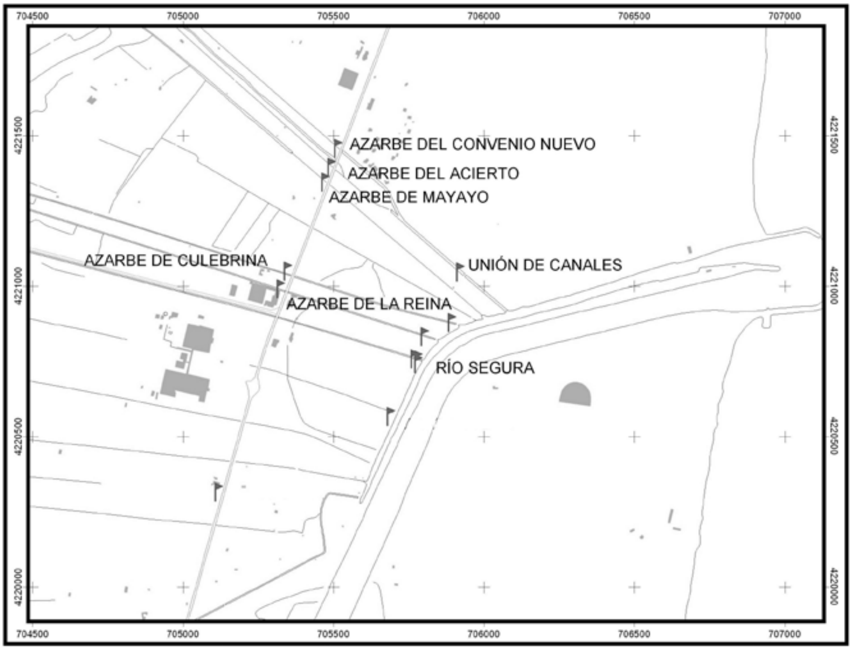


Figure 3. Sampling points in the Segura River mouth.



In order to obtain information regarding the names of the network of canals and biodiversity associated with them, we conducted a series of interviews (n = 48). These interviews were semi-structured based on a number of key points relating to different types of fishing, the season of the year in which different methods are used, species caught, problems, etc. The information gathered in interviews was also contrasted with field observations, through an approach considered close to participant observation (Guasch, 1997). The open nature of semi-structured interviews made it possible to discover several important issues not previously identified. Thus, during days of field work researchers accompanied fishermen in their jobs, and participated in the preparation of materials, catching and processing of fish and in a range of dining and recreational activities and social relationships that are related to these tasks.

People consulted, considered as local experts were characterized by their long association with the rural environment and rural practices or who have practised fishing throughout their lives. They included farmers, members of the local community of irrigators, pond owners of different social classes, Spanish and Valencian-speaking informants. Historically, this activity has been linked to male gender. So, we only interviewed people from this gender group.

Figure 4. La Balanza. Traditional fishing local method.

Results and Discussion

The most important results obtained from the study, with a differentiation between the system of canals and azarbes (n = 16) and the system of ponds and reservoirs (n = 6) are presented in Tables 1 and 2.

Table 1. Water quality and diversity of fish in the channels and *azarbes* of the Bajo Vinalopó-Vega Baja Region.

Point	Conductivity (mS/cm)	TDS (ppt)	Species	Richness
Azarbe Ancha	13.98	7.88	*Anguilla anguilla* *Aphanius iberus* *Cyprinus carpio* *Mugil cephalus* *Mugil ramada* *Mugil auratus* *Sparus aurata*	7
Azarbe de Dalt	11.60	5.83	*Atherina boyeri* *Cyprinus carpio* *Mugil cephalus*	3
Azarbe del Acierto	10.15	5.10	*Anguilla anguilla* *Cyprinus carpio* *Mugil cephalus*	3
Azarbe del Convenio	13.92	6.94	*Anguilla anguilla* *Aphanius iberus* *Atherina boyeri* *Cyprinus carpio* *Mugil cephalus* *Mugil ramada* *Mugil auratus*	7

Point	Conductivity (mS/cm)	TDS (ppt)	Species	Richness
Azarbe del Mayayo	5.20	2.63	*Anguilla anguilla* *Cyprinus carpio* *Mugil cephalus*	3
Azarbe del Riacho	7.78	3.85	*Anguilla anguilla* *Cyprinus carpio* *Mugil cephalus*	3
Azarbe del Robatori	12.80	6.35	*Anguilla anguilla* *Aphanius iberus* *Cyprinus carpio* *Dicentrarchus labrax* *Mugil cephalus* *Mugil ramada* *Mugil auratus* *Sparus aurata*	8
Azarbe Dulce	5.34	2.65	*Carassius auratus* *Cyprinus carpio* *Mugil cephalus*	3
Azarbe La Culebrina	8.60	4.27	*Anguilla anguilla* *Atherina boyeri* *Cyprinus carpio* *Mugil cephalus*	4
Azarbe La Pastora	14.80	7.43	*Anguilla anguilla* *Mugil cephalus*	2
Azarbe La Reina	6.49	3.26	*Anguilla anguilla* *Mugil cephalus*	2
Canal del Progreso	8.26	4.16	*Anguilla anguilla* *Cyprinus carpio* *Mugil cephalus* *Mugil auratus*	4
Canal de Levante	6.38	3.4	*Anguilla anguilla* *Cyprinus carpio* *Mugil cephalus*	3
Mayayo (Plaza toros)	5.30	2.67	*Anguilla anguilla* *Mugil cephalus*	2
Río Segura	5.59	2.79	*Anguilla anguilla* *Barbus sclateri* *Cyprinus carpio* *Dicentrarchus labrax* *Gambusia holbrooki* *Mugil cephalus* *Mugil auratus* *Micropterus salmoides* *Oedalechilus labeo* *Pomatoschistus microps* *Syngnathus abaster* *Sparus aurata*	12

Point	Conductivity (mS/cm)	TDS (ppt)	Species	Richness
Río Vinalopó	13.49	6.67	*Anguilla anguilla* *Carassius auratus* *Cyprinus carpio* *Gambusia holbrooki* *Mugil cephalus* *Micropterus salmoides*	7

Table 2. Water quality and diversity of fish in the ponds and reservoirs of the Bajo Vinalopó-Vega Baja Region.

Point	Conductivity (mS/cm)	TDS (ppt)	Species	Richness
Balsa mayor Sivaes	8.42	4.16	*Anguilla anguilla* *Carassius auratus* *Cyprinus carpio* *Mugil cephalus* *Mugil auratus*	5
Balsa menor Sivaes	8.21	4.10	*Anguilla anguilla* *Carassius auratus* *Cyprinus carpio* *Mugil cephalus* *Mugil auratus*	5
El Charcol norte	17.78	10.90	*Anguilla anguilla* *Chelon labrosus* *Gambusia holbrooki* *Mugil cephalus* *Mugil auratus* *Sparus aurata*	6
El Charcol sur	21.70	8.91	*Anguilla anguilla* *Chelon labrosus* *Gambusia holbrooki* *Mugil cephalus* *Mugil auratus* *Sparus aurata*	6
El Hondo (Levante)	18.96	9.54	*Anguilla anguilla* *Aphanius iberus* *Atherina boyeri* *Cyprinus carpio* *Gambusia holbrooki* *Mugil cephalus* *Mugil auratus*	7
Hondo (Poniente)	16.22	8.07	*Anguilla anguilla* *Aphanius iberus* *Cyprinus carpio* *Gambusia holbrooki* *Mugil cephalus* *Mugil auratus*	6

Salt concentration is higher in the ponds sampled (15.22 ± 5.63 mS / cm) than in the channels (9.66 ± 3.82 mS / cm). These results agree with local knowledge and influence the abundance and distribution of the ichthyofauna. With the highest conductivity values (21.70 mS / cm) in the area of Bajo Vinalopó, ponds have an average conductivity value of 10.74 ± 4.68 mS / cm. This is however lower than those *azarbes* at the mouth of the Segura River (12.90 ± 4.98 mS / cm), because of the leaching of nutrients from surrounding agricultural fields. However, the low water quality in channels may be synonymous with a high fish abundance, especially for mullet and eel.

Some channels appear to have been maintained over time as a source of supply of fish resources. The *azarbes Ancha*, *Convenio* and *Robatorio*, north of the study area in the vicinity of El Hondo Natural Park, show a higher quality for fishing due to a greater regularity in water flow and saline concentrations. In contrast, *Dulce* and *de Dalt*, which are *azarbes* for irrigation, show greater irregularity in the concentration of salts, due to the rainfall and water regulation to which they are subjected, and therefore have fewer resources available, which translates, according to informants, into lower fish abundance.

The system of *azarbes*, which reaches the final stretch of the Segura River, and management measures applied are key determinants of the physical and chemical characteristics of water. Depending on the nature of the land and measures employed there will be a higher or lower concentration of salts and nutrients, turbidity of the water, and so on. This is the case of *azarbes* of *Mayayo* and *Culebrina* which present, according to users, a greater amount of mud and hence higher turbidity. This together with lower salinity, results in lower water quality for species prized for fishing in the area.

The Segura River presents the highest fish richness (12 fish species), because it is a transitional zone between freshwater and the sea buffer area, and thus hosts species typical of both environments. *Azarbes* generally present low richness values because of pollution and loss of water flow, which are responsible for eutrophication processes whereby channels gradually age and provide higher productivity to the algae group. These algal blooms lead to oxygen depletion and result in fish mortality. Many native fish species have disappeared and been replaced by species more resistant to the new conditions, especially species of the Cyprinidae Family.

Conclusions

Local stakeholders provide important reservoirs of authentic information because they are experts about fish populations, their distribution and temporal trends as well as appropriate ways to manage local hydrological infrastructures. Complementary historical documents show local actors have inherited knowledge through generations which have witnessed a great deal of environmental exploitation and management practices. Awareness of local fish resources and their traditional use as feed is high among local users. For this reason, residents and users of the system have been critical to the maintenance and transmission of this rich cultural heritage, which would have otherwise fallen into oblivion.

GIS used to represent geographical, biological and ethnological characteristics of local water resources are a valuable tool for the development of management strategies related to the conservation of the freshwater and transitional water bodies and surrounding landscapes and to maintain their cultural diversity. GIS also enables the incorporation of names of places, thus providing a means of identifying and locating areas which would otherwise be difficult to study.

Finally, species diversity is greater in the system of canals and *azarbes* that in the system of ponds and reservoirs. Being the collector for the network of *azarbes*, the main channel of the River Segura presents the highest values of biodiversity. The intensification of agricultural uses in the surrounding zone of this network has a direct impact on the quality and availability of water and, therefore, on the diversity of fish fauna.

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LOCAL KNOWLEDGE ASSESSMENT OF FISH DIVERSITY AND TRADITIONAL FISHING METHODS IN IRRIGATED SYSTEMS IN THE BAJO VINALOPÓ REGION, SOUTHEASTERN SPAIN

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Abstract: The aim of this paper is to obtain a comprehensive picture of the importance of the fish fauna in the wetlands and coastal lagoons of the Bajo Vinalopó region (Alicante) and the ecological, historical and cultural value of the traditional knowledge on fishing maintained by local people. We have compiled data from different information sources: (1) the revision of historical archives, (2) personal interviews and collaborative research, and (3) ecological and water quality data. The results show that the area sustains important fish fauna diversity (17 species) and that local people have inherited a considerable traditional knowledge on fishing methods (11 modalities), on the maintenance and sound management of the water system and on the ecology and behaviour of fish. We conclude that a comprehensive consideration of all these ecological, historical and socio-cultural aspects related to fish and fishing shows clearly the value of this ecological and cultural heritage and provides a necessary base for a sustainable management of the area.

Introduction

In the last decades, some authors (Huntington, 2000; Berkes *et al.*, 2000; Reyes-García & Martí Sanz, 2007) have emphasized the importance of human knowledge to ecologists, with a focus on Local Ecological Knowledge (LEK) or Traditional Ecological Knowledge (TEK), and in general, on Indigenous Knowledge (IK).

There have been many studies on the value of ecological knowledge of local fishing communities, including the relation to freshwater or transitional water bodies (Eythorson, 1993; Johannes, 2001; Baird, 2007). Several communities are dependent on the dynamics of aquatic resources, and as a result of their experience, have accumulated a wealth of knowledge which is of great value to formal investigation. In Spain, this combination of scientific research, information gathering and ethnological research is well established, since the classical studies of Gandolfi (1916) or, especially, Pardo (1942; 1945) to another more recent Docavo-

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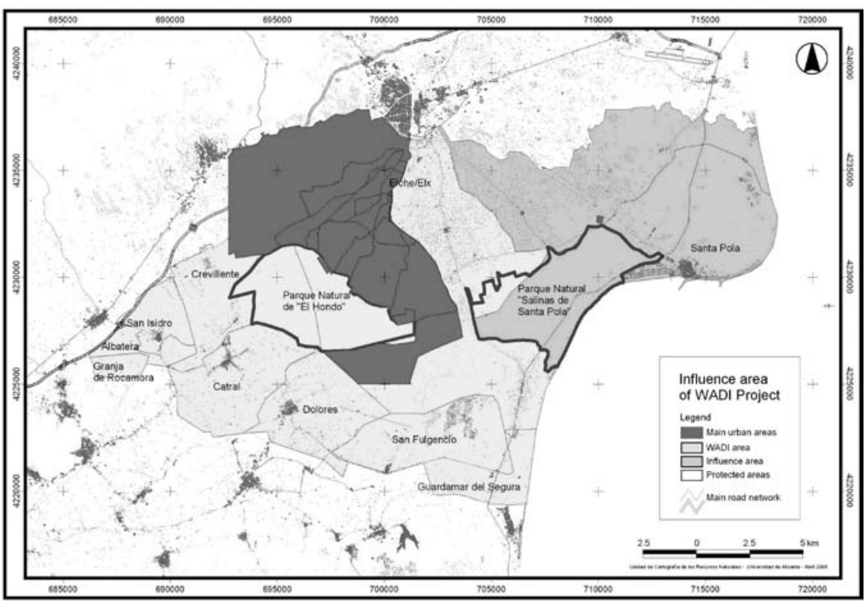
Alberti (1979) and Mas (1986) studies, with the latter basing his work on the consultation of numerous local historical sources.

The main goal of this study is to evaluate fish diversity and local fishing methods in the traditional irrigated systems used in SE Spain, which has a high environmental and cultural value. We have compiled data from different information sources: (1) historical archives, bibliography and grey literature, (2) ethnological knowledge, obtained through personal interviews and collaborative research, and (3) ecological and water quality data, obtained in the field through standard measurement methods.

Study area

This study was carried out in Southeastern Spain, specifically, in the Bajo Vinalopó region, which is situated in the Alicante province (UTM 30N: 667000, 4191000; 781000, 4321000).

Figure 1. Influence area of WADI Project in Spain (El Hondo and Salinas de Santa Pola Natural Parks).



The hydrological system, object of this study, is composed of a complex of irrigation ditches, channels, ponds and dams, characterized by a high level of human intervention. The zone includes two Natural Parks (El Hondo and Salinas of Santa Pola), with important environmental and landscape values.

Traditionally, the region has been dedicated to irrigated groves and industrial activities. On the other hand, it is characterized by a semiarid and dry Mediterranean climate, with an average annual temperature of 18 °C and annual rainfall lower than 350 mm.

Methods

The methodology and results, concerning information related to fish and traditional fishing methods, are structured in three distinct sections depending on the source of the data obtained:

a) Historical and documentary analysis

First, the historical and documentary analysis focused on the review of any historical documentation that made some reference to fishing in the area, including both ancient sources as well as recent historical studies, in order to provide data relevant to understanding the historic role of fishing. Secondly, we carried out direct consultation of documentary funds relating to fisheries and management of wetlands preserved in the historical archives of the area, especially the AHE (Historical Archives of Elche), the Archives of Notary Protocols of Dolores and the archives of the local community irrigation managers, particularly Carrizales in Elche.

We have studied documentation such as administrative regulations and management plans, as well as reports of activities of the Park and plans for fishing in private farms. The review also included some of the scientific reports, published and unpublished, that are related to wildlife and fish from this area. Finally, the review also included an analysis of the portrayal of the conflict offered by the media, both in recent press and further in the past.

b) Traditional knowledge

Whilst the value of recording traditional ecological knowledge is recognized, collection of data presents a series of methodological problems which have not always been given due attention. The significance and relevance of the data obtained can only be assured through rigorous design (Davis & Wagner, 2003). It is necessary to follow the media in order to identify the "local experts" because these informants are the basis of the LEK research.

People consulted (n = 48), considered as local experts (seniors), were characterized by their long union to the rural environment and rural practices (farmers, irrigation managers, shepherds, pond owners, etc) or who have practised fishing throughout their lives. It is not possible establish categories due to small population size which practicing this activity. Historically, this activity has been linked to male gender. So, we have only interviewed people about this gender. In our case, the relations of trust built with communities of irrigation managers (mainly Carrizales, El Progreso and Riegos de Levante) were instrumental in carrying out this research.

The semi-structured interviews addressed a number of key points relating to different fishing tackles, the season of the year in which they are used, types of captured species, the problems, etc. The information gathered in interviews was also contrasted with field observations, through what can be considered close to participant observation (Guasch, 1997). Thus, during days of field work researchers accompanied fishermen in their jobs, and participated in the preparation of materials, catching, processing of fish and in a range of dining and recreational activities and social relationships that are related to these tasks.

c) Scientific monitoring

The study of water electrical conductivity (EC) in different environments is a parameter that expresses the total concentration of soluble salts in irrigation water and provides an indication of water quality. We also calculated the value of total dissolved solids (TDS) as well as water temperature, which affect this concentration. Random points were selected and geographically located in the network of channels and ponds as a representative sample of the study area, allowing time analysis of sampling points ($n = 31$). Measurements were taken directly in the field using a portable conductivity meter, CON 110, Eutech Instruments ®, to avoid any disruption that may occur by transport of samples. Moreover, points at which water samples were taken were geo-referenced using Trimble GPS ® and subsequently exported to ArcView ® format (*. shp).

Excel 2003 ® was used to conduct a basic analysis of the data and to enable an evaluation of the frequency of usage of different fishing types and to estimate the most popular fish species.

Results and Discussion

The historical documents show the considerable fish richness in the ancient lagoon (Albufera) of Elche since Middle Ages. Some authors describe this area like a place with an important abundance of fish (Escolano, 1611; Sanz, 1621) and high species diversity (Esquerdo, 2002). According to a document from March 1st, 1802, the mullet of the lagoon was considered of higher quality than those captured on the beach (Ramos-Falqués, 1973).

The information reveals the historical conflicts over the exploitation of fishery resources in the area, because the fishing was a major source of income of the lords of Elche, reaching 10% of total revenues of the lordship (Ibarra, 1895). In later centuries the percentage will not be as high but will be important.

Besides the historical significance of the fishery also shows off its significance in the landscape structure, because it should remain an important and regular flow of fresh water from the Segura River, been the only water resource in the area. The lords strove to maintain a channel of fresh water into the lagoon over the opposition of the neighbours of irrigated areas of Guardamar and Orihuela (Escolano, 1661).

The need to eliminate health problems associated with water in the catchment area of the old lagoon triggered a series of conflicts that confront the health of the area and the exploitation of the fishery resource (Alonso, 1950; Canales-Martínez & Vera-Rebollo, 1985; Gil-Orcines & Canales-Martínez, 1987).

The fishery remained important in the irrigation channels and azarbes integrated in the new landscape resulting from drain lands and agricultural colonization of the eighteenth century. Many documents from the eighteenth and nineteenth centuries refer disputes between farmers and fishing tenants. The *azarbes* were leased by the Irrigation Managers Communities for fishing using traditional methods in exchange for money or payment in kind. This arrangement was in force until 1965 (Belda et al., 2008).

Two elements are to make the situation more complex during the twentieth century. On the one hand, the private irrigation companies that take remaining water from the Segura River or the drainage of irrigated areas to supply the Campo de Elche. This action favours the creation of new water bodies on the landscape, ecologically connected with the Segura hydrological system, standing out the construction of reservoirs of El Hondo. In fact, the companies exploited the fishery resources, both in reservoirs and canals, producing conflicts between administration and local people (Sansano, 2000).

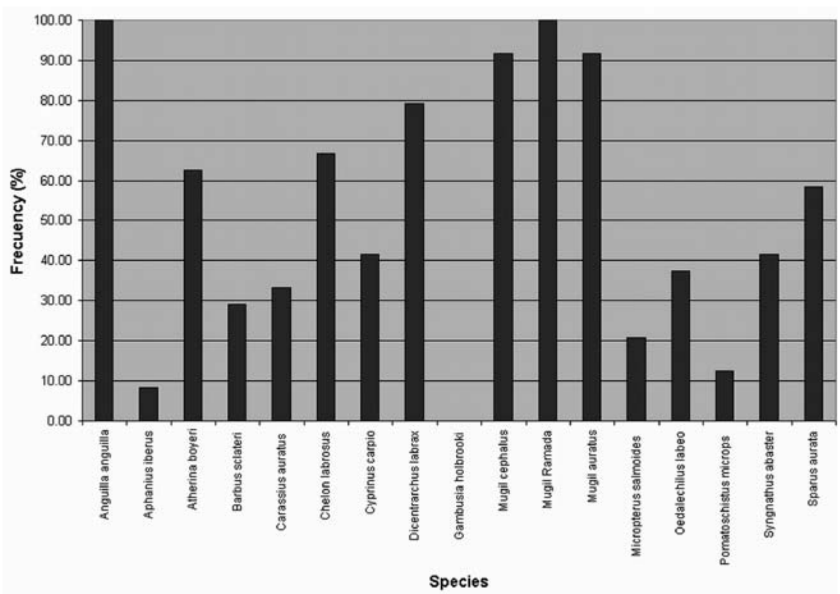
In 1980, a new factor appeared with profound implications: the conservationism. The ecological richness will wake an increasing interest in the zone from birdwatchers and conservation groups, until finally, in 1988, the area is declared a Natural Site, and subsequently Natural Park in 1994.

It is significant that the regulations of the Park prohibit the use of all types of traditional fishing methods because they restrict the "sport fishing" in ditches and channels. In the fishing preserves is necessary the approval by the Fishing Management Plan. This will generate a series of conflicts with frequent importance in the media.

The review of environmental documentation shows limited scientific studies on fish and fisheries. A local LIFE Program includes a conservation plan to preserve interesting indigenous species such as *Aphanius Iberus* and *Valencia hispanica* (Torralva *et al.* 2002).

The area sustains an important fish fauna diversity (17 species) and local people have inherited a considerable traditional knowledge on fishing methods (11 modalities), on the maintenance and sound management of the water system and on the ecology and behaviour of fish. The frequency of awareness refers to the number of citations that have been recorded, for each fish species and capture method, for all the interviews (Fig. 2). In an indirect way, this provides crucial information on the diversity of fishes and techniques in the study area.

Figure 2. Frequency of fish species in the Bajo Vinalopó irrigated network.



The frequency of use refers to the number of citations that have been recorded for each of the traditional fishing methods and fish species, for all interviews (n = 48) (Fig. 3). In an indirect way, this provides interesting data on the socio-cultural heritage and traditional use of natural resources.

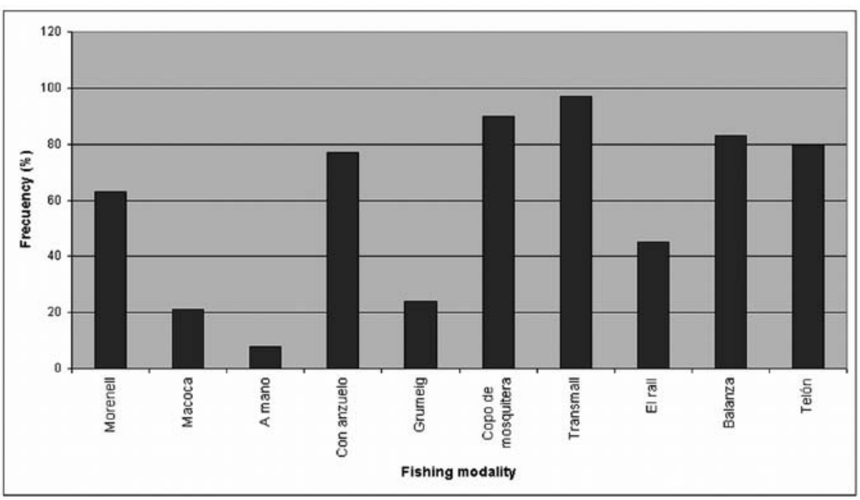
The data collected has allowed to know the changes in the fish community produced in recent decades. Compared with the data presented by Mas (1986) on the number of species of freshwater fish mostly in the Segura River, according to data derived from the study, has increased significantly (9 species recognized in 1986) and are similar to those presented by Andreu-Soler in 2006 (18 species recorded) and Oliva-Paterna in 2007 (16 species recorded).

Table 1 provides values for water samples taken in a total of 31 points in *azarbes* network and water ponds, which characterize the study area. Salt concentration of water in ponds sampled is much higher (15.22 ± 5.63 mS/cm) than in sampled channels (9.66 ± 3.82 mS/cm), which is coincident with the opinions of local informants.

Table 1. water quality in the irrigation channels of Bajo Vinalopó. In this table the (*) symbol identify pond elements in the irrigation network.

Local name	Conductivity (mS/cm)	TDS (ppt)	Temperature (°C)
Azarbe de Acierto	10.15	5.10	26.4
Azarbe de la Ancha	13.98	6.96	25.2
Balsa mayor Sivaes (*)	8.42	4.16	24.2
Balsa menor Sivaes (*)	8.21	4.10	24.6
Azarbe del Convenio	13.92	6.94	23.9
Azarbe de la Culebrina	8.60	4.27	26.1
Azarbe de Dalt	11.60	5.80	24.2
El Charcol (*)	21.70	10.90	19.7
El Hondo (*)	18.96	9.54	26.4
Azarbe la Dulce	5.34	2.65	21.8
Azarbe la Pastora	14.80	7.43	25.5
Azarbe la Reina	6.49	3.26	25.5
Levante (*)	6.38	3.15	23.5
Azarbe del Mayayo	5.20	2.63	22.9
Azarbe del Mayayo	5.28	2.61	22.6
Plaza de Toros	5.30	2.67	21.8
Azarbe del Progreso	8.26	4.16	23.4
Azarbe del Riacho	7.78	3.85	23.4
Segura River	5.59	2.79	25.8
Azarbe del Robatorio	12.80	6.35	24.5
Vinalopó River	13.49	6.67	24.7

Figure 3. Traditional fishing methods in the Bajo Vinalopó irrigated network.



Based on the data obtained, we have detected a total of 17 species of fish, either in the field samplings either by the information provided by informants. Of the total 15 species of them (88.23%) currently consumed or are consumed at any time by fishermen in the area. Thus, all species, the ones that has not been used for cooking by such informants are *gambusia* and *fartet*.

Thus, the richness of traditional fishing techniques (11 modalities), and popular knowledge about fish and their exploitation, are the legacy of the long historical relationship between humans and biological resources from the marsh. For their popularity are among these modalities, the *transmall* (95.83%), *telón* (91.67%) and *balanza* (83.33%). By contrast, probably due to the difficulty, the type of fishing "by hand" (a mano) is the lowest among the fans informants interviewed (8.33%).

Conclusions

The historical analysis provides important insights on the antiquity of the practice of fishing in the area and its historical importance for the configuration of present landscape, on the historical transformations of fishing rights and conflicts (including conflicts with recent conservation decisions), and on the present decline of fish fauna and local fishing culture. We conclude that a comprehensive consideration of all these ecological, historical and socio-cultural aspects related to fish and fishing shows clearly the value of this ecological and cultural heritage and provides a necessary base for sustainable management of the area.

In order to establish new management plans, according to ecological values in the study area, the local ecological knowledge on the wealth of the fish fauna is very important. By the other hand, stakeholders are the role of authentic information reservoirs because they are experts about the fish populations, fish distributions, temporal evolution and the best form to manage the hydrological infrastructures. Complementary, historical documents show this local knowledge as an inheritance of some centuries of environmental exploitation and modulation. By this reason, the knowledge of stakeholders needs to be captured now; when these people die, local ecologic knowledge disappears.

The knowledge of stakeholders shows that mullet and eel have the most popularity into local fisheries. In respects to fish methods, the *transmall*, *telón* and *balanza* are the usually used by the fishermen. It is necessary to remember the role of stakeholders as key piece in order to conserve the ethnological heritage.

Management plans have to consider these patrimonial values in order to design the best exploitation strategies. So, fishing could be an economic resource that would help to promote new tourism and educational strategies in the study area. However, we must bear in mind the importance that decision makers have gotten in the History, contributing to modulation of the south part of Alicante Province. Traditional management should be a strategic tool to guarantee sustainable exploitation and to conserve threatened species.

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EFFECTS OF ABANDONMENT OF AGRICULTURE AND SOIL SALINIZATION ON ARTHROPOD FAUNA IN EL HONDO AREA (SOUTH-EAST SPAIN)

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Abstract: Agricultural land abandonment and the related process of soil salinization are among the most important contemporary changes affecting the coastal landscape of El Hondo study site, with important social and environmental management consequences. This paper presents preliminary data from a comparative study on the arthropod communities inhabiting several types of cropped and abandoned fields with different soil conductivity levels. Seemingly, field abandonment and subsequent soil salinization usually cause a marked decline in arthropod abundance, species richness and diversity, almost at first recolonization stages. Cicindellids, with halophilous habits in study area, appear as the best bioindicators of soil salinization. High landscape heterogeneity between crops and natural formations favour the increase of biodiversity, due to there are several arthropod groups specific of particular habitats.

Introduction

The present El Hondo landscape is the result of centuries of human transformation, consisting mostly of extending irrigated agricultural activities on former natural saltmarshes and halophilous scrub formations (*saladar*). This historical tendency towards a decrease in edaphic salinity due to the application of traditional soil management and irrigation techniques is nowadays being reversed due to the decline of agricultural activity. Complex circumstances (socioeconomic changes, and the quantitative and qualitative decline of available irrigation water) are causing abandonment of agriculture and a return of cultivated lands to spontaneous halophilous vegetation. Additionally, the present management of the remaining cultivated fields that consists in irrigating with poor-quality, brackish water and using chemical fertilizers, also increases soil salinity in many cultivated lands.

Following the declaration of the Hondo Natural Park, the return of cultivated land to halophilous scrub (*saladar*) ecosystems has been promoted by the environmental administration. Several management decisions favoring the extension of mediterranean halophytic shrubs (Sarcocornetea fructicosae, 1420, Habitat Directive, 92/43/CEE) at the expense of agricultural land have already been implemented. The clearing and breaking up of uncultivated land is prohibited by the Management Plan of the Natural Park of 1994, also in the surroundings of the protected area by other regulations, for example the Decree 60/2003 for the ordination of the peripheral area of the Natural Park. The problem is the definition of "uncultivated land": land

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not cultivated at the moment of the approval of the Management Plan (i.e., in 1994). The conflict arises because many areas considered "uncultivated" have been cultivated previously, in some cases during centuries, although they were left set aside during several years for several reasons and were colonized by halophilous formations. Due to the application of the above mentioned regulations, some farmers have been fined when they have tried to put in cultivation again these lands, so generating a very conflictive situation.

Also the draft of the new Management Plan presented in 2006 endorses the same restrictions, although some breaking up could be allowed, under special circumstances, when authorised by the Environmental Administration.

Is really beneficial from an ecological point of view this policy promoting the set aside of cultivated lands, and the extension of halophilous scrubs at the expense of cultivated fields?

Here we briefly expose preliminary results of a study to assess the environmental consequences of these recent land use changes, using terrestrial arthropods as bioindicators of salinity levels in different types of cropped and abandoned fields (Duelli & Obrist, 2003; Gobbi & Fontanero, 2008; Jeanneret *et al.*, 2003).

In this paper our objectives are 1) to compare total arthropod abundance and species richness in different types of cropped and abandoned fields, and 2) to evaluate the effect of salinity on several selected bioindicators.

Materials and methods

Study area

Located in a humid zone of Alicante (Southeast of Spain), between two important wetlands, Hondo Nature Park and Salinas de Santa Pola Natural Park, the study area lies within the coordinates NW X:704351, Y:4227343; SW X:704403, Y:4227153; NE X:704961, Y:4227509; and SE X:705004, Y4227269.

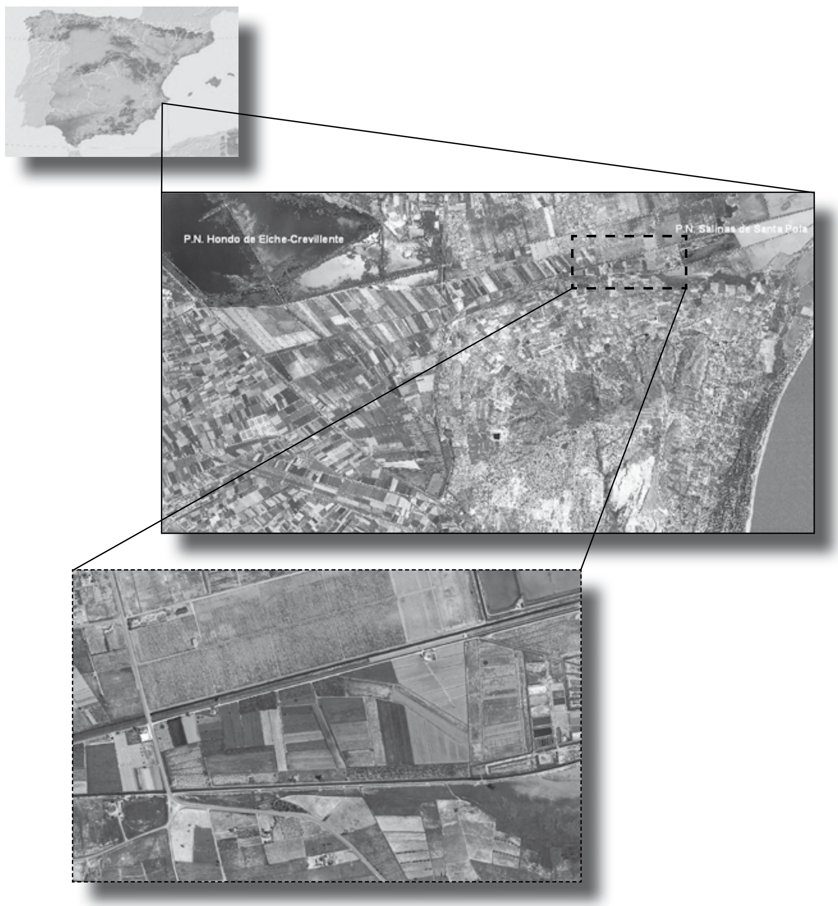
Currently, it is an area with intensive irrigated agriculture in an heterogeneous landscape where various agricultural land uses are associated with saltmarshes and reed formations. The main current crops are herbaceal crops as artichoke, broad beans and melon; cereal crops as avena; and arboreal crops as palm tree and pomegranate.

Sampling points were chosen in a closed area, where a group of the most traditional crops and some abandoned fields are delimited and separated by field margins in agriculture patched zone. In order to represent contrasted habitats, the following sampling points were selected by their different vegetation estructure and management conditions:

- Salty habitat (*saladar*): Old cultivated field abandoned 8 years ago, now occupied by colonizing vegetation of halophilous scrub dominated by *Suaeda vera* and *Sarcocornia fruticosa* (Chenopodiaceae).

- Palm tree plantation: Arboreal system, with annual herbaceous vegetation; no chemical spraying; summer irrigation.
- Artichoke crop: Low cover herbaceous vegetation, with chemical spraying every 2-3 weeks, and irrigation every two weeks. Fertilization in autumn.
- Oat cereal crop: 100% cover of herbaceous vegetation. Land worked before cultivation; irrigation twice a year. No chemical spraying.
- Pomegranate grove: Arboreal system, without herbaceous vegetation (chemical spraying 4-5 times a year), irrigated once in February (for sprouting) and every two weeks during summer.

Figure 1. Study area map. Points are the sampled fields. Source: Unidad de Cartografía de los Recursos Naturales – U.A. Instituto Cartográfico Valenciano.



Sampling method

In each of the 5 sampling points, 5 pitfall traps (11cm diameter and 17cm high, filled with 3cm of salt water) were used in the shape of a cross, with 1m between traps. Pitfall traps were collected and inspected weekly during 6 weeks, during the Spring (April-June) 2008. All trapped individuals were counted and identified to morphospecies.

Salinity analysis

Three superficial ground samples, in each sampling point, were taken, during sampling time, to determine the soil salinity. Salinities were measured by saturated paste extraction. Results of average soil conductivity per site are shown in Table 1.

Table 1. Values of average soil conductivity in cropped and abandoned fields.

Habitat	Conductivity (mS)
Halophilous scrub	41.65 ± 0.35
Palm tree	4.2 ± 0.97
Artichoke crop	17.55 ± 0.15
Cereal crop	2.71 ± 0.29
Pomegranate grove	5.42 ± 1.77

Data analysis

Only terrestrial arthropods were considered. Hymenoptera (Formicidae) and Collembola orders were ruled out of analysis because of their extreme abundances. Insect counts per trap location were used to analyse the total arthropod abundance, species richnnes and Shannon-Wiener diversity index in each habitat type.

Results

Total arthropod abundance

A total of 1737 total terrestrial arthropods was captured, belonging to 170 different morpho-species. The dominant groups were Coleoptera (569), Isopoda (528), Araneae (441) and Opilionidea (130).

The habitat with the highest total arthropod abundance was the cereal crop (615), practically twice as high as the rest (Table 2; Fig. 2). The less populated crop was the pomegranate grove (160). Bettles are more abundant in cereal crops because they prefer low salinized soils and high herbaceous cover (ground beetles in cereal crop are even 6 times more numerous than in the other habitats). Cicindellidae species in this area had a low abundance, but they appeared associated with the halophilous scrub and artichoke field. Spiders were more common in the artichoke field (Agelenidae and Therididae) and the palm tree system (Lycosidae).

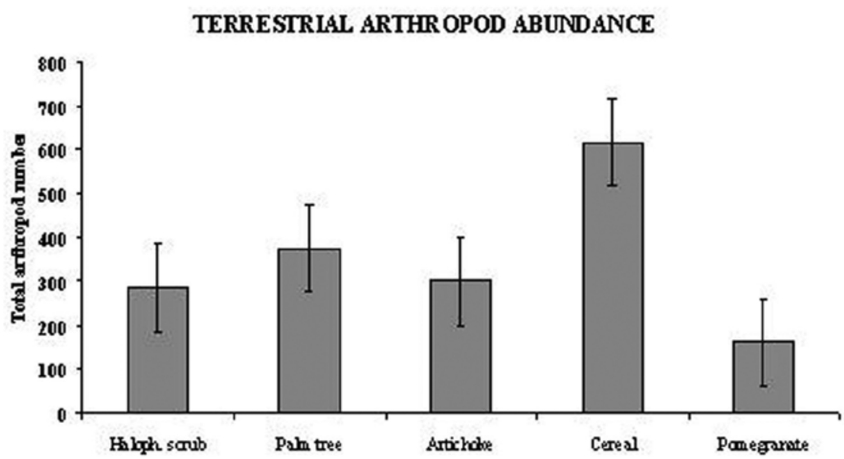
Isopoda were more abundant in the palm tree and cereal crop fields and Opilionida presented a greater abundance in the salt marsh than in cultivated fields.

Table 2. Total number of individuals trapped by taxonomical groups in cropped and abandoned fields.

Order	Family	Halo. scrub	Palm tree	Arti-choke	Cereal	Pome-granate	
O. ARANEAE	Fam. Agelenidae	16	42	49	34	14	155
	Fam. Dysderidae	0	2	1	4	2	9
	Fam. Eresidae	0	3	0	0	0	3
	Fam. Pholcidae	1	2	0	0	0	3
	Fam. Lycosidae	7	25	13	19	4	68
	Fam. Oxyopidae	9	3	2	6	1	21
	Fam. Salticidae	4	4	2	3	3	16
	Fam. Sicaridae	0	3	0	0	0	3
	Fam. Tomisidae	1	10	3	12	2	28
	Fam. Therididae	37	25	55	11	7	135
O. COLEOPTERA	Fam. Anthicidae	0	0	1	7	2	10
	Fam. Buprestidae	0	0	0	2	1	3
	Fam. Byrrhidae	0	3	0	0	1	4
	Fam. Cantharidae	0	0	0	5	1	6
	Fam. Carabidae	14	39	33	206	3	295
	Fam. Cerambycidae	0	0	2	0	0	2
	Fam. Chrysomelidae	4	0	0	2	2	8
	Fam. Cicindelidae	5	1	8	0	0	14
	Fam. Cleridae	0	0	0	1	0	1
	Fam. Coccinelidae	0	1	1	6	0	8
	Fam. Curculionidae	1	0	0	6	2	9
	Fam. Dermestidae	0	6	13	23	0	42
	Fam. Dytiscidae	0	1	0	1	1	3
	Fam. Elateridae	0	1	2	18	0	21
	Fam. Hydrophilidae	0	0	3	21	0	24
	Fam. Oedemeridae	1	1	1	3	0	6
	Fam. Scarabeidae	0	0	5	1	0	6
	Fam. Scolytidae	5	3	11	3	5	27
	Fam. Silphidae	0	1	5	7	0	13
	Fam. Staphylinidae	5	4	12	23	5	49

Order	Family	Halo. scrub	Palm tree	Arti-choke	Cereal	Pome-granate	
	Fam. Tenebrionidae	6	5	6	1	0	18
CL. CHILOPODA		0	1	1	3	1	6
CL. ISOPODA		65	177	53	169	64	528
O. DYCTIOPTERA	SO. BLATTOIDEA	0	1	2	2	1	6
O. DERMAPTERA		0	5	9	13	3	30
O. EMBIOPTERA		0	3	5	0	17	25
O. OPILIONIDEA		106	3	2	3	16	130
O. PSEUDOSCOR-PIONIDEA		0	0	0	0	2	2
		287	375	300	615	160	

Figure 2. Number of individuals trapped in contrasted cropped and abandoned fields during 6 weeks of Spring 2008. $\alpha = 0.05$. N=25.



Species richnnes

A total of 170 different arthropod morphospecies were captured (Table 3; Fig. 3). Among them, 76 were beetle species and 62 were spiders. Many families showed a low richness. Many species only appeared in specific habitats, as for example some cicindelid and tenebrionid species in the salt marsh, carabids in the cereal field, agelenids in the palm tree system and scarabeids in the artichoke field. Other taxa were captured in all habitats, for instance some agelenids and tomisids (Araneae), staphylinids (Coleoptera), isopods and opilionids.

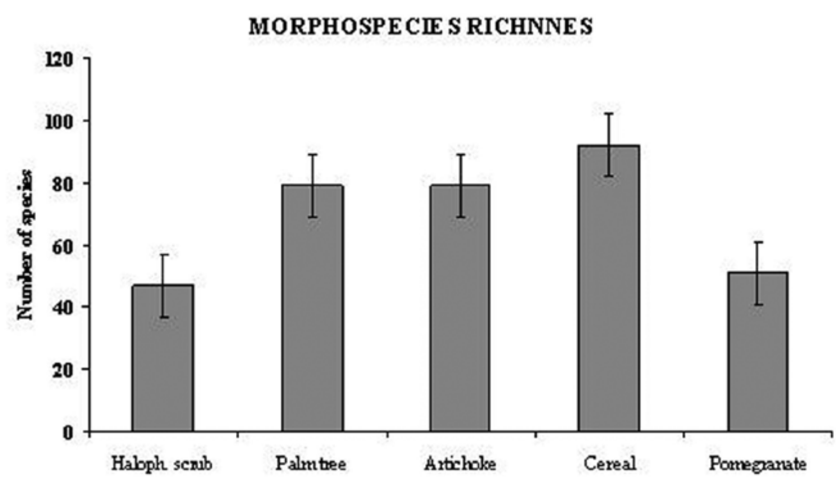
The highest species richness was found in cereal crops, and the lowest diversity in post-cultivation halophilous vegetation. The same taxonomic groups appeared in the abundance analysis.

Table 3. Total number of morphospecies trapped by taxonomical groups in cropped and abandoned fields.

Order	Family	Halo. scrub	Palm tree	Arti-choke	Cereal	Pome-granate
O. ARANEAE	Fam. Agelenidae	7	13	11	9	5
	Fam. Dysderidae	0	2	1	2	2
	Fam. Eresidae	0	1	0	0	0
	Fam. Pholcidae	1	1	0	0	0
	Fam. Lycosidae	4	6	5	6	3
	Fam. Oxyopidae	2	1	1	1	1
	Fam. Salticidae	4	3	1	2	3
	Fam. Sicaridae	0	1	0	0	0
	Fam. Tomisidae	1	4	1	2	1
	Fam. Therididae	5	7	6	6	5
O. COLEOPTERA	Fam. Anthicidae	0	0	1	2	1
	Fam. Buprestidae	0	0	0	1	1
	Fam. Byrrhidae	0	1	0	0	1
	Fam. Cantharidae	0	0	0	1	1
	Fam. Carabidae	5	10	10	19	3
	Fam. Cerambycidae	0	0	1	0	0
	Fam. Chrysomelidae	1	0	0	2	1
	Fam. Cicindelidae	2	1	1	0	0
	Fam. Cleridae	0	0	0	1	0
	Fam. Coccinelidae	0	1	1	2	0
	Fam. Curculionidae	1	0	0	2	2
	Fam. Dermestidae	0	2	2	2	0
	Fam. Dytiscidae	0	1	0	1	1
	Fam. Elateridae	0	1	2	3	0
	Fam. Hydrophilidae	0	0	1	2	0
	Fam. Oedemeridae	1	1	1	2	0
	Fam. Scarabeidae	0	0	4	1	0
	Fam. Scolytidae	1	3	3	3	2

Order	Family	Halo. scrub	Palm tree	Arti-choke	Cereal	Pome-granate
	Fam. Silphidae	0	1	2	2	0
	Fam. Staphylinidae	3	3	8	7	4
	Fam. Tenebrionidae	2	1	2	1	0
CL. CHILOPODA		0	1	1	2	1
CL. ISOPODA		4	5	5	4	4
O. DYCTIOPTERA	SO. Blattoidea	0	1	1	1	1
O. DERMAPTERA		0	3	3	1	2
O. EMBIOPTERA		0	1	2	0	2
O. OPILIONIDEA		3	2	1	1	1
O. PSEUDO-SCORPIONIDEA		0	0	0	0	2
		47	78	78	91	50

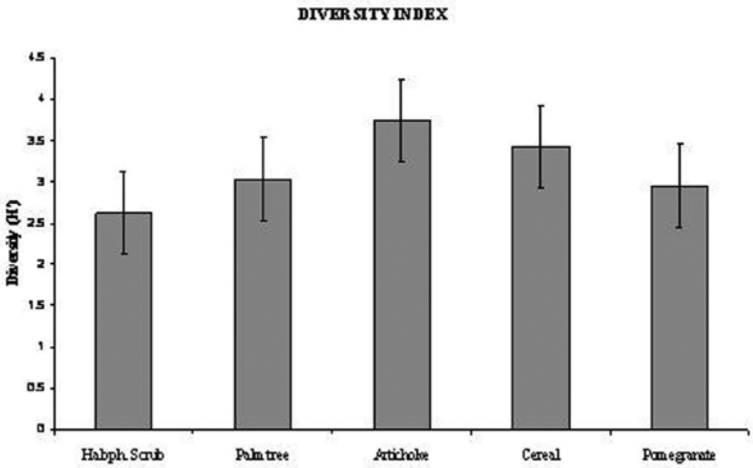
Figure 3. Total morphospecies trapped in contrasted cropped and abandoned fields during 6 weeks of Spring 2008. $\alpha = 0.05$. N=25.



Species diversity

The Shannon-Wiener's diversity index showed a different pattern as regards species richness. The highest diversity index (Fig. 4) was found in the artichoke crop, and the lowest diversity in the halophilous scrub.

Figure 4. Shannon-Wiener's diversity index (H') to total arthropod fauna in contrasted cropped and abandoned fields during 6 weeks of Spring 2008. $\alpha = 0.05$. N=25.



Discussion

As suspected, agricultural abandonment in the El Hondo area seems to cause a significant increment of salt content in soils, due to the cessation of soil washing through irrigation. As a consequence, setting aside of agricultural fields cause the spontaneous colonization of fields by salt-steppe formations of the Pegano-Salsoletea class (*saladar*).

Field abandonment and reversion to halophilous spontaneous vegetation causes, in the first years at least, a decrease in total terrestrial arthropod abundance and species richness.

However, not all cultivated fields sustain similar levels of arthropod richness. A positive relationship between arthropod abundance and richness one on hand and herbaceous cover and the absence of spraying on the other can be suggested, in accordance with other studies (Liu *et al.*, 2006). Similarly, carabids seem to prefer crops with low soil conductivity and high herbaceous cover. The highest abundance and species richness can be positively influenced by a higher ruderal vegetation cover and the absence of spraying.

Cicindellids in this region present halophilous habits, and were more abundant in the halophilous scrub and in the artichoke crop (with a high salinity also) than the other crops caracterized by lower salinity. So, they appear as the best bioindicator of soil salinization in our zone. Tenebrionids also appear related with the same habitats than cicindellids, but their presence is usually related to arid environments, and these habitats have a high insolation. Except for the case of cicindelids, a direct relationship between salinity and presence/absence of specific bioindicators does not appear, at least in general terms.

It must be remarked that two Coleoptera species with a great conservation value, the cicindellids *Megacephala euphratica* and the endemic *Cicindela deserticoloides*, are linked to the halophilous scrub habitat and our study zone presents the northern limit of their distribution area (data not shown but they have been identified), so they seemed favored by agricultural abandonment and soil salinization in former crop fields. However, the decline in arthropod abundance, species richness and diversity, at least during the first years, after agricultural setaside and consequent soil salinization, should be also taken into account from a conservation point of view. Although preliminary, our data seem to point out that enhanced biodiversity in the area will result from an appropriate mixture of agricultural fields and halophilous natural formations in this area.

Additional research would be necessary to compare arthropod population at same study area in other seasons and to assess arthropod population evolution after abandonment of different kinds of crops in the long term.

Acknowledgements

This work has been possible thanks to the active collaboration of local farmers, formalized by the formal Agreement signed between WADI-UA and the "Irrigating Farmers Association of Carrizales (Elche)"

We haved also benefited from methodological discussions with Claudia Rossano, of the University of Florence WADI team, who is carrying out similar studies in the Italian WADI site.

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GIS-ASSISTED QUANTIFICATION OF CHANGES BETWEEN 1956 AND 2003 IN THE HEDGEROW NETWORK OF EL HONDO NATURE PARK ECOSYSTEM IN ALICANTE REGION, SPAIN.

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Abstract: The loss of hedgerows in agrarian landscapes in the last decades is a common fact in western Europe. The disappearance of these important and longstanding landscape elements has critical but insufficiently understood consequences on ecological patterns and processes. The aim of the study is to understand changes over the past fifty years in the hedgerow network dominated by palm trees (*Phoenix dactylifera*) in the agrarian landscape that encompasses El Hondo water bodies and Natural Park. The study area is included in the lower sectors of the Vinalopó and Segura rivers basins and comprises the most complex as well as the most spatially heterogeneous network structure in the area around the park. Two maps representing the hedgerow network in 1956 and 2003 were elaborated. Changes in the network over the last fifty years were quantified. Total hedgerow perimeter in 1956 for the study area was 201 linear km with a higher concentration in some municipality subsectors. Mean density is 4.86 linear km per km^2 of land. The linear extension of hedgerow in the area of influence of El Hondo water bodies has been reduced by 50%. Hedgerow reduction and fragmentation have not been homogeneous. There is a need for a more detailed analysis of the El Hondo mosaic of hedgerows at a higher resolution in order to identify the importance of hedgerow density versus connectivity for specific species of interest.

Introduction

Landscapes are spatially-explicit resource management scenarios in continuous change. Landscape changes have either natural or antropic origins. However, among human activities over past centuries, management intensification has been the greatest cause of landscape transformation. The mechanization of agricultural practices has changed the structure of these agrarian ecosystems, accompanied by a steady degradation and loss of landscape elements with important ecological functions. Non-cultivated elements such as ditches, streams, bushes or hedgerows form a network that is embedded in a 'matrix' of cultivated fields (Agger & Brandt, 1988). These elements represent important biotopes and their network configuration is essential for the connectivity of agrarian landscapes, which in turn is vital for the survival of many species that use these structures for shelter, food or movement (Gurrutxa, 2004).

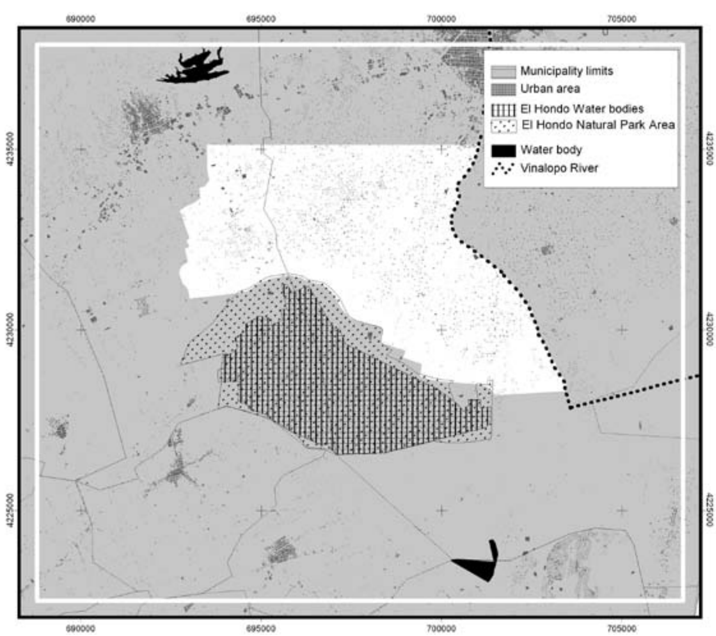
Felicita Scapini, Jean-Marc Boffa, Elisabeth Conrad, Louis F. Cassar and Mariella Nardi (editors), *Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socio-economic and environmental analysis of changes and trends to enhance and sustain stakeholder benefits*, ISBN 978-88-6453-015-4 (online)

The study focuses on hedgerows as important elements within agrarian landscapes. Their loss in last decades is a common fact in Western Europe, which is causing the fragmentation of these semi-natural ecosystems. Although conservation has focused on species extinction, fragmentation as a spatial process has effects on almost all ecological patterns and processes (Forman, 1995). The aim of the study is to understand how the structure of the hedgerow network in the El Hondo Nature Park agrarian landscape has changed over past decades. The identification of these changes in the landscape will be useful to predict possible future change scenarios and develop strategies for the maintenance, restoration and management of the ecosystem from ecological, social and economic points of view. Reasons that have led farmers to remove these elements from the El Hondo agrarian landscape are highlighted.

Study area

This study took place in the El Hondo Nature Park landscape located in the Bajo Vinalopó county in the southern sector of Alicante province, Spain. The park extends over almost 24 km^2 and is mostly located in the municipalities of Elche and Crevillente (Fig. 1).

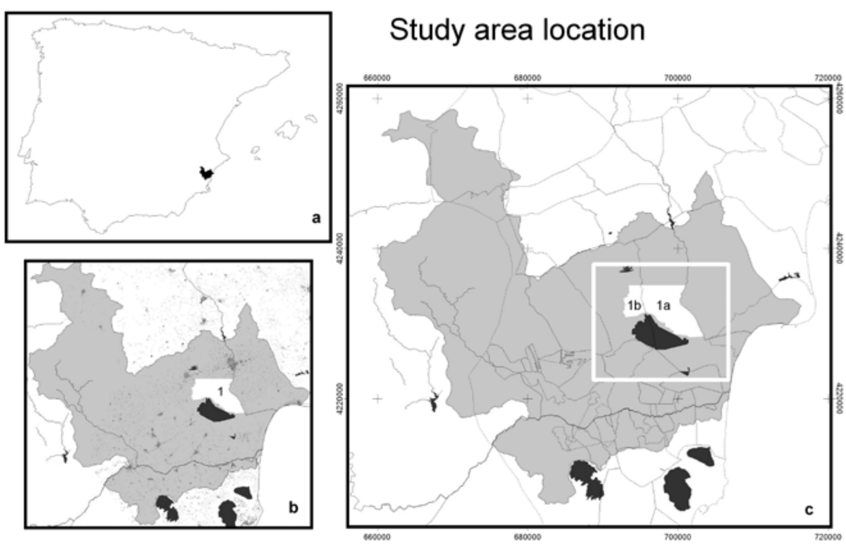
Figure 1. Study area (in white) extends north of El Hondo Nature Park. Southern limits of El Hondo Nature Park and water bodies almost coincide.



This area of Alicante province has a long agricultural tradition, with an emphasis on the cultivation of palm trees (*Phoenix dactylifera*) and many horticultural plants including mainly vegetables, fruit trees and forage. This is possible due to the climatic conditions of the region and extensive irrigation systems. The ombrotype of the study area is Mediterranean semiarid, with a mean annual temperature of 18º C, presenting two differentiated periods, one with torrential precipitations in autumn-winter and another very dry one in summer. Mean annual rainfall is less than 300 mm.

The study area corresponds to the lower sectors of the Vinalopó and Segura river basins (Fig. 2). We selected the agricultural landscapes located north of the park and west of the Vinalopó River (Fig. 2b). This area comprises the most complex as well as the most spatially heterogeneous network structure in the area around the park. The area includes most of the old alluvial delta of the Vinalopó river. The complexity of these landscapes is mainly due to a long human activity since the Middle Ages responsible for the creation of an extended irrigation network.

Figure 2. Study area location. 2a: Lower basins ofVinalopó and Segura rivers; 2b: Study area (in white) coded with 1 located north of the El Hondo Nature Park.Water bodies in blue; Urban settlements in grey; Lines indicate main hydrological network of rivers; 2c: Subzones of study area including 1a in Elche municipality and 1b in Crevillente municipality.



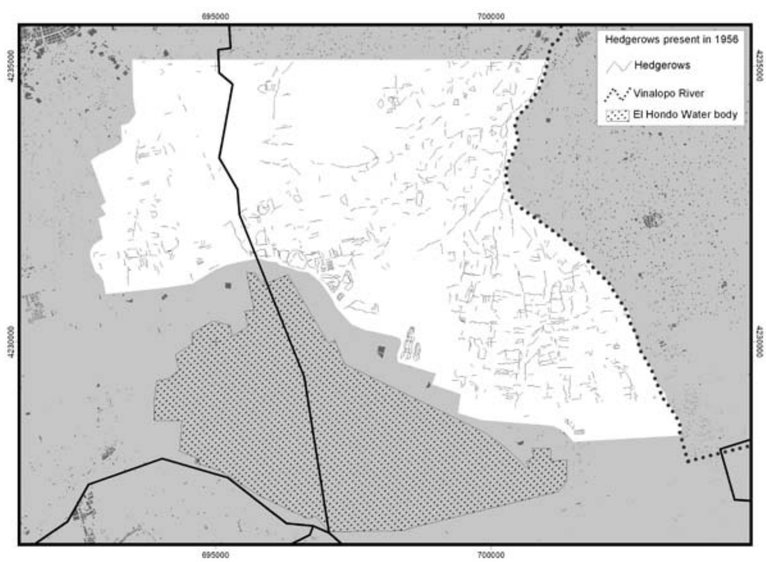
Methods

Landscape changes were assessed comparing aerial photographs taken at different periods of time, namely the aerial photographs taken in 1956 by the Spanish Air Force Cartographic Centre and the orthophotograph made by the Cartographic Valencian Institute (ICV) in 2003. Aerial photos from 1956 were corrected photogrametically using ER Mapper and used to generate an orthoimage of the study area. Detailed identification of both images was done through the visual analysis of these images on the computer. All information obtained from the images was processed with CartaLinx software in order to generate the linear coverage of hedgerows. Two maps were elaborated from the 1956 and 2003 orthoimages to represent the hedgerow network in these two years. Changes in the network over the last fifty years were quantified. Two categories were established:

1. Hedgerows maintained over the 50-year period with no noticeable change in the aerial photographs.
2. Hedgerows removed during the period with a complete dissapearance or significant change in the aerial photographs.

Figure 3 and 4 represent the hedgerow network in 1956 and 2003 respectively.

Figure 3. Hedgerow map in 1956. Thick black line represents municipality limits.



In a second stage, new coverages were generated using ArcGIS software defining the three spatial land units considered including the whole area, municipalities and "*partidas*" or administrative subsectors of municipalities included in the study area. Figure 5 represents the limits of municipality subsectors and the numerical codes assigned to them.

Figure 4. Map of hedgerows present in 1956 which remained in 2003. Thick black line represents municipality limits

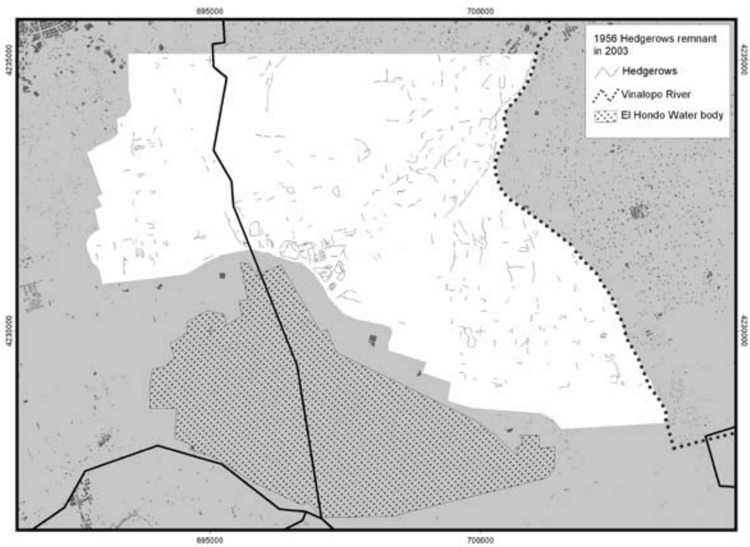
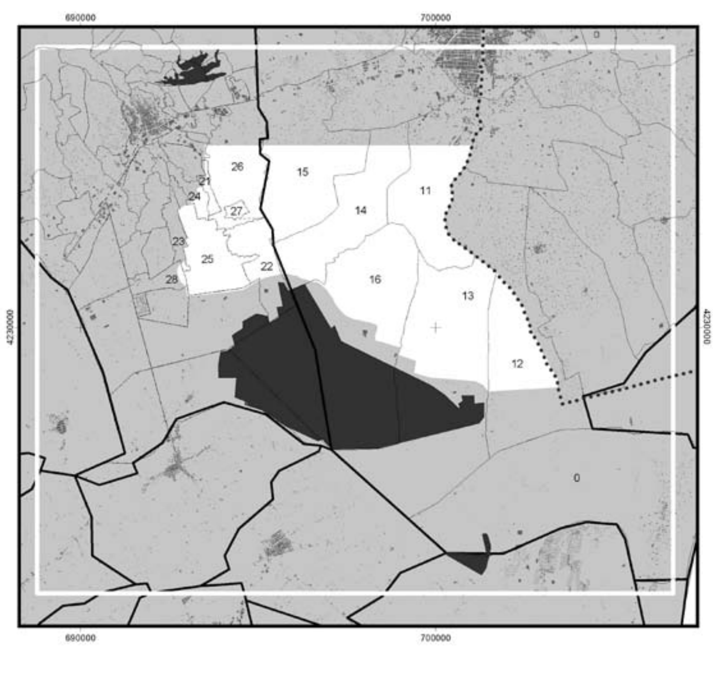


Figure 5. Location of "*partidas*" or municipality subsectors in the study area. Most partidas have limits outside the area, but still it is useful for the connection with the socio-economic analysis. Same numerical codes as in Table 1 are used.



The analysis of fragmentation was determined and quantified measuring hedgerow length in 1956 and 2003 for each one of the specific land units considered. Differences in hedgerow length over time resulted in the determination of the percent of network loss. This hedgerow reduction measure was also considered in relation to the spatial distribution of the land units studied.

Results

Within the study area which covers 42.82 km^2 (zone 1), the length of hedgerows reached 208 km in 1956, or an average density of 4.86 linear km of hedgerows per km^2 (Table 1). The contribution of the two municipalities to total hedgerow length was radially asymmetrical with Elche and Crevillente contributing 88.8% and 11.2%, respectively. Similarly the distribution of the hedgerow network in administrative subsectors (partidas) of Elche (1a) and Crevillente (1b) was unequal. For instance, in Elche, the lowest value was for the Matola sector with 7.4 km, while the largest was El Derramador with 61.8 km. In contrast, in Crevillente the lowest value was for Camino de Catral with 0.095 km and the largest was Derramador with 12.4 km.

The contribution of municipality sectors to total hedgerow length in respective municipalities also varied widely (Table 1), with Elche *partidas* representing 4 % to 33.5%, and 3 *partidas* with values around 17%, and ranging from 0.4 to 54.6% in Crevillente.

During the past 50 years, 50% of hedgerow length has been lost over the whole study area (Table 1). However, there are large differences in the pattern of loss between the two municipalities. The loss in Elche (51.69%) has been more marked than in Crevillente (38.77%). Differences are also found within municipalities, at the partidas level. In Elche, 'El Derramador' sector has lost almost 70% of its hedgerow length in the period observed. It is important to mention that the network length of this sector represented one third of the network in Elche and one quarter of the study area.

Table 1. Hedgerow length and proportion per municipality and municipality sector and hedgerow loss between 1956 and 2003.

Municipality	Partidas Municip. Sector	Total length 1956 (m)	%Respect Municipality Total	% Respect Total in Study Area	% Loss Between 1956 & 2003
Elche	Algoros (11)	34305	18.55	16.47	37.20
Elche	Daimes (12)	15480	8.37	7.43	51.78
Elche	El Derramador (13)	61877	33.47	29.71	67.27

Elche	L'Algoda (14)	31321	16.94	15.04	42.98
Elche	Matola (15)	7445	4.03	3.57	52.30
Elche	Puçol (16)	34467	18.64	16.55	45.87
Subtotal Elche		184,895	100	88.78	51.69
Crevillente	Alteron (21)	1431	6.12	0.69	0.00
Crevillente	Cachap (22)	3689	15.79	1.77	38.16
Crevillente	Camino de Catral (23)	95	0.40	0.05	0.00
Crevillente	Canyada Juana (24)	868	3.71	0.42	0.00
Crevillente	Derramador (25)	12741	54.55	6.12	48.84
Crevillente	El Boch (26)	3870	16.57	1.86	26.86
Crevillente	Estacion (27)	161	0.69	0.08	7.42
Crevillente	Vereda (28)	507	2.17	0.24	73.99
Subtotal Crev.		23361	100	11.22	38.77
Total Elche-Crev.		208,257			50.24

Discussion

Most hedgerows present in the study area were planted by farmers since the Middle Ages. Dominant species include palm trees (*Phoenix dactylifera*), *Punica granatum,Pinus halepensis* and *Arundo donax*. They have been probably connected with the irrigation system in these fields and their lower geographical limit has been El Hondo. Therefore this hedgerows network has been a common pattern in the vicinity of this water body. The data presented in this paper clearly show that this relevant landscape feature has suffered a considerable reduction since 1956. While this was not measured in this study, it is expected that this direct elimination of habitat associated with hedgerows has had a strong negative impact on many species of plant and animals that need these field margins to sustain their populations in a matrix dominated by active agriculture.

Agricultural practices associated with agricultural intensification which dates back to the 1950s have a strong responsibility in habitat transformation (Forman, 1995). Agriculture modernization has generated changes both in agricultural practices and in landscape structure (Le Coeur *et al.*, 2002). As a consequence, small biotopes (such as woodlots, hedgerows, ditches and grassy riversides) have largely disappeared from modern agricultural landscapes (Agger & Brandt, 1988). Hedgerow removal has been done either by individual farmers or through reallotment programmes at the municipality level (Burel & Baudry, 1995). In the case of Elche and Crevillente the aggregation of smaller field units has been one of the main causes of the observed fragmentation. Individual farmers, small enterprises mainly in the horticultural sector and individuals constructing second residences were the main actors responsible for this change. Municipality or public administrations were not directly involved in reallotment programs. Nevertheless, fragmentation related to transformation and pavement of roads as well as the development of small urban nuclei in the rural area has been common.

The reasons that have led farmers to eliminate hedgerows from field boundaries may be of both economic and sociocultural nature. With increased mechanisation of agriculture, costs of field boundaries were considered to be greater than benefits and larger fields were thought to be more cost-effective to manage with modern machinery (McCollin, 2000). Besides, many farmers argue that hedgerows shelter species that may become pests in adjacent cultivated fields.

The origin of the loss of hedgerows should nevertheless be found in the change and subsequent loss of the past functions of hedgerows. Hedgerows serve as a marker to establish field boundaries or a physical barrier to keep cattle inside the limits of the property. Besides, they were a source of goods such as food, medicine or wood. Hedgerows have almost lost their original function because of the dominance of crop production in the landscape (Baudry *et al.*, 2000).

Nowadays, there is a wider knowledge about hedgerows and their functions in agroecosystems, some of which are of great interest to farmers. Hedgerows are very important in soil conservation and quality, as well as in water and air quality. Besides, hedgerows host beneficial insects for agriculture, such as polinators or natural enemies of pests. In the study area hedgerows' beneficial effects on water quality have been reduced as a consequence of replacement of the associated irrigation channels directly excavated in the ground by concrete ones.

From an environmental perspective, Hedgerows' functions as habitat, refuges, corridors or barriers are critical for many plants and animals that otherwise could not exist in the agrarian landscapes (Baudry *et al.*, 2000). Before land use intensification starting in the 1950s, patches and linear elements of semi-natural habitats facilitated the movement of some species. Since then, these habitats have decreased dramatically in intensively farmed regions (Henle *et al.*, 2003). Pressures for land use change have led to a steady loss of habitat and to an increasing isolation of habitat remnants (Henle *et al.*, 2004). Hedgerows control physical, chemical and biological fluxes (Baudry *et al.*, 2000), hence, their loss implies a reduction in connectivity and as a consequence in the alteration of essential processes for ecosystem sustainability.

Throughout history, management of agroecosystems has been done by farmers who have acted as individual decision makers on individual farms, rather than at community level on contiguous pieces of a larger landscape. However, many of the ecosystem services potentially attributable to farm edges occur at a landscape scale (Brodt *et al.*, 2008). Therefore, the issue of hedgerow management and conservation must be addressed by a wider range of actors, including farmers, scientists and public administration. In order to do so, people need to understand that vegetated field boundaries provide many social and ecological services (Zuria & Gates, 2006) as well as economic ones. Demand for better information and cost accounting will likely increase along with the growing awareness of farmers of the potential capacity for on-farm planted features to provide ecosystems services (Brodt *et al.*, 2008).

Conclusions

Hedgerow length in 1956 in the study area was 201 linear km with a higher concentration in some municipality sectors. Therefore there is a rather heterogenous mosaic of hedgerow corridors around El Hondo. Mean density of hedgerows in the study area is 4.86 linear km per km^2.

Hedgerow fragmentation in the area of influence of El Hondo water bodies have been reduced by 50% between 1956 and 2003 with a considerable reduction in corridors in this landscape.

Hedgerow reduction has not been homogeneous. The *partidas* with larger abundance have suffered a reduction in the range of 37% to 67% which represents a loss of one to two thirds of the hedgerow length present in 1956. Only *partidas* representing less than 1% have remained unchanged.

There is a need for a more detailed analysis of the hedgerow mosaic and the spatial density of this feature at a higher resolution in order to identify the importance of density versus connectivity for specific species of interest.

Acknowledgements

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IS *HALOCNEMUM STROBILACEUM* (PALL.) M. BIEB. A GOOD FLAGSHIP SPECIES FOR CONSERVATION OF BIOLOGICAL DIVERSITY IN COASTAL WETLANDS ECOSYSTEMS? A PERSPECTIVE FROM WADI SITES IN SPAIN, ITALY AND TUNISIA

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Abstract: Halocnemum strobilaceum (Pall.) M. Bieb is an extreme halophyte species that occupies coastal and inland environments from the Mediterranean basin to the East African and Central Asian continents. It presents different morphotypes related to environmental conditions and community age. The species is protected in some countries, but further knowledge is needed to manage its singular plant formations.

The study was carried out to review the biogeographical, environmental and structural characteristics of three stands selected in the west and central Mediterranean basin, El Hondo (Spain), La Maremma (Italy) and Gar El Melh (Tunisia). The final objective was to evaluate the use of *Halocnemum strobilaceum* as a flagship, umbrella or just an indicator species in conservation and management strategies. A two-level approach including *in situ* and aerial image analyses was followed for the structural characterization of stands.

H. strobilaceum's distribution areas in the three sites were very different, with the Tunisian distribution area being 50 times larger than its Italian counterpart. Differences in proportion of individuals' morphotypes, plant species composition, plant structure and environmental conditions were found in the seven stations studied. Total plant cover in all stations as characterized in situ ranged from 24% to 43.4%. Estimation of total plant cover using aerial ortophotoimage analysis proved useful.

Halocnemum is listed in the Endangered Plant Red List in Spain and Italy as vulnerable. In Tunisia it is considered a common plant, although there is a large heterogeneity in the types of environments where it may appear and hence its rarity. It could be used as a good indicator species for different levels of salinity and flooding gradients. In addition, this species can facilitate the presence of other interesting species in its communities. Further studies of these communities' species composition are needed. These salinity/inundation ecotones linked to lagoons and other water bodies are rapidly disappearing due to important tourism-related pressures in Mediterranean coastal environments. So, it is urgent to define their rarity index.

Due to its community dominance, its pioneering character in extreme conditions, and being a woody perennial of aesthetic appeal, *Halocnemum strobilaceum* can be considered an optimum candidate as a flagship species for the conservation of the ecological diversity of coastal lagoon landscapes.

Introduction

Halocnemum strobilaceum (Pall.) M. Bieb is a high salt tolerant species of the family Chenopodiaceae (in the Cronquist System), or Amaranthace-

Felicita Scapini, Jean-Marc Boffa, Elisabeth Conrad, Louis F. Cassar and Mariella Nardi (editors), *Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socio-economic and environmental analysis of changes and trends to enhance and sustain stakeholder benefits*, ISBN 978-88-6453-015-4 (online)

ae for some authors. It appears mainly as a perennial woody camephyte with a distribution along the Mediterranean basin, the Middle East and Central Asia. It appears in coastal and inland areas in soils of high salt content, and seasonal water accumulation. These particular conditions (salt and water inundation) are represented in well defined habitas that correspond with land-water transitional areas throughout its distribution area. These places are mainly related to geomorphologic structures such as actual and ancient river deltas, coastal lagoons and salt lakes.

Simberloff (1998) considered that an indicator species can be used for environmental management due to its capacity to reflect particular physics-chemical conditions of an area or changes in the biological community. In other cases, a flagship species approach consists in using a species to represent an ecosystem as a central theme of protection campaigns for this ecosystem because it arises public interest and sympathy. The umbrella species approach is based on species that need large habitats which if protected will save many other species. *Halocnemum strobilaceum* may be used in these approaches, but further information about community's distribution, composition and structure is required.

The main objectives of this work have been to 1) review the ecological information on the species and analyze in a common framework *H. strobilaceum*'s distribution in the three WADI project study sites; 2) quantify the environmental and structural variability of *H. strobilaceum* stands studied; 3) identify the main inter-site and intra-site differences, and 4) to assess the potential of the species to serve as a flagship, indicator or umbrella species. The overall goal of the study is to facilitate the localization of stands of biological interest that should be taken into account in coastal land planning and conservation programmes around the Mediterranean Basin.

Methods

Study sites

Three sites investigated in the WADI project are long-term study sites dating back to the previous MEDCORE project.

Halocnemum strobilaceum populations in the three sites considered in this project are located near water bodies. Nevertheless, the particular environmental conditions in the three places are very different. We selected El Hondo in Alicante province (Spain), La Maremma in Grosseto province (Italy) and Gar El Melh in the governorates of Bizerte (N), Ariana (S & SE) and Manouba (W & S) in Tunisia (Fig. 1).

The Spanish site, El Hondo, is an inland lagoon that presently constitutes a semi-artificial water reservoir. It is one of the two remaining wetlands formed as a result of the silting of the Elche's old Bay. It preserves some geomorphologic structures of the old Vinalopó River delta, where most of *H. strobilaceum* appears. The brackish water of the reservoir and the gypsum materials of the surrounding slopes are the principal salt sources for the region. Nowadays the area is included in a Nature Park.

The Italian site, La Maremma, is the mouth and delta system of the active Ombrone River. Marine salt accumulates in the sediments of areas near the river mouth. Inundation can occur as a result of dynamics of both the river and the sea. This site is included in a Nature Park too.

The Tunisian site, Gar El Melh, is a coastal lagoon formed in the alluvial plain of the Medjerdah River lower basin. It is the result of the silting process of the old bay where the river ends. At present, the lagoon still communicates with the sea. In the surrounding area of the lagoon there is a salty plain. Other small lagoons along the coast have been created by local coastal dynamics. The main salt source in *Halocnemum* stands has a marine origin, combined with the arid climatic regime.

Methodology

A bibliographic and internet search on *Halocnemum strobilaceum*'s global distribution was done. Next, field surveys were conducted between 2003 and 2008 in the three sites selected to identify the presence and characteristics of the species.

In a first step, we selected stations in the Spanish, Tunisian, and Italian sites during the different field sampling surveys. In these surveys, qualitative descriptions were done to identify the heterogenity of environments found in the distribution area of *Halocnemum*.

In a second step, we did *in situ* descriptions of the structure and composition of *Halocnemum* communities in selected environments. Quantitative measurements of plant cover and plant community composition and vertical structure were done for El Hondo (Spain) and La Maremma (Italy) (three and one stations respectively). Line-intercept transects of 200 meters in length per station was the method used, combined with plant height measurement at the point of interception to allow the elaboration of layer diagrams.

Due to the large area occupied by the species in the Tunisian site of Gar El Melh, a transect sequence of vertical images using a digital video camera were taken in one site. Twenty digital photograms were selected randomly in the transect, and plant shapes were drawn using an image processing software. Treated photogram images were analysed with Image Tool 3.0 software using a similar threshold (defined manually) and counting pixels for covered areas. Finally, average plant cover, expressed in percentage, was obtained for the station.

The last characterization step used had two main objectives: 1) test a more feasible way to describe the spatial heterogeneity of large formations of the species; 2) allow rapid plant cover comparisons between sites in different areas of the world. To reach these goals the characterization used two protocols.

The first one combined the use of Google-Earth images with high resolution overlapped with a grid of 200m-side quadrats, and field surveys. This procedure allowed a quick representation of the detailed distribution area in every site. The overlapping of the grid needed appropiate georeferencing of the images which was done with GIS software Esri ArcGis.

The second protocol for more detailed plant cover estimates was conducted using aerial orthophotoimages extracted with the Google Earth software. Images of actual 100m x 100m quadrats on the ground were captured and four 100m x 100m pixel images were sampled randomly for each of the seven stations. Table 1 indicates the UTM coordinates of the central point of these quadrats. The images were analysed with Image Tool 3.0 software (using the manual threshold processing tool and the count black/white pixels analysis tool). Average plant cover, expressed in percentage, was obtained for each station.

The different types of *Halocnemum* morphotypes were studied in the field. Other field observations were conducted to verify the presence of interesting animal and plant species in the *Halocnemum* communities.

Results

Halocnemum is a shrub that can reach almost 1m in height. It is very well adapted to salt stress by the development of succulent stems, and it has an extensive superficial as well as deep root system. It is classified as a Type 3 Halophyte in Woodell's halophyte classification, with high survival and germination rates in high salinity environments (Pujol *et al.*, 2000).

World geographical distribution

Its particular environmental requirements explain its reduced spatial distribution in the Northern Mediterranean region (Figure 1). There, it mainly appears in river deltas and coastal lagoons, being environments with a marine source of salt. The species is also common around the Red Sea (see for reference <http://www.iwmi.cgiar.org/assessment/files_new/research_projects/Bibliography_ICBA.pdf>,), it has been cited in Djibouti and Ethiopia (see for reference <http//www.um.u-tokyo.ac.jp/publish_db/Bulletin/no29/no29002.html>) (not included in Figure 1). In addition, in the North African and the West and Central Asian regions with arid climates the species has more extensive stands, and is found mainly in salt deserts, salt lakes and inland depressions, where the main source of salt is continental.

Spatial distribution around water bodies

Figure 2 (images A, B and C) shows the distribution area of the species in the three study sites. The spatial location of *Halocnemum* patches in relation with the main water bodies can be observed. The number

Figure 1. World distribution of *Halocnemum strobilaceum*. Red dots represent the species locations. Countries where the species is present appear in green. Study sites are represented with larger dots and a letter code: A El Hondo (Spain); B. La Maremma (Italy); C. Gar El Melh (Tunisia).

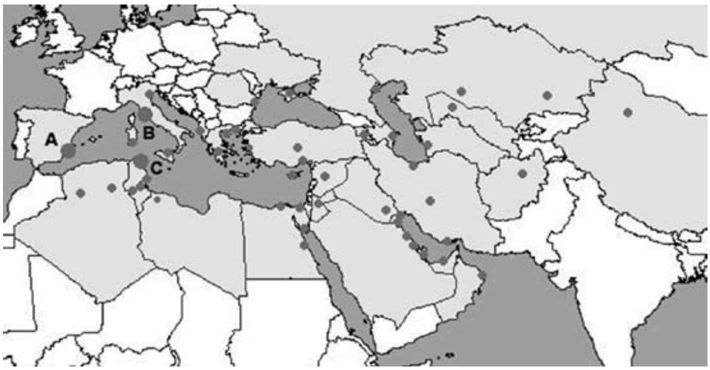
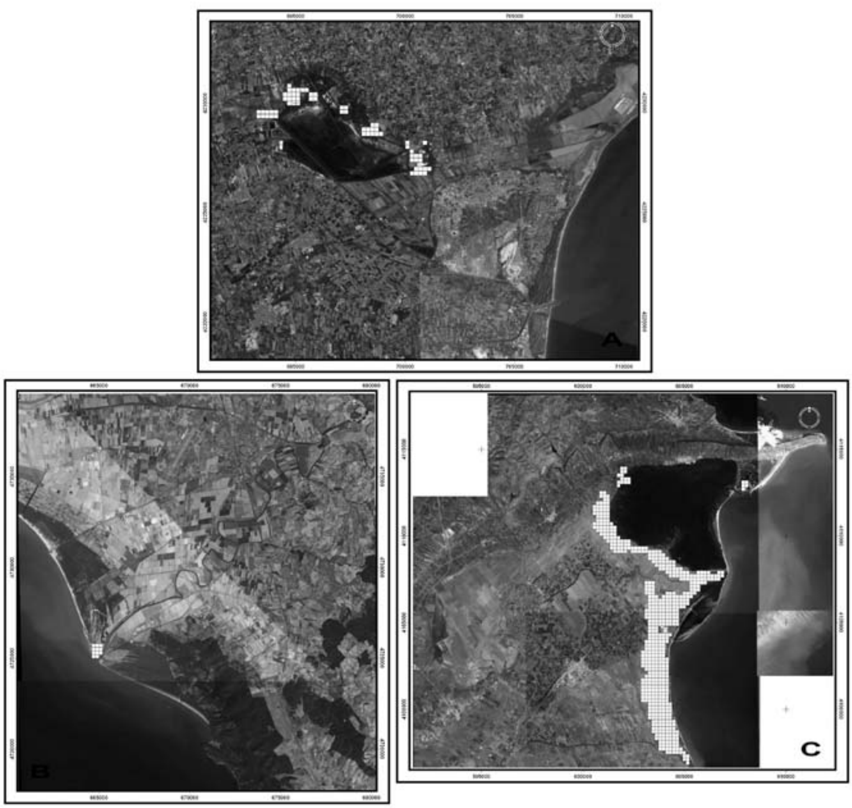


Figure 2. *Halocnemum strobilaceum* distribution in the three study sites selected. A. El Hondo (Spain); B. La Maremma (Italy); C. Gar El Melh (Tunisia). Shaded quadrats on orthoimages obtained from Google-Earth represent an area of 200x200 m^2.



of quadrats occupied by *Halocnemum* in the different sites was 67 for El Hondo, 11 for La Maremma and 576 for Gar El Melh. This corresponds to a maximum area of 268ha, 44ha and 2304ha respectively, showing important differences between them. It must be noted that not all the area in the sites was completely occupied by *Halocnemum* formations, but the species was clearly present.

Halocnemum is considered one of the most halophytic species. It forms practically monospecific stands in its optimum conditions of salinity and soil inundation, dominating these places by ecological adaptation. When conditions are more extreme (large periods of inundation or high salinity in summer), the species reduces its density and cover, and if the condition persists the species disappears. In more favourable conditions for other less halophytic plants, *H. strobilaceum* coexists with other halophytic shrubs like *Arthrocnemum macrostachyum*. If salty conditions disappear, *H. strobilaceum* is the first plant to vanish by competitive exclusion (Ungar, 1998).

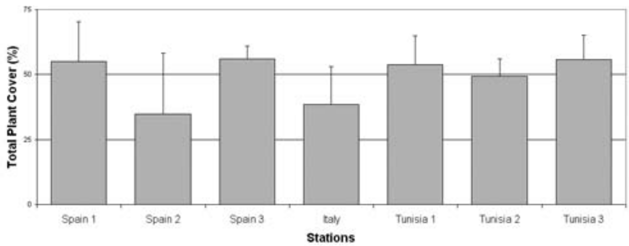
Individual and community structure

The formations of *Halocnemum strobilaceum* in the three sites showed clear differences, but they also displayed similarities. It is not usual to see vegetation between *Halocnemum* patches. This permits the use of aerial photographs and image analysis to estimate plant cover for each formation. As it can be observed in Figure 3, the species dominates the community in all three sites, but vegetation patterns, species composition and morphotypes differ.

Figure 3. Aspect of *Halocnemum strobilaceum* formations in the three study sites: A. La Finca (Spain 2); B. Gar El Melh (Tunisia 2); C. La Trappola (Maremma, Italy).

In the first characterization exercise, values of plant cover obtained from aerial ortophotographs ranged from 34.7 % to 56 % for the seven stations (Fig. 4). Five of the stations had similar values of plant cover, approximately 50 to 55 %. Only two stations presented relatively lower values around 35 to 40 %. Spain 1, Spain 2 and Italy stations have the highest level of within-site variability.

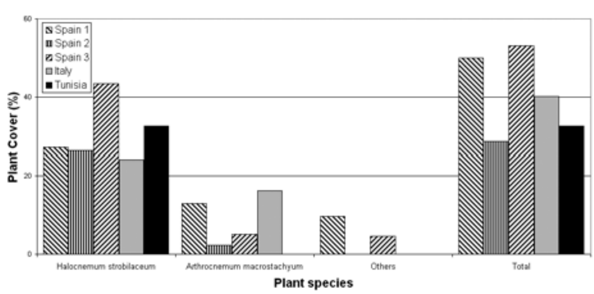
Figure 4. Plant cover (%) in the seven stations studied obtained by aerial orthophotoimage analysis. Bars represent average values. Lines on top represent the standard deviation.



For the *in situ* approach, total estimated plant cover in the different *Halocnemum* populations ranged from 24% to 43.4% (Fig. 5). The Italian population had the lowest *Halocnemum* plant cover, with 24%. The three Spanish populations studied ranged from 26.4% to 43.4%. For the Tunisian station, the estimated value obtained was 32.7%.

In terms of dominance in species composition of the stands, the Italian site showed a near co-dominance of *Arthrocnemum macrostachyum*, with a cover of around 16%. In the Spanish sites, plant composition differed (Fig. 5). Spanish Station 2 has the highest *Halocnemum* dominance, with a scarce Arthrocnemum plant cover. Spanish Station 1 has a non-*Halocnemum* cover of almost 23%, made up of *Arthrocnemum* and other plants (*Mesembryanthemum nodiflorum*, *Suaeda vera* and other annual species). Spanish Station 3 has the highest *Halocnemum* plant cover and a low *Arthrocnemum* and annual species cover. In the Tunisian site, no quantitative information about plant composition was obtained.

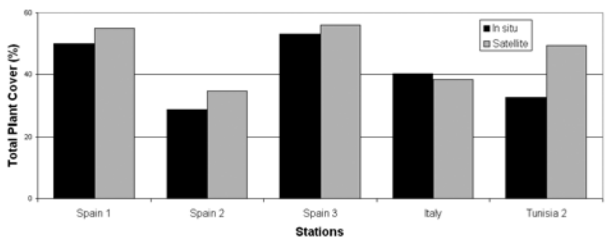
Figure 5. Plant cover (%) obtained for five study stations with the linear transect method and the vertical video image analysis method.



The variety of plant composition types in *Halocnemum* communities in project sites can be categorized as follows: 1) *Halocnemum* monospecific sites; 2) *Halocnemum-Arthrocnemum* mixed communities; 3) *Halocnemum* mixed with other species and annual therophytes; 4) *Halocnemum* with *Limonium* species. In the Tunisian site, the four composition types were observed and the three stations can practically be included in the first type. These four types were observed in the Spanish site too, and the three populations studied corresponded with the first three types. The Italian site can be classified in the second type.

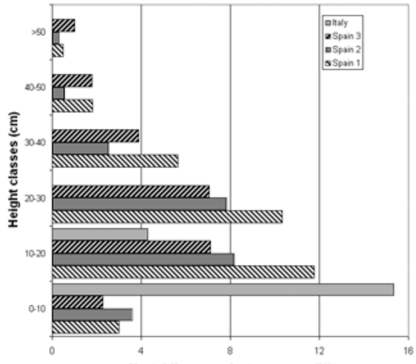
If we compared the two different methods to estimate total plant cover of a plant community, it is clear that the *in situ* method is more accurate (Fig. 6). But the usefulness of the lower scale approach can be evaluated by comparing estimates of plant cover in the five places where both methods were applied. In the Spanish and Italian sites, differences were small, ranging from 2 to 6% of total plant cover (Fig. 6). In contrast, differences were larger (16.7%) in Tunisia.

Figure 6. Comparison between the two methods used for the estimation of the total plant cover in five of the study sites.



The height of *Halocnemum* plants in study sites depended on populations studied (Fig. 7). The Italian site has the shortest plants, and most of them were shorter than 20 cm. No data were collected in the Tunisian site, but medium heights were observed. The Spanish sites presented the tallest plant heights. Most plants in the Spanish sites were concentrated in height intervals of 10 to 30 cm. Comparing the three Spanish stations, Spain 2 had the highest proportion of shorter plants but Spain 3 has the tallest individuals, reaching heights of almost 1m.

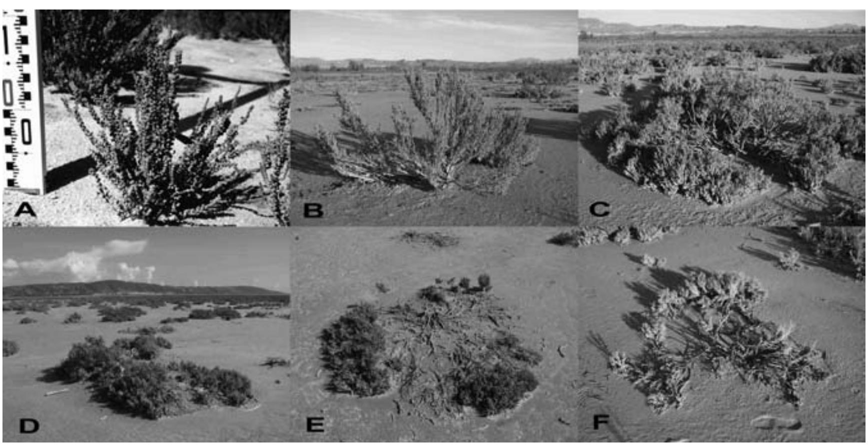
Figure 7. Height classes of *Halocnemum strobilaceum* in the different stations of Spanish and Italian sites.



Individual morphotypes

Different stages of development, ranging from young to senescent stages were described in the plant community (Fig. 8) (Caballero, 1999). Often a plant community is dominated by one or two types of individuals, indicating the age of this formation and/or dominating environmental conditions. Seeds germinate in the wet season, when salinity decreases. It is very normal to find seedlings grouped in depressions. Plants develop vegetatively and go from young to erect mature stages (A and B in Figure 8). External branches start to open and go down until they touch the ground. Plants start to develop a radial shape, growing more horizontally than vertically, and with the development of roots from external branches. This is the mature stage (C in Fig. 8). Mature plants create a microhabitat that permits other plant species to colonize the area by facilitation (Callaway, 1994), as well as provide habitat to animal species. Mature forms can accumulate sediments or prevent soil erosion, changing to a domed-shape plant (D in Figure 8). Then, central areas of the plant start to senesce and the main stems die. Plants reach a senescent form, while forming several new small individuals in the external parts due to stem death and concurrent root development (E in Figure 8). Such situations can occur when environmental factors change to unsuitable conditions. When such change is drastic the entire plant may die.

Figure 8. Different growth stages of *Halocnemum strobilaceum*, young (A), erected (B), large, mature (C), dome-shaped, mature (D), senescent (E) and dead (F).



Field observation revealed different morphotypes of *Halocnemum* plants in the sites (Table 1). In the three Spanish stations, the B form (Fig. 8) or erect individuals are very common. Yet in Station 2 (La Finca) mature individuals are common too. In the single Italian station, creeping individuals are more common, belonging to types D and E. This is clearly reflected in the plant height distribution (Fig. 7). There are differences among Tunisian stations. While in Station 1 large individuals are common (mature and domed-shaped), Tunisian station 2 is similar to the Italian site, with a predominance of creeping forms and Station 3 has more erect individuals, principally near the sand dune areas.

Table 1. Dominant morphotypes in study stations selected in the three countries. UTM coordinates represent the central point of the quadrat selected for the image cover analysis. UTM zones: Spain – 30S; Italy – 32T; Tunisia – 32 S.

Study stands	Spain 1	Spain 2	Spain 3	Italy	Tunisia 1	Tunisia 2	Tunisia 3
	Balserones	La Finca	El Saladar	La Trappola	Medjerda old mouth	West Gar El Melh Lagoon	Southern Lagoon
UTM East	694073	697192	693589	644893	604137	601770	603881
UTM North	4229468	4229756	4229609	4725134	4105176	4109627	4101996
Dominant morpho-type	B	B,C	B	D, E	C,D	D,E	B,C

This species can occupy conditions of lower salinity and seasonal inundation, resulting in a variety of community compositions. A *Halocnemum* formation can have very different plant morphotype composition, due to variations in its environmental characteristics over time. This important aspect adds heterogeneity.

In some *H. strobilaceum* formations, other plant or animal species that enhance the conservation value of these habitats were observed in a qualitative manner. Rare *Limonium* species were found in the Tunisian and Spanish sites. Other interesting halophyte species, like *Halopeplis amplexicaule,* listed as vulnerable in the Spanish Red List of Endangered Species (Domínguez-Lozano, 2000), was found in the Spanish site. Habitat provided by *Halocnemum* formations can be used by steppe and water birds, and other interesting and rare species even though this may not have been reported in the scientific literature. An example is the insect *Megacephala amplexicaule* found in the Spanish sites.

Discussion

This study reveals common features in the three study sites; for example the presence of a brackish or salty water body in the vicinity of *H. strobilaceum* populations. These water bodies may be coastal lagoons, the sea or endorheic depressions where the relatively high soil salinity is or has been actively accumulating. *Halocnemum strobilaceum* formations are linked to geomorphological scenarios where high salinity content and prolonged inundation combine as a selecting factor. As mentioned by Mayaux *et al.* (2003) the species can withstand extreme salinity conditions of environments where salt hardpans are formed. In such environments only *Halocnemum strobilaceum* and *Sporobolus salsus* can withstand those limiting conditions. We observed that other species, in the genus *Artrocnemum* for example, are able to withstand prolonged inundation but not combined with such extreme salinity stress. This makes *Halocnemum* a real emblem, an arrow point of perennial and woody species in a difficult ecotone that is present along borders of most coastal lagoons. These geomorphologic scenarios favour extensive areas of a very slow topographical transition, common in the flat plains close to river mouths in the sea or in lagoons. *Halocnemum* introduces both horizontally and vertically heterogeneous cover as a rather productive chamaephyte or nanophanerophyte, and offers food and shelter to many organisms in these transition ecosystems. These transitions can be very wide in extension inward but they are also present seaward. In the latter case, their width depends on the distance between the lagoon or water body and the inward limit of the dune fields or just the small topographic elevations separating the lagoon from the beach.

However clear differences between study sites have also been shown. First, the amount of area covered by these *Halocnemum* formations is very different. The ratio in surface area of these formations between sites is 1:5:50 for Italy, Spain and Tunisia respectively.

Besides, the degree of connectedness of *Halocnemum* patches differed in the sites. In El Hondo (Spain), vegetation patches have no connection between them, the reason being related to human impact due to agricultural activities. It is possible that the *Halocnemum* area in the Spanish site had been drastically reduced. Italy is a particular case, because of its limited and concentrated distribution. The species has a very punctual distribution situated on the front area of the actual Ombrone river delta. It is possible that this species is relatively new in the region and may have arrived and colonised the area, using water birds as a seed dispersion vector. Finally, the Tunisian site has the wider distribution area. There, *Halocnemum* occupies extensive areas of appropriate habitats due to climatic and topographical conditions. It appears in continuous stands which are apparently very homogeneous, except in marginal and transitional areas near lagoons, in depressions of sand dunes and coastal sand barriers or in specific locations associated with ramifications of the hydrological network.

In addition to the diversity of characteristics between sites, there are further differences among formations within sites. Consequently, each stand of *H. strobilaceum* dominated vegetation (with different morphotypes, plant species composition or plant structure) could be an indicator of specific environmental conditions.

Comparison with other sites

In all study sites, maximum total plant cover in *Halocnemum strobilaceum* formations approximates 50 to 55%. This maximum may correspond to a limit in this type of plant community. We found that the most reliable method to estimate plant cover in these communities is the field linear transect method. But aerial photoimage analysis can be a good approach to determine *Halocnemum* areas of medium density. It can be used to evaluate the structure and environmental conditions of *Halocnemum* stands in its global distribution area. Accuracy of vertical photograms needs to be improved for estimating plant cover reliably. Differences in total plant cover using this and the field transect methods in one of the Tunisian stations showed that a larger number of photograms must be used to increase the accuracy of estimates.

Research in *Halocnemum strobilaceum* communities conducted in other countries showed different results. In Asia Minor, low values of *Halocnemum* cover were found, as for example 11,3 % in Kuwait (Abbadi & El-Sheikh, 2002) or 10 % in Iran (Breckle, 1983). In North Africa, maximum values of 15 % were found in Egypt (El-Din et al., 1993) and in Europe the highest plant cover values for the species were found in the Volga river delta, with 30% (Golub & Corbadze, 1989). No studies were found in the western Mediterranean region.

Halocnemum strobilaceum seems to be a species with a very specific habitat preference. It is an extreme halophyte that is best adapted to this type of environmental conditions. Based on field observations, however, the plant can grow in less saline ecosystems, and can be excluded by competition of other halophytes or non halophytes (Ungar, 1998). Therefore *Halocnemum* can occur in its favourable high saline habitat, in a less saline habitat and even in non-saline ones (if environmental changes took place). Therefore, a variety of communities and formations have *Halocnemum* as their common factor, but other characteristics like plant species composition, community structure, morphotypes or hydrological dynamics can vary.

Halocnemum's ecological value also comes from the diversity of associated plant and animal species. Different approaches may be followed to conserve biodiversity reservoirs associated to *Halocnemum* in the different countries studied. In the two European sites, *Halocnemum strobilaceum* is considered a rare plant species of great interest and it is catalogued as vulnerable in their respective Endangered Plants Red Lists. In fact, distribution of the species is very punctual with just three localities in Spain and four in Italy. There, the plant will have an intrinsic conservation value, and the appearance of other rare species in the community could be added value. In Tunisia, as in many Asian sites, the conservation scenario is very different. There, the species has an extensive habitat and distribution range due to climatic conditions and to the lack of human pressure on soils with high salinity. For this reason the plant is considered common and unprotected by law. Its conservation value may then be related to the presence of endangered species that may be associated with *Halocnemum*. This could be the case of areas surrounding coastal lagoons, where *Halocnemum* appears mixed with some rare *Limonium* species and forming a complex system of beaches – sand dune systems – coastal lagoons – halophytes steppes, that must be taken into account in conservation and management planning in the region. As in other Mediteranean countries urban tourism-related developments are completely modifying land and destroying ecological characteristics of these coastal ecosystems and landscapes. Nevertheless, the demand for land is still higher in the inland Chotts and/or Sebkhas than in the coastal ones.

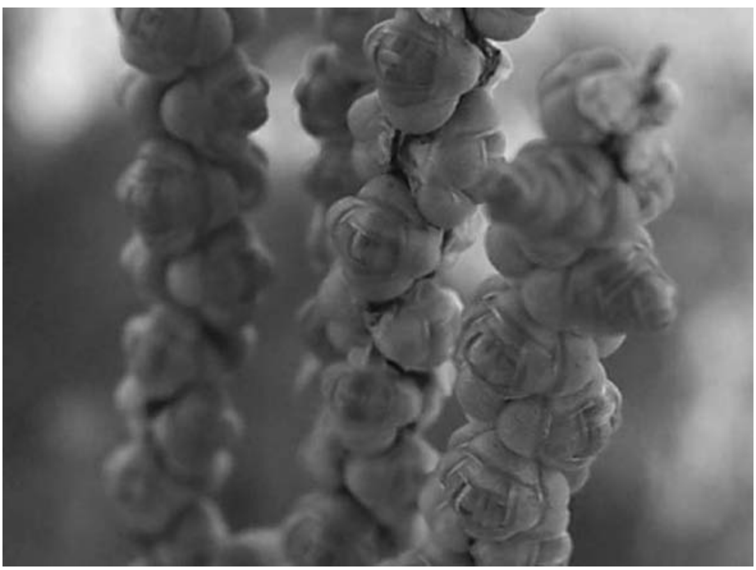
Halocnemum strobilaceum as a potential flagship species

These considerations lead us to evaluate if this species could be a good flagship, umbrella or just indicator species. Because of its strong relationship with particular environmental conditions, *Halocnemum* could be used as an indicator species. For example, the hydrological conditions of a particular place can be evaluated by studying the morphotypes of this plant community. By monitoring changes in plant community health, we could be able to prevent early ecosystem damage. Hence, it could be used with this objective in all sites.

When the flagship species label is used, important differences will be found between sites. The flagship species concept has been used mainly in conservation programs for large animals. It can be applied to conserve other species, but the flagship species has to be very singular and with possibilities of becoming popular in diffusion campaigns. Plant species are not very commonly used as flagship species, but in a place where the plant is scarce and endangered this could be a good solution. Such is the situation in La Maremma (Italian site), where *Halocnemum* is very rare and is threatened by Ombrone's River delta erosion and by infrastructures built to stop this coastal process. In the Spanish site, the species has been artificially restricted to the limits of El Hondo Natural Park. Here, it can be used as a flagship species for the wet and dry halophyte formations or in combination with other animal species. For example, the insect of the Carabidae family *Megacephala euphratica*, a rare beetle that was proposed for inclusion in the Spanish Red List of Endangered Species, appears in El Hondo. In the Tunisian site, a different strategy has to be used. It is necessary to identify subunits in the formations of *Halocnemum* that could have more singular characteristics. Protecting the very large area where the species occurs is incompatible with other societal demands. Nevertheless, pointing out relevant subunits as part of a coherent landscape mosaic would help the public understand large-scale ecological processes. Explaining how dynamics in space and time affect the spatial distribution of *Halocnemum* would be an enlightening example for the sustainable management of coastal areas. It is important to stress the links among landscape components and management decisions. The consequences of where to locate a harbour in a very dynamic coast, as it is the case in Gar el Melh would be a very useful and illustrative example. The oldest formations or those ones with rare species, must be taken into account.

As seen in Figure 9, *Halocnemum strobilaceum* is a species aesthetically appealing due to the curious alternate branching pattern and pseudo-brachyblast aspect of its branches. It is different to the rest of halophytes and very photogenic.

Figure 9. Detail of *Halocnemum strobilaceum* stems with alternate branches. These lateral branches seem brachyblasts (lateral branches with limited, genetically defined growth in length) but we have observed that depending in the environmental conditions many of them can grow longitudinally in consecutive seasons. The crassulacean aspect of leaves give the impression of thickened buds. This morphological pattern, besides being photogenic, helps to easily identify the species among other halophytes by non-specialists.



Finally, more knowledge about characteristics of *Halocnemum* communities would help improve environmental management of the sites studied. These halophyte communities are exposed to environmental impacts (such as agricultural land expansion, tourism, urban development, soil pollution or coastal erosion) that can deteriorate their condition and could lead to severe biodiversity loss. Compatible management and conservation practices are needed to maintain these habitats under future scenarios. The dominant ones, at the moment, show a destruction of coastal wetlands, which are being rapidly dried out and only conserved in old pictures or paintings in dining-rooms of hotels. It is necessary to explore alternatives for combining urbanisation and conservation; and developing mosaics where coastal water bodies are incorporated as natural assets in a new landscape design compatible with the conservation of these important ecosystems. Integrated coastal zone management will be one of the most important challenges for the Mediterranean in the next fifteen years at least.

In coastal management scenarios, there is a need for easily identifiable species in the terrestrial and transition compartments of these wetland ecosystems that help the conservation of the entire community. If small and rare species were to be found in the specific communities, *Halocnemum strobilaceum* might be used as a potential umbrella species candidate for their conservation (Simberloff, 1998).

Conclusion

There are evident differences of *Halocnemum strobilaceum* formations between and within the three study sites. Differences are seen in terms of proportion of morphotypes, plant species composition, plant structure and environmental conditions. Formations with more saline conditions and high inundation periods have lower plant cover. On the contrary, less saline and drier places present higher cover and vertical development.

Linear transects are the most reliable method for estimating plant cover. Aerial ortophotograph analysis has potential to be used in the preliminary characterization of halophyte communities in large areas and multiple locations of its biogeographical distribution.

Halocnemum strobilaceum's formations can include other species that enhance the conservation value of these communities. Strategies for the conservation of land-seawater transitional ecosystems with high salt content and seasonal water accumulation can use *Halocnemum* as a flagship species. Depending on their specific conditions and characteristics, this species can be used alone or in association with other species or habitat characteristics.

Further studies must be carried out to better understand *Halocnemum strobilaceum*'s dynamics and biodiversity status outside the locations considered in this study along the Mediterranean basin and adjacent areas, in order to holistically conserve the biological diversity of these singular plant formations.

The salinity/inundation ecotones linked to lagoons and other water bodies are rapidly disappearing due to important tourism-related pressures in Mediterranean coastal environments. So it is urgent to define their rarity index.

Due to its community dominance, its pioneering character in extreme conditions, and being a woody perennial of aesthetic appeal, *Halocnemum* *strobilaceum* can be considered an optimal candidate flagship species for the conservation of ecological diversity in coastal lagoon landscapes.

As an indicator species many structural characteristics of *Halocnemum* stands can be used to define specific environmental regimes and disturbance patterns. However, there is a need to increase our knowledge about associated species in these apparently homogeneous but extreme habitats in order to use *Halocnemum strobilaceum* as an umbrella species.

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MACROINVERTEBRATE DIVERSITY IN CULTIVATED AND UNCULTIVATED SOILS IN RELATION TO ENVIRONMENTAL FEATURES IN THE MAREMMA REGIONAL PARK (GROSSETO, ITALY)

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Abstract: Near the Ombrone River mouth (Grosseto, Italy) groundwater withdrawal and sea water ingression have caused secondary soil salinization. Clover and wheat production in this area is low as a direct result of these processes. An inspective analysis on soil macro- and mesoinvertebrate communities was conducted in June and September 2007 in the Alberese Regional Farm in the Maremma Regional Park near to the Ombrone River, to investigate the relationships of macrofauna, cropping practices and soil features. Localities characterized by rich or poor crop production were chosen and soils with different characteristics (texture, salinity and pH) compared. Pitfall traps were positioned in eleven different sites to collect macroinvertebrates, and soil samples were collected to extract mesoinvertebrates with a Berlese-Tullgren extractor. There was no clear spatial trend across the sampled sites, from the river mouth inland; nevertheless relationships were found between macrofauna and mesofauna diversity, vegetation, season and soil features, such as salinity and pH.

Introduction

Water uses and climate change can affect the environment and induce alterations, such as drying up of fresh water springs and saltwater ingression in the groundwater table. The case of coastal areas, where groundwater resources are near to salty basins, is typical (Bear *et al.*, 1999). Massive freshwater extraction associated with fault structures can cause salty water intrusion and the mixing of salty and fresh water can deeply affect the environment and crop performance.

The Ombrone River low plain, partly included in the Maremma Regional Park (Grosseto, Italy), is one of these threatened areas. This plain was in the past a marine gulf that naturally evolved in a marshland, with progressive progradation due to the deposits of the Ombrone and Bruna rivers (Innocenti & Pranzini, 1993). Around the eighteenth century drainage of the marshes was carried out through infilling, and now the Consorzio di Bonifica (Land Reclamation Consortium) is the organization in charge of land maintenance works and fresh water management in this coastal area. On the seaward side, coastal erosion caused by the

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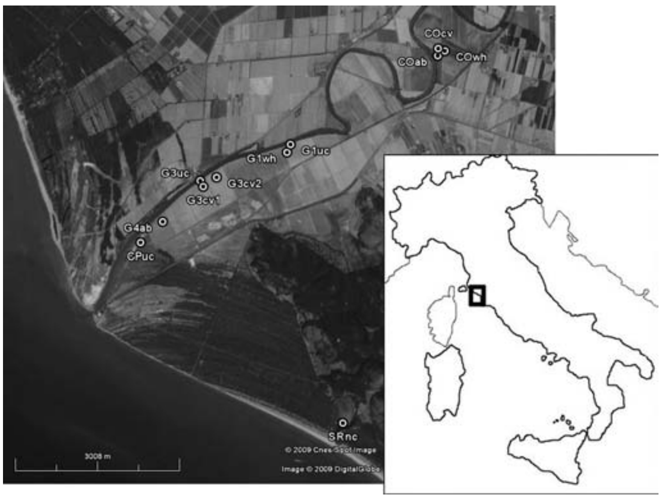
diminishing contribution in sediments of the two rivers, has had a large impact on the area and the consequence is the retreat of the coastline. The phenomenon mainly occurs south of the Ombrone River mouth (Pranzini, 2001). A further source of impact is fresh water withdrawal from the groundwater table for various human uses (mainly for urban and agricultural uses). The consequence of freshwater withdrawal is marine water intrusion in the groundwater table, resulting in secondary soil salinization where irrigation is practised. The visible result of irrigation with this salty water is the recession of the crop area year by year (Bucciantini & Nuvoli, 1998). In this area of Tuscany, the struggle to protect soils from salinization and from sea erosion is a very topical problem, and conflicts between nature conservation and increasing human activities are emerging. The aim of the Park is the preservation of biodiversity and of the natural environment, while that of the Alberese Farm is to produce crops and forage. The impacts on biodiversity caused by agronomic techniques are well known. Fertilisers, pest control chemicals, tillage and even crop rotation have been shown to profoundly impact the richness and diversity of agricultural ecosystems (Beringer, 2000; Ross *et al*,. 2002) and consequently they deeply influence the species richness of wild flora and fauna (McLaughlin & Mineau, 1995). Differences in community composition even within the same invertebrate order have been highlighted in relation to different kinds of vegetation or cropping practices (Warren & Zou, 2002; Argyropoulou *et al*., 2005; Schuldt *et al*., 2008); in particular soil-invertebrates react differently to different land use types (Parisi *et al*., 2005). Within the Maremma Regional Park, the Alberese Farm manages the land and the organically cultivated fields along the Ombrone River, for the greatest part producing organic fodder for the local breeds of cows and horses. From the river mouth to a few kilometers upstream, no irrigation is practised. However salt efflorescences are visible in some localities near the river mouth, probably due to saline water intrusion between soil layers. Uncultivated areas are rare in this region excluding those unproductive soils near to the coastline that have been abandoned because of saltwater intrusion. There is a progressive abandonment of cultivated fields and where traditional crop cultivation such as maize and clover is no longer practicable, land is assigned to pasturage.

The main aim of this preliminary study was to investigate the relationships between arthropod biodiversity and soil tillage and salinization, considering that the main aim of the protected area is preserving biodiversity. With this research we wanted to clarify the disturbance level for arthropodofauna in an organic cultivated area where soil salinization problems were noted. The detection of salinity bioindicators was desirable considering the poor literature concerning salty soil effects on arthropod communities.

Materials and Methods

We considered an area along the Ombrone River course from the river mouth to about 9km upstream, with different cropping practices and where different soil salinization levels were expected, based on observations by land owners and the Alberese Farm workers.

Figure 1. Sampling sites within the Maremma Regional Park (Italy). (42°40'54"N, 11°03'28"E, Google Earth™, v 4.0.2722). See Table 1 for identification of sampling site.



The samples were collected in May-June 2007 and in September–October 2007. Within the area of the Alberese Farm 11 sampling sites were chosen (Figure 1) with different characteristics related to soil use and salinization affecting crops (organically cultivated, uncultivated, abandoned, Table 1). Organic cultivation in this area relies on crop rotation and mechanical cultivation to maintain soil productivity and control pests, strictly limiting the use of synthetic fertilizers, synthetic pesticides and plant growth regulators. No genetically modified organisms are used. All the cultivated plots sampled in this study were organic. The uncultivated plots were small grasslands along the river course, or cultivated fields abandoned at least 20-25 years ago (Campo al Pino, CPuc, Fig. 1). Were considered abandoned plots those that were cultivated or where there was some kind of soil tillage until 10 years ago. In each sampling site two samples were taken, both using pitfall traps (for walking macroinvertebrates as coleopterans and spiders), and by Berlese-Tullgren extraction (for ground-dwelling mesoinvertebrates as mites and springtails). The first sample was taken not less than 10m from the second one, and both were collected at least 10m away from the field border. The choice of 10m was a compromise between the necessity of avoiding edge effect and the limited field dimensions.

Table 1. Sampling sites within the Azienda di Alberese area (see also Fig. 1).

	locality	site	soil use
1	Corsica	COcv	clover
2		COwh	wheat
3		COab	abandoned (ex-quarry)
4	Golena 1	G1wh	wheat
5		G1uc	uncultivated
6	Golena 3	G3cv1	clover1
7		G3cv2	clover2
8		G3uc	uncultivated
9	Golena 4	G4ab	abandoned
10	Campo al Pino	CPuc	uncultivated
11	Serrata	SRuc	uncultivated

The distance from the river mouth decreases from 1 to 10. Serrata is in the southern part of the Park

Each set of pitfall traps was composed of 5 transparent polystyrene glasses (diameter 9cm, height 13cm) positioned in a cross each one 1m away from the others and filled with about 2cm of soil. No preservative liquids or baits were used since the traps were kept active for only 24h and the aim of sampling was to detect the real invertebrates' frequency.

Close to each set of traps a soil core of 10x10cm and 10cm deep was collected (Borcard, 1991; Parisi *et al*,. 2005). The depth of 10cm was chosen based on literature. Since Benito *et al* (2004) reported that approximately 80% of invertebrates are concentrated in this first soil layer. The soil samples were preserved in separated plastic bags for no more than 48 hours before putting them individually on Berlese-Tullgreen funnel extractors at the Evolutionary Biology Department in Florence. The extractor was composed of a 35cm diameter funnel with a 2-3mm mesh to support the soil sample. A 40W lamp was positioned at about 20-25cm above the soil sample. The samples were positioned under the light for 7 days to perform the complete extraction (the length of a 7 days extraction was defined during the May-June sampling, removing the extracted arthropods and controlling every 2 days for the presence of new individuals). The arthropods were collected in small jars containing 2cm of alcohol 75%.

On the dry soil sample processed with the Berlese-Tullgren extractor, salinity, pH and texture were measured. The salinity diagnosis of the soil was performed through the determination of electrical conductivity of a water-soil suspension (expressed as mS/cm) using the conductivity method in distilled water with 1:5 ratio.

Laboratory identification of macroinvertebrates was done at least up to family level and up to genus and species level when possible; mesoinvertebrates were identified up to order level and further identification was done by morphotypes depending on their adaptation to soil habitat following the QBS index that attributes higher scores to soil-dwelling arthropods (Parisi *et al.*, 2005; Angelini *et al.*, 2002).

Biodiversity indexes, Cluster, MDS and SIMPER analysis were performed using the software Primer v. 6.0. Community descriptors were species number (S), the Shannon diversity index ($H'=-\sum P_i \log_e(P_i)$) and Pielou's evenness index ($J'=H'\log_e/S$). The analysis of similarity percentage (SIMPER) was carried out on square root transformed data using a threshold of 10% of contribution to define typifying species and of 5% to define discriminating species (Rueda & DeFeo, 2003).

For the regression analysis of soil invertebrates a rank was attributed to sites related to increasing impact on biodiversity, i.e. disturbance to arthropods' survival in the soil. Salinity, soil tillage and ploughing and high sandy component in soil texture were considered disturbing to mesoinvertebrates' survival based on literature (Neave & Fox, 1998; McKenzie *et al.*, 2003; Gregory *et al.*, 2005). Clover cultivation was considered more invasive than cereal cultivation, since seeding bed preparation is more invasive in clover (ploughing reaches 45cm depth in the soil) than in cereals. Abundant orders such as Formicidae, Acarida and Collembola were kept in the analysis to highlight seasonal community differences. To avoid the over-domination of the resulting analysis by the very abundant and common species an initial square root transformation was carried out on the data sets. Flying insects like Hymenoptera and Diptera were discarded from the analysis, as the sampling was not conceived to collect these taxa.

Results

The environment

During the 2007 spring and summer a low level of precipitation was recorded (Table 2) with the lowest amount of rain in July and the highest in May. A progressive drought of the area was observed from June to September, with a drastic change in vegetation cover. In September herbaceous plants were dry as a result of seasonal processes.

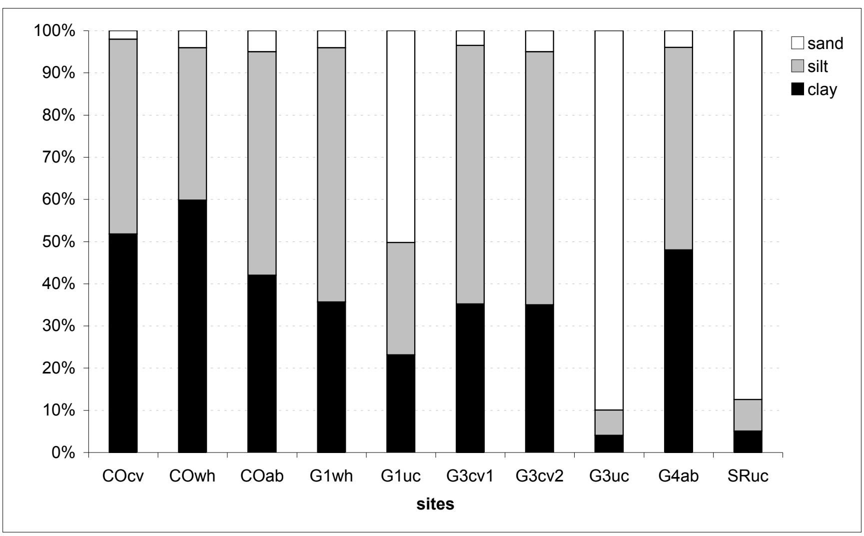
Most of the soil samples were classified (following the USDA classification) as fine or moderately fine soils for their high percentage of clay, except for the samples along the river bed and those in the Park protected area that were classified as coarse soils due to their high sand percentage (Fig. 2).

Table 2. Rain precipitations in mm before and during the samplings.

months	no. of rainy days	amount (mm)
April	3	7.60
May	9	55.00
June	3	18.80
July	0	0.00
August	8	26.00
September	2	10.20

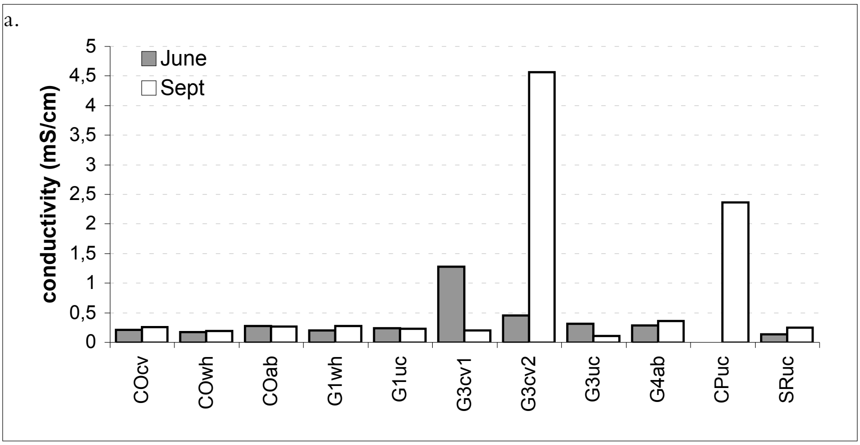
Data from LaMMa (Laboratory of Monitoring and Environmental Modelling).

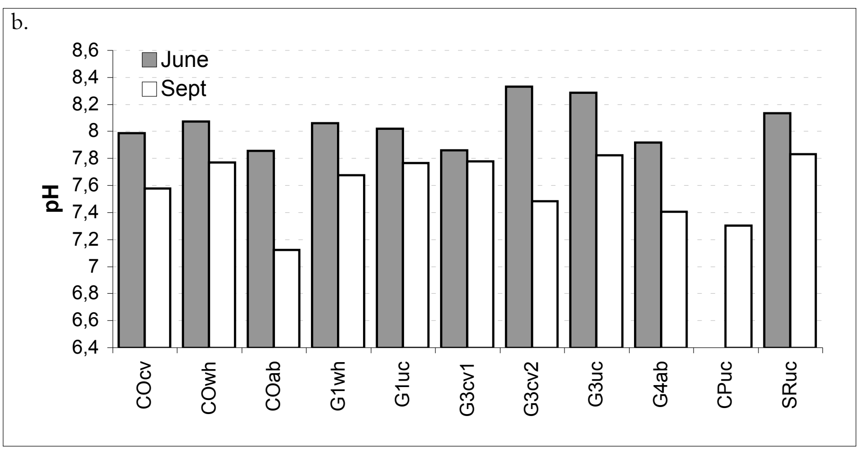
Figure 2. Soil texture with sand, silt and clay percentage in each sampling site.



A general increase in soil salinity and decrease in pH were observed from June to September (Fig. 3) but no gradient related to the distance from river mouth was apparent. In the sites G3cv1, G3cv2 and CP a relevant higher salinity was measured compared to the other sites. The first two sites were characterized by saline efflorescences and in CP a Salicornietum association was well established.

Figure 3. Soil features. Soil salinity as conductivity in mS/cm (a) and soil pH (b) in June (grey) and September (white).





The communities

Pitfall traps

Dominant taxa in cultivated fields in June were Araneae in clover fields and Coleoptera in maize fields (Table 3), while in abandoned and uncultivated fields dominant groups were Acarida, Collembola, Hymenoptera (Formicidae), Isopoda and Opiliones. In September the scene completely changed for the cultivated fields where Formicidae greatly dominated as in most of the other sampling sites (Table 3).

Table 3. Dominant groups captured with the pitfall traps in June and September. Percentages of dominance in each site are reported.

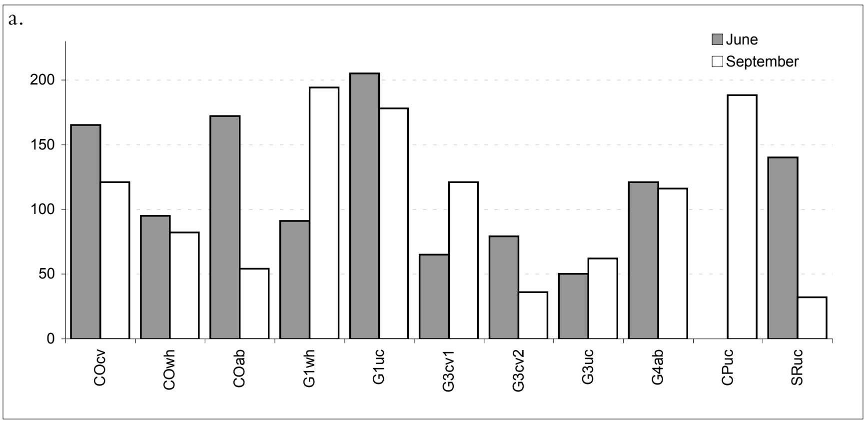
JUNE					SEPTEMBER			
Site	Order	Family	Species	%	Order	Family	Species	%
COcv	Araneae	Lycosidae	*Pardosa proxima*	19	Hymenoptera	Formicidae	Formicidae sp20	57
	Coleoptera	Carabidae	*Brachinus immaculicornis*	13	Hymenoptera	Formicidae	Formicidae sp16	12
	Araneae	Titanoecidae	*Nurscia albomaculata*	5				
COwh	Coleoptera	Carabidae	*Harpalus oblitus*	27	Hymenoptera	Formicidae	Formicidae sp12	26
	Araneae	Lycosidae	*Pardosa sp1*	7	Thysanura	Thysanura	Thysanura sp1	9
	Araneae	Linyphiidae	*Prinerigone vagans*	6	Hymenoptera	Formicidae	Formicidae sp14	7
	Araneae	Gnaphosidae	*Drassodes cupreus*	5	Acarida	Acarida	Acarida sp2	6
	Araneae	Linyphiidae	*Linyphiidae sp2*	5				
Coab	Isopoda	Isopoda	Isopoda sp3	24	Diplopoda	Diplopoda	Diplopoda sp1	24
	Collembola	Entomobry-oidea	Entomobryoidea sp6	9	Araneae	Lycosidae	*Pardosa proxima*	17
	Collembola	Entomobry-oidea	Entomobryoidea sp2	8	Coleoptera	Carabidae	*Pterostichus macer*	15
	Diplopoda	Diplopoda	Diplopoda sp1	8	Coleoptera	Lampyridae	Lampyridae Larvae sp1	6
	Isopoda	Isopoda	Isopoda sp2	6	Hymenoptera	Formicidae	Formicidae sp9	6
					Hymenoptera	Formicidae	Formicidae sp15	6
					Isopoda	Isopoda	Isopoda sp4	6
G1wh	Coleoptera	Carabidae	*Harpalus oblitus*	26	Hymenoptera	Formicidae	Formicidae sp7	47
	Araneae	Linyphiidae	Linyphiidae sp2	8	Collembola	Entomobryoidea	Entomobryoidea sp6	14
	Araneae	Lycosidae	*Pardosa proxima*	5	Opilionida	Opilionida	Opilionida sp6	6
	Araneae	Linyphiidae	*Prinerigone vagans*	5	Coleoptera	Carabidae	*Scybalicus oblongiusculus*	5

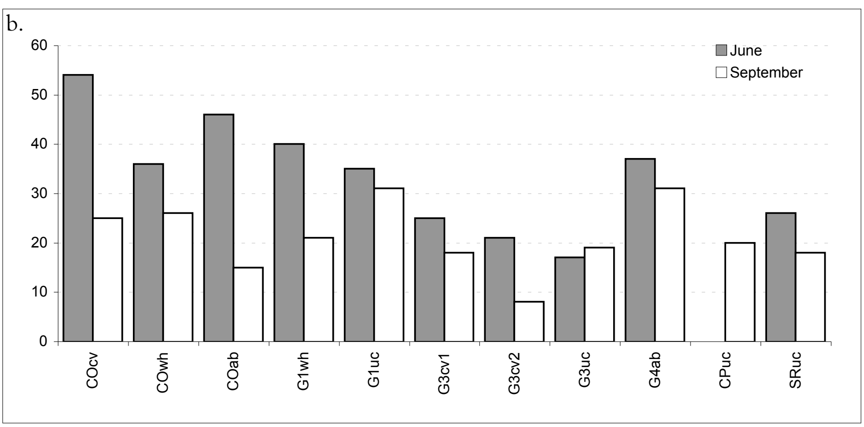
JUNE					SEPTEMBER			
Site	Order	Family	Species	%	Order	Family	Species	%
G1uc	Acarida	Acarida	Acarida sp5	28	Collembola	Entomobryoidea	Entomobryoidea sp2	51
	Acarida	Acarida	Acarida sp1	10	Hymenoptera	Formicidae	Formicidae sp15	7
	Coleoptera	Carabidae	*Harpalus serripes*	6	Hymenoptera	Formicidae	Formicidae sp14	6
	Collembola	Entomobry-oidea	Entomobryoidea sp1	6	Hymenoptera	Formicidae	Formicidae sp10	5
	Coleoptera	Carabidae	*Bembidion tethys*	5				
	Hymenoptera	Formicidae	Formicidae sp1	5				
G3cv1	Araneae	Linyphiidae	Linyphiidae sp1	22	Hymenoptera	Formicidae	Formicidae sp7	82
	Araneae	Lycosidae	*Pardosa agricola*	9				
	Araneae	Lycosidae	*Pardosa proxima*	9				
	Araneae	Linyphiidae	*Prinerigone vagans*	6				
	Hymenoptera	Formicidae	Formicidae sp12	6				
G3cv2	Araneae	Lycosidae	*Pardosa proxima*	19	Hymenoptera	Formicidae	Formicidae sp7	42
	Araneae	Linyphiidae	*Prinerigone vagans*	18	Hymenoptera	Formicidae	Formicidae sp6	22
	Araneae	Linyphiidae	Linyphiidae sp1	16	Dermaptera	Dermaptera	Dermaptera sp1	14
	Hymenoptera	Formicidae	Formicidae sp1	11	Opilionida	Opilionida	Opilionida sp6	8
	Araneae	Lycosidae	*Pardosa agricola*	6	Coleoptera	Tenebrionidae	Tenebrionidae sp3	6
	Araneae	Linyphiidae	Linyphiidae sp2	6				
G3uc	Hymenoptera	Formicidae	Formicidae sp5	40	Hymenoptera	Formicidae	Formicidae sp7	50
	Acarida	Acarida	Acarida sp1	20	Opilionida	Opilionida	Opilionida sp4	10
	Anfipode	Talitridae	Talitridae sp1	6	Hymenoptera	Formicidae	Formicidae sp1	6

JUNE					SEPTEMBER			
Site	Order	Family	Species	%	Order	Family	Species	%
G4ab	Opilionida	Opilionida	Opilionida sp4	18	Hymenoptera	Formicidae	Formicidae sp7	53
	Hymenoptera	Formicidae	Formicidae sp1	10	Opilionida	Opilionida	Opilionida sp1	7
	Collembola	Entomobry-oidea	Entomobryoidea sp2	9	Collembola	Entomobryoidea	Entomobryoidea sp2	7
	Araneae	Lycosidae	*Pardosa proxima*	8				
	Acarida	Acarida	Acarida sp1	8				
	Opilionida	Opilionida	Opilionida sp3	7				
CPuc					Hymenoptera	Formicidae	Formicidae sp7	34
					Hymenoptera	Formicidae	Formicidae sp5	17
					Hymenoptera	Formicidae	Formicidae sp1	12
					Hymenoptera	Formicidae	Formicidae sp18	12
					Araneae	Lycosidae	*Pardosa proxima*	10
SRuc	Acarida	Acarida	Acarida sp3	34	Hymenoptera	Formicidae	Formicidae sp2	31
	Hymenoptera	Formicidae	Formicidae sp2	22	Hymenoptera	Formicidae	Formicidae sp14	9
	Coleoptera	Scarabaeidae	Scarabaediae sp4	7	Coleoptera	Carabidae	*Amara aenea*	6
	Coleoptera	Anthicidae	Anthicidae sp2	6	Collembola	Entomobryoidea	Entomobryoidea sp1	6
					Hymenoptera	Mutillidae	Mutillidae sp1	6

In 7 out of 10 sites the abundance of invertebrates decreased from June to September (CP was excluded from this analysis since we only had September data for this site, Fig. 4a). The highest abundances were found in June in G1nc with a high contribution of Acarida, in September in G1wh with a high number of Formicidae and Collembola and in CPnc with different species of Formicidae.

Figure 4. Abundance (a) and number (b) of total species in each site of collection in June (gray) and September (white).





The highest number of species in June was found in the cultivated COcv sample and in 9 out of 10 sites the number of species in September was lower than in June (Fig. 4b). Ranking the sites following the Shannon index, the highest biodiversity was found in the cultivated ones in June, whereas in September the highest biodiversity was observed in abandoned and uncultivated fields. Biodiversity Shannon index (S) of total arthropods and of Coleoptera was negatively correlated with increasing pH in June (F-statistic, $p<0.01$ for both, Table 4). In September both Shannon and Pielou indexes for Araneae were negatively correlated with salinity (F-statistic, $p<0.01$ and $p<0.05$ respectively, Table 4) and in the same group Pielou and Simpson were positively correlated with pH (F-statistic, $p<0.01$, Table 4).

Table 4. Linear regression analysis between biodiversity indexes for macroinvertebrates and salinity and pH in June and September.

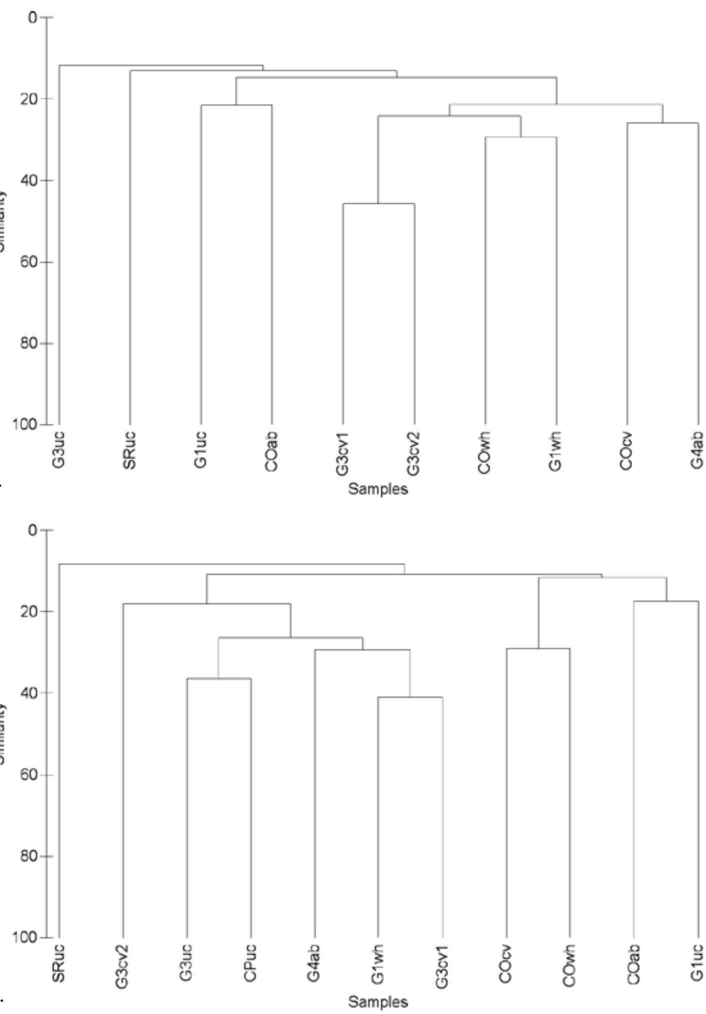
			June 2007			September 2007		
			coefficient	R^2	p	coefficient	R^2	p
salinity	Arthopods	Shannon	-0.0342	0.0009	—	-0.0886	0.0671	—
		Pielou	0.0839	0.300	↗	0.0216	0.0365	—
	Arachnida	Shannon	0.0588	0.0009	—	-0.2699	0.5026	** ↘
		Pielou	-0.0303	0.0268	—	-0.1255	0.4152	* ↘
	Coleoptera	Shannon	0.2987	0.035	—	-0.2282	0.2302	↘
		Pielou	0.241	0.2125	↗	0.0109	0.009	—
pH	Arthopods	Shannon	-1.7231	0.5285	** ↘	-0.0819	0.001666	—
		Pielou	-0.1639	0.267	↘	-0.1458	0.04815	↘
	Arachnida	Shannon	-1.9701	0.2417	↘	0.7421	0.1104	—
		Pielou	0.0176	0.001567	—	0.3928	0.5487	** ↗
	Coleoptera	Shannon	-2.399	0.5266	** ↘	1.2678	0.2066	↗
		Pielou	0.0036	1.13E-05	—	0.3167	0.2114	↗

Arrows indicate direction of tendency line with increasing salinity and pH.
* = $p\leq0.05$, ** = $p\leq0.01$, *** = $p\leq0.001$

Cluster analysis on the whole arthropodofauna in June (Fig. 5a) pooled clover plots in the Golena 3 with an average similarity of 45.8% mainly provided by arachnid species belonging to Linyphiidae and Lycosidae families. Typifying macroinvertebrate species in June analysis of similarities for the group G3cv1-G3cv2, based on Bray-Curtis similarity matrix, were Linyphiidae sp1 (contributing with 21.94%) and two species of Lycosidae, *Pardosa proxima* and *P. Agricola*, with respectively 14.90% and 13.60%. Maize fields are grouped by the presence of the Carabidae coleopteran *Harpalus oblitus* (contributing with 31.87%) and of Linyphiidae (*Prinerigone vagans* and Linyphiidae sp2 both contributing with 14.55%) and Lycosidae arachnids (*Pardosa proxima* with 13.01%). The uncultivated sites in the Golena 3 and in Serrata produced very different results from all the other sites for the presence of mites and ants and the absence of the arachnids and coleopterans that characterized the other sites (Fig. 5a). The main difference concerning the community structure of these two sites was with groups COwh-G1wh and G3cv1-G3cv2. The dissimilarity level of about 90% was mainly given by the presence of Formicidae and Acarida characterizing the sites G3uc and SRuc and by the absence in these sites of the species typifying the COwh-G1wh and G3cv1-G3cv2 groups. The group COcv-G4ab was around 85% of dissimilarity with G3uc and SRuc, also for the low abundance of Acarida and Formicidae within the group and presence of *Pardosa proxima*.

In September the situation changed: the Corsica sites and the Golena 1 uncultivated site were grouped together. Ants became the discriminant species being the most abundant taxonomic group (Table 3). The second clover site (G3cv2) was isolated from the first Golena 3 clover site, which in turn was most similar to the 1st maize Golena 1 field (Fig. 5b).

Figure 5. Dendrograms representing the cluster analysis for all macroinvertebrates samples based on Bray-Curtis similarity coefficients in June (a) and in September (b).



a.

b.

Berlese-Tullgren funnel extraction

A positive significant correlation was found in September between Pielou index and salinity (F-statistic, $p<0.01$) and a negative correlation was found between Shannon index and pH (F-statistic, $p<0.05$) (Table 5). There was no correlation between QBS index and salinity or pH, nor with increasing impacts on sites.

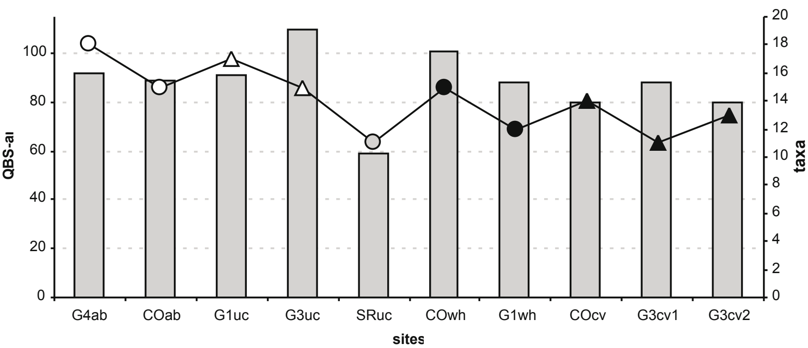
Table 5. Linear regression analysis between biodiversity indexes for soil invertebrates and salinity, pH and rank order.

		June 2007				September 2007			
		coefficient	R^2	p		coefficient	R^2	p	
salinity	Shannon	-0.0209	0.000519	0.9502	—	-0.0305	0.00708	0.8057	—
	Pielou	0.0298	0.01028	0.7805	—	0.0827	0.4945	0.02329	** ↗
	QBS	2.5998	0.004202	0.8588	—	-8.5241	0.1608	0.2216	—
pH	Shannon	-0.9243	0.2363	0.1543	—	-1.3244	0.3887	0.04042	* ↘
	Pielou	-0.2966	0.2368	0.1538	—	-0.3423	0.228	0.1628	↘
	QBS	1.7713	0.000455	0.9534	—	-49.1201	0.1552	0.2306	—
ranks	Shannon	-0.0776	0.5758	0.01094	** ↘	-0.0413	0.07355	0.4198	—
	Pielou	-0.0214	0.4271	0.04042	* ↘	0.0033	0.004488	0.8541	—
	QBS	-1.1758	0.06922	0.4627	—	-2.9909	0.1117	0.315	—

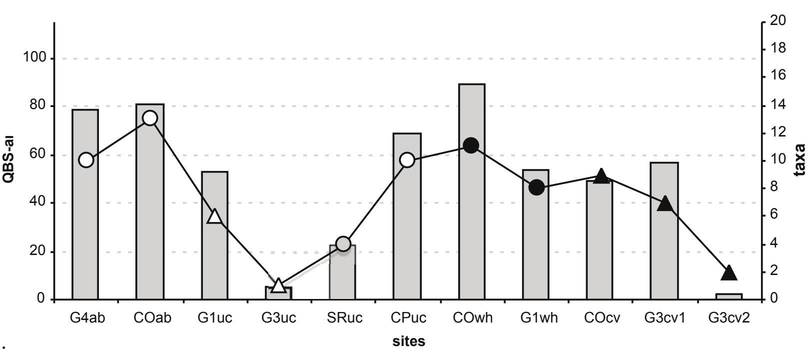
Arrows indicate direction of tendency line with increasing salinity, pH and rank order. * = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$

Negative correlations between Shannon and Pielou indexes and sites ranked according to increasing disturbance were significant in June (F-statistic, $p<0.01$ and $p<0.05$ respectively) (Table 5). QBS index had a low variability in June even if it was slightly lower in cultivated fields and very low in site SRuc. The index considerably changed from June to September (Fig. 6). In September the sites G3uc and G3cv2 lost almost all their soil-dwelling arthropods, since GBS at SRuc was visibly lower than in June and the number of taxa also clearly decreased (Fig. 6a, b). The two main groups in June based on a Bray Curtis resemblance matrix were G3cv1 together with SRuc separated by all the other sites. Acarida Oribatida, Collembola Enthomobrioidea and Acarida Gamasida contributed to similarity and discriminated in analysis of dissimilarity between the main groups and single sites and within groups (Fig. 7a) and were the most abundant in group G3cv1-SRuc (46% average dissimilarity with the other sites). In September the scene completely changed also for soil invertebrates as for macroinvertebrates captured with the traps (Fig. 7b): G3cv2 and G3uc were completely separated from all the other sites with an average dissimilarity of about 100% for the absence in these sites of Acarida Oribatida, Gamasida and Collembola entomobrioidea. Two main groups can be recognised among the nine remaining sites, the first one grouping the Corsica sites, Campo al Pino and the cultivated Golena 1 with a similarity of 63%, and the second one grouping the first cultivated Golena 3 (G3cv1) with the remaining uncultivated and abandoned sites with a similarity of 60% (Fig. 7b). Even if in September the same taxa as in June pooled the sites, coleopteran larvae and Carabidae, present in many sites, and Tenebrionidae (in G3cv2), contributed to dissimilarity among G3cv2, G3uc and the other sites.

Figure 6. QBS index and number of taxa of soil arthropods for each site. Site order is determined by increasing impact (further details in the text). In white non cultivated fields, in black cultivated fields, circles represent less impacted sites within the category, triangles represent more impacted sites within the category. (a) June 07, (b) September 07.

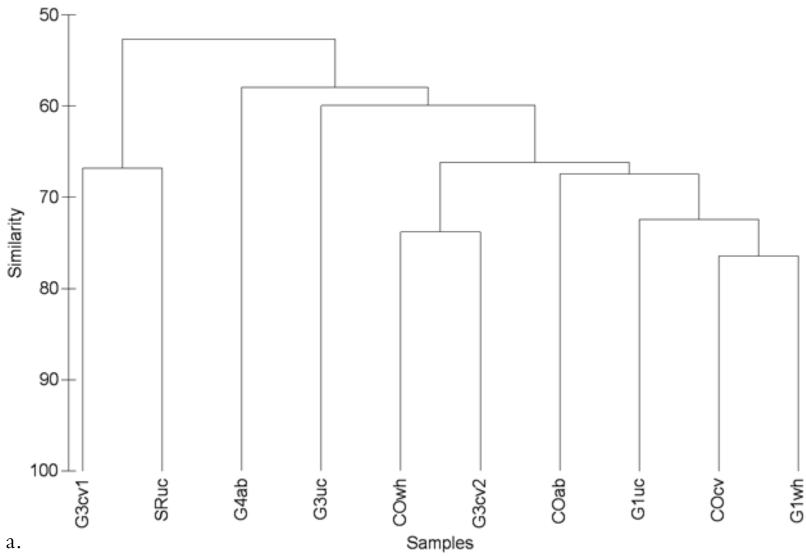


a.

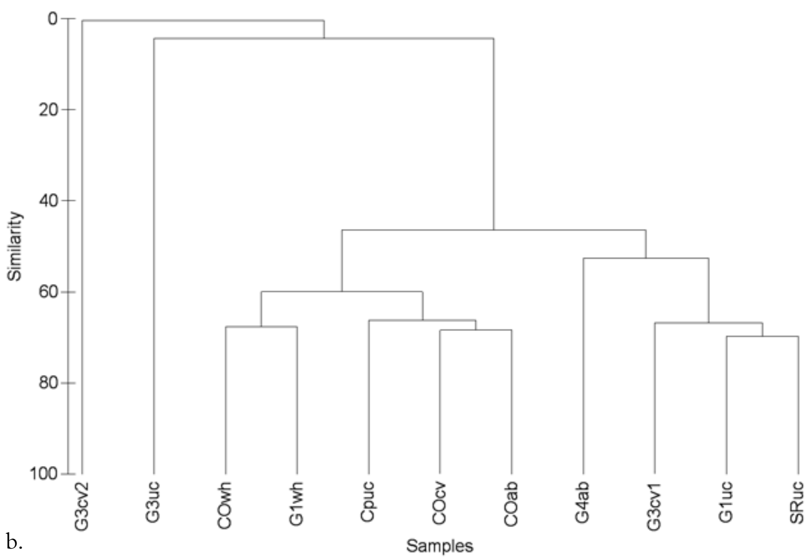


b.

Figure 7. Dendrograms representing the cluster analysis for all samples of soil invertebrates based on Bray-Curtis similarity coefficients (a) in June and (b) in September.



a.



b.

Discussion

No salinity gradient was found along the river course and soil analysis confirmed the patchy distribution of salty soils, showing that salinization was more relevant in the Golena 3, where saline efflorescences were observed, and in Campo al Pino, where halophile species *Halocnemum strobilaceum* and *Arthrocnemum macrostachyum* are the prevailing vegetation.

A seasonal environmental change with a progressive drying up of soil and vegetation was clear from June to September, and a consequent (site by site differentiated) fauna impoverishment was observed. With the drought a mean increase in salinity (more relevant in some sites such as G3cv2) and a general decrease in pH in all sites were observed (Fig. 3a, b). Maize and clover crops, providing refuge for many invertebrates and shelter against soil water evaporation, reduced the plant cover in September causing a reduction of biodiversity and change in communities in cultivated fields.

A coarse soil texture, due to a high sandy component, found along the river bed and in the Serrata locality (Fig. 2) may explain the poor water retention of the soil in these sites with obvious consequences for both flora and fauna in September when the vegetation was completely burned. In June the highest species richness was found in the Corsica clover field, where no salinization occurred and plant coverage was high. In June, species richness in the Corsica abandoned field (COab) was comparable to that of the clover plots in the same locality and in the same season showing the positive effect of pesticide-free organic agriculture. The species decrease in COab in September was remarkable, also compared to the other uncultivated and abandoned fields. On the other hand the site G3cv1 had a minimum seasonal change in number of species presenting the lowest biodiversity in June and maintaining a minimum number of species also in September. It is possible that the annual nature of most plants in COab and the salinity in G3cv1 (as well as in G3cv2) were responsible for the low density of species in each one of these sites and its further decrease.

The major results deal with the seasonal changes in community structures. The most representative groups in the cultivated fields in June were Araneae and Coleoptera. In clover plots the most common families of Araneae were Lycosidae and Linyphidae with different species of *Pardosa* and *Prinerigone* (species list available upon request), which being running spiders (the first) and flying spiders using their silk (the second), may find good refuge and hunting field in the grass carpet among clover plants. The Carabidae *Harpalus oblitus* was the characterizing species in both maize fields, which provide good refuge for its larvae, as shown by their abundance in soil samples. This genus is indeed a stenotopic carabid typical of dry soils (Wallwork, 1976). Presence of these species of Araneae and Carabidae, which are mainly predators, was greatly reduced in September in favour of species most tolerant to harsh conditions and absence of vegetation. Communities in cultivated sites that were more diverse in June, were in line with the other sites' communities in September, with Formicidae as dominant species, and Collembola and Opiliones among the characterizing species.

Coleopterans and in particular groundbeetles (Coleoptera: Carabidae) and spiders (Araneae) have been widely recommended as bioindicators (Duchesne & McAlpine, 1993; Niemelä *et al.*, 1993; Churchill, 1997; Heyborne *et al.*, 2003). In our study these groups were also the emerging taxa in those sites with highest biodiversity. Few studies have been carried out concerning relationships between invertebrates and soil salinity (Harvey *et al.*, 2004; Liu *et al.*, 2006) and limited data are available on this topic with which to compare our results.

A clear trend related to salinity was observed in arachnid diversity in September, when no spiders were found in the site G3cv2 that had the highest salinity (4.559 mS/cm) followed by the low value of the Shannon index of Campo al Pino where the salinity was 2.356 mS/cm. In the other sites salinity was lower and the Shannon index was high except for the case of G3cv1 and COab, with a limited salinity value, where the Shannon index was also low (0.950 and 0.721 respectively compared to the highest value of COcv with 1.972). The conclusion of a high sensibility of Lycosid to the soil salt content is in contrast with precedent studies by McKenzie *et al.* (2003) and Harvey *et al.* (2004) who found an increasing species richness in Lycosid spiders in soils with secondary salinity. As Pearce and Venier (2006) observed, other factors, such as the absence of shelter, may have influenced the presence of arthropods. Clover plants and low vegetation, being very sensible to high salt concentrations and to harsh conditions were present in the Golena 3 at very low densities. It does not seem that soil salinity was the major limiting factor for the coleopteran community, even if the whole system of flora and arthropodofauna seemed to be subjected to climatic seasonal changes and marine water intrusion in the soil.

Soil arthropodofauna confirmed the expectations related to impact assessment in the area. In June, when the soil tillage effect was still present and drought was not already acting on species distribution as a standardizing factor, a significant correlation was found between the Shannon index and ranks attributed to sites according to an increasing impact scale. Crop type (with clover seeding considered more invasive than maize), salt content and sand percentage influenced arthropodofauna presence, reducing Oribatida, Gamasida mites and Collembola and increasing the evenness of these taxonomic groups in September (Table 5).

Several studies suggest that biodiversity contributes to ecosystem stability, structure and productivity (*i.e.* Naeem *et al.*, 1994; Larsen, 1995; Tilman *et al.*, 1996) giving the environment higher potential resilience (Peterson *et al.*, 1998). In this part of the Maremma Natural Park the practice of organic agriculture provides a temporary source of biodiversity for above-ground running invertebrates such as Lycosidae spiders and Carabidae coleopterans. However in our study soil ploughing associated with it always has a large negative impact on ground-dwelling fauna, which is richest in uncultivated and abandoned fields.

Conclusions

The main conclusions that can be drawn from this study are the following: 1) in both seasons an increase in disturbance led to a decrease in biodiversity and evenness; 2) if organic agricultural practices favour high levels of biodiversity above soil, below-ground soil biodiversity is higher in abandoned fields; 3) a direct negative effect of salinization was observed in September on Araneae; 4) on other arthropods, no clear effect of salinization was observed, except where salt concentration was very high and vegetation was already impacted.

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SPATIAL AND TEMPORAL CHANGES IN THE COMMUNITY STRUCTURE OF A BEACH-DUNE ECOSYSTEM OF THE MAREMMA REGIONAL PARK IN RELATION TO ENVIRONMENTAL FEATURES

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Abstract: Within the Wadi Project (INCO-CT-2005-015226) a study was conducted at the Maremma Regional Park to assess how changes occur over space and time in the biotic components of the beach ecosystem in relation to salt water intrusion. Changes in macroinvertebrate diversity and plant biomass were analysed according to their height from the water table and to their distance from the sea taking into account substrate features, vegetation type, water quality and seasonality. The study site was chosen at about 1 km to the south of Collelungo, in an area where the process of aggradation reached its highest level. Here the area was characterised by a shallow back dune depression that could be periodically flooded by heavy rain or invaded by marine water during violent sea storms. Monthly surveys, starting in October 2006, were carried out for an entire year. Two transects with pitfall traps perpendicular to the shoreline were set from the shoreline to the back dune to assess species diversity, richness and abundance. Along the transects, wells were drilled to reach the water table and levels were assessed together with water quality (temperature, conductivity, pH) by direct measures. To assess soil characteristics (grain size, moisture, pH, conductivity and organic matter) substrate samples were collected with cores and analysed in the laboratory using standard methods. Furthermore, beach features (slope, width and orientation) were assessed along transects. During the field trips of July 2006 and April 2007 the vegetation along the two transects was determined qualitatively within sample plots (quadrats of 1 x 1m). To assess the vegetation quantitatively along transects quadrats (50 x 50 cm) of vegetation were sampled. All material in the sample was collected and weighed. Sampling for plant biomass was conducted seasonally (October, January, April, July). Successively in the laboratory each sample was oven dried and then weighed again. Wet vs. dry weights were used to determine water content of plants. Vegetation biomass was then calculated on dry weights.
Environmental data showed that the water table reached its lowest level in spring-summer months with conductivity and pH values decreasing from the sea to the back dune. Annual mean moisture values of the substrate showed highest values towards the sea and in the back dune depression where peaks in conductivity and pH values also occurred. With hierarchical cluster analysis plant community species (42 species) were pooled into three groups according to substrate parameters and groundwater characteristics. These groups reflected the zonation of the vegetation on the dune, back dune and inland wetland area. β diversity values for plant species showed that the community changed in 50% of its species every 40 m and differed slightly seasonally. Biomass values were greatest in the back dune depression. Species richness was correlated positively with soil moisture contents and negatively with pH. The abundance of the endemic plant *Limonium etruscum* was positively correlated with substrate conductivity whereas its presence was strictly related to moisture contents. The α diversity value of the macrofaunal community was highest in April and differed significantly from the other months. The annual

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α diversity value showed a very rich invertebrate community that was highly correlated with the vegetation biomass and distance from the sea thus to the complexity of the habitat. The annual β diversity value for macroinvertebrate species indicated a change in the composition of the community every 20 m and in July every 15 m. At a dissimilarity level of 40% the macroinvertebrate species were pooled into five groups according to the substrate characteristics. The first two groups belonged to sandy beach areas whereas the third group was characterised by typical dunal species. Species of group four and five inhabited the back dune depression and its bordering areas. The study indicated a very healthy, dynamic and complex environment with well organised biotic components that rapidly changed perpendicularly to the shoreline. These results are discussed in relation to local management plans and policies.

Introduction

In recent years there has been a growing interest in the rapid evolution and changes of coastal environments. These highly dynamic ecosystems have been undergoing huge human impacts due to high concentrations of population along the coast that have inevitably led to modifications of sandy beach ecosystems. Threats to sandy beaches span from direct anthropogenic impacts on beaches to more global effects due to climate change that are forcing the coastline's retreat inland in response to rising sea levels (Feagin *et al.*, 2005; Harley *et al.*, 2006). Sandy beaches provide a wide range of ecosystem services valuable both from a socio-economic and ecological point of view (Schlacher *et al.*, 2008) and thus are vitally important. These include recreational activities (sun bathing, sports, human well-being, etc.), fishing and shellfish harvesting, mining, real estate potential, maintenance of genetic and biodiversity resources, seawater filtration and purification, buffering effects against sea storms, nursery areas for juvenile fishes, nesting sites for turtles and shorebirds etc (Defeo *et al.*, 2009). However, these sensitive environments are squeezed between rising sea levels on the marine side and human development on the landward side thus management of coastal environments in relation to what occurs in more inland areas has become a critical issue. In recent years it has become clear that coastal water bodies (rivers) are intrinsically linked to beach environments and that any changes in the watershed (dams, quarrying, land reclamation, afforestation) that decrease sediment loads or water flows, directly affect beach morphologies (Nordstrom, 2000; Sherman *et al.*, 2002; Bonora *et al.*, 2002; Snoussi *et al.*, 2002, Valpreda & Simeoni, 2003). Therefore sustainable use and management of these water bodies becomes extremely important for the dynamics of coastal ecosystems and the need for a scientific integrated research to understand ecosystem functioning is urgent. One main objective of the WADI Project (INCO-CT-2005-015226) was to assess and estimate the impacts of various water uses on coastal ecosystems. For this reason several sites along the Mediterranean were selected in order to study different problems occurring in various countries and to assess how these issues were managed by local stakeholders and managers.

At the Italian site, the Grosseto plain, one of the main problems related to the Ombrone river watershed was the strong erosion process occurring at its mouth. From mid-XVIII Century up to date it was estimated that there was approximately 800,000 m^3/year of sedimentary loss at the apex of the delta and since 1977 an erosion rate of 11 m/year (Pranzini, 1994; 2001). This has led to the destruction of large sections of the beach, to marine water intrusion at the surface and to the consequent loss of pasture and agricultural lands within the Maremma Regional Park. Another phenomenon linked to the erosion process is the salinisation of the water table that has determined changes in the water quality of wells, previously used to extract freshwater for agriculture, and has affected the historical pinewood plantation (Teobaldelli *et al.*, 2004) with direct impacts on the pine trees in various parts of the Park. In the Grosseto plain, the salinisation of the water table is a complex phenomenon (Pranzini 1996; Grassi & Netti, 2000). In fact, marine water intrusion is seasonal, advancing in summer and receding in winter, and progressive, as it tends to advance towards land through time. At the Maremma Regional Park a study was conducted to assess how changes occurred over space and time in the biotic components of the beach ecosystem in relation to salt water intrusion. In a previous study (Colombini *et al.*, 2006) it was shown that diversity indices of the macrofaunal beach community changed in relation to the distance from the Ombrone River mouth and that the erosion process taking place at the mouth of the river was the main forcing factor structuring the entire beach dune ecosystem. The current study aims to identify the present state of health of the beach and to verify how marine water intrusion and peculiar substrate features affect the spatial distribution of the local flora and fauna. For this reason the characteristics of the water table were assessed over a one year period of time and special attention was given to certain species capable of surviving in particular environmental conditions. Plans and future actions of local authorities to manage coastal erosion and salt water intrusion are discussed in relation to the outcomes of the present study.

Materials and Methods

Study site and sampling procedures

The study area was located at 6 km to the south of the Ombrone River mouth in the Maremma Regional Park (N 42° 38' E 11° 2' to N 42° 37' E 11° 4') (Grosseto, Italy). This coastal area has very dynamic characteristics as it is currently undergoing a strong erosion process at the mouth of the river and a phenomenon of accretion to the south. The study site lies in the section of the beach in progradation and consists of a wide eu- and supralittoral (45 m in width), a low dune (1.10 m in height) and a vegetated back dune with a depression that is flooded during winter months. The beach section of the area had been previously monitored within the Medcore project (ICA3-2002-10003) so a previous data set is available for comparisons (Colombini *et al.*, 2006). Monthly surveys, starting in October 2006, were carried out for a period of an entire year. To assess species diversity, richness and abundance two transects perpendicular to the shoreline were set starting from the shoreline and proceeding landwards for 150 m to the back dune. The transects consisted of pitfall cross traps, with intercepting bands of 50 cm and containing glycol ethylene, set at a 5 m interval. The traps captured macroinvertebrates moving at the surface and were kept active for a period of 48 consecutive hrs. Fauna samples were collected, and transferred in 70 % alcohol. In the laboratory, samples were sorted under binocular microscopes and where possible individuals were identified to species level. In other cases morphologically recognisable taxonomic units (RTUs) (Krüger & McGavin, 1997) were used.

During July 2006 and April 2007 two field trips were organised together with the International Environment Institute of Malta during which the vegetation was assessed qualitatively. Vegetation was recorded on a presence/absence basis within 1 m^2 quadrat along two contiguous belt transects from the shoreline to 150 m inland. For transect 1 plant species were sampled within three contiguous quadrats on either side of the transect line at each metre for a total of 900 quadrats. For transect 2 vegetation was assessed within one quadrat on either side of the transect line for a total of 300 samples.

To assess the vegetation quantitatively along transects in the different seasons quadrats (50 x 50 cm) of vegetation were sampled every 5 m at 1m (October), 2m (January), 3m (April) and 4m (July) distance from the reference pegs of the transects. All material in the sample was collected and weighed. Successively in the laboratory each sample was oven dried at 70° and then weighed again. Wet vs dry weights were used to determine water content of plants. For vegetation biomass a mean value was calculated every 5 m and referred to 1 m^2.

To assess groundwater level and quality wells were dug with a drill and a PVC tube (1-2 m in length according to the depth of the wells) was placed at the same 5 m interval of the pitfall traps. Monthly samplings of wells were carried out to determine water table depth and to assess the chemical characteristics of the water table taking direct measures of temperature, salinity (conductivity) and pH.

Substrate samples were also taken pushing cores (3 cm in diameter) at a depth of 10 cm. In the laboratory samples were analysed to determine moisture content, salinity (conductivity), pH, organic matter and grain size with standard methods (Folk & Ward, 1957, cit. in Società Italiana del Suolo 1985) (respectively dry weight vs. wet weight for moisture contents; conductivity and pH of 10 g of sand in 50 cm^3 demineralised water; weights of sand samples previously oven dried at 105°C for 24 hours and then burned for 3 hours in a muffle furnace at 600°C for organic matter). Granulometric analysis was carried out using an automatic sieve shaker with meshes of different sizes (from 4 mm to 45 μm).

Beach morphology (slope, width and orientation) was assessed through transect profiling.To determine total rainfall during each month a permanent rainfall station was placed on the dune close to the transects. Each month the station was checked and rainfall recorded.

Data analysis

Macroinvertebrate abundance was log-transformed to normalise the data. Abundance, species richness and values of α-diversity were correlated with distances from the sea through linear regression analysis.

Alpha- and β-diversity values were calculated together with Shannon's index, Pielou's evenness index, and Simpson's dominance index (Fisher *et al.*, 1943; Pielou, 1978).

Hierarchical cluster analysis using Ward's Method and Euclidian distance was employed to group plants and macroinvertebrates according to the chemical and physical parameters of the substrate (moisture, pH, conductivity, organic content, mean grain size) and only for plants according to ground water characteristics (pH, conductivity, depth from the ground surface). For macroinvertebrates only species with $n > 50$ were chosen whereas plant species were selected when present in at least 10 quadrats.

Mean zonation patterns were calculated on the four seasons for both plant and invertebrate species. For the plants the criteria was based on a presence/absence basis namely on the number of times a specific plant occurred at a certain distance from the sea, whereas for macroinvertebrates the number of individuals was considered.

Regression analysis (Zar, 1984) was applied to correlate abundance, species richness, alpha-diversity and single plant species (*Limonium etruscum*) with the environmental parameters (distance from the sea, substrate moisture, pH, conductivity, organic matter, grain size, vegetation biomass).

Results

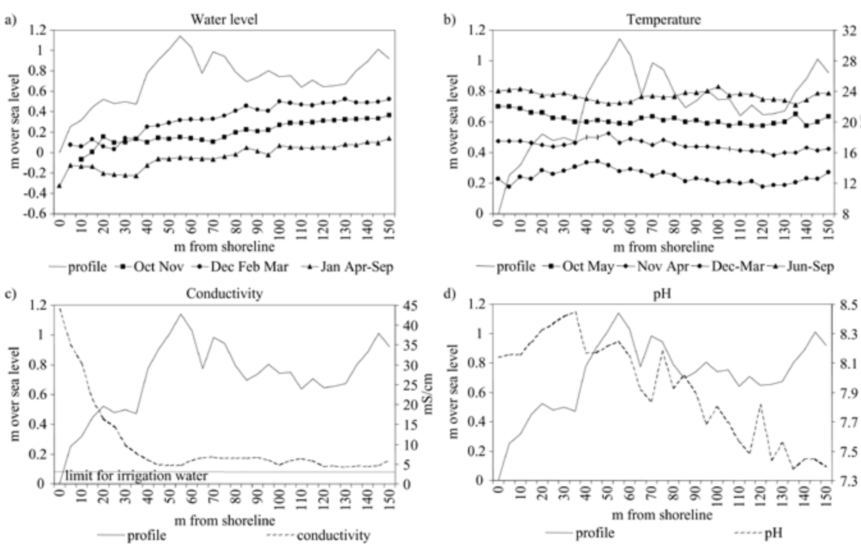
Environmental data

a) *Water table characteristics*

The analysis of the water table level recorded along transect 1 throughout the year mainly showed three groups of months (Fig. 1a): high water levels were registered for the months of December, February and March, intermediate values for October and November and very low values for

January, and from April through September. The low values recorded for January reflected the hot-dry weather conditions that characterised this winter season. Rainfall was instead responsible of the highest values recorded during the month of February. Water temperatures of wells reflected the increasing or decreasing seasonal temperatures with slightly lower values in the back dune areas (Fig. 1b). Four groups can be pointed out: December, January, February and March showing the lowest values (around 12°C), November and April with intermediate ones (around 16°C) followed by October and May (around 20°C), while June, July, August and September (around 24°C) had the highest ones. The analysis of monthly mean values indicated that the water table of July had the hottest values (mean 24.27°C ± 0.29) whereas February the coolest one (mean 12.25°C ± 0.41). The annual mean values of conductivity of the water table (Fig. 1c) clearly showed that there was a constant decrease from the sea to the base of the dune (about 35-40 m) reaching values over those indicated as maximum limit for irrigation water (>3 mS/cm) in the back dune areas. No significant variations in the values of conductivity were found between months at the different distances. Furthermore in the depressed section of the back dune there was just a slight increase in water salinity. Also annual mean pH values of the water table decreased steadily proceeding from the sea towards land and reached a value of 7.8 in the back dune depression (at 120 m) (Fig. 1d).

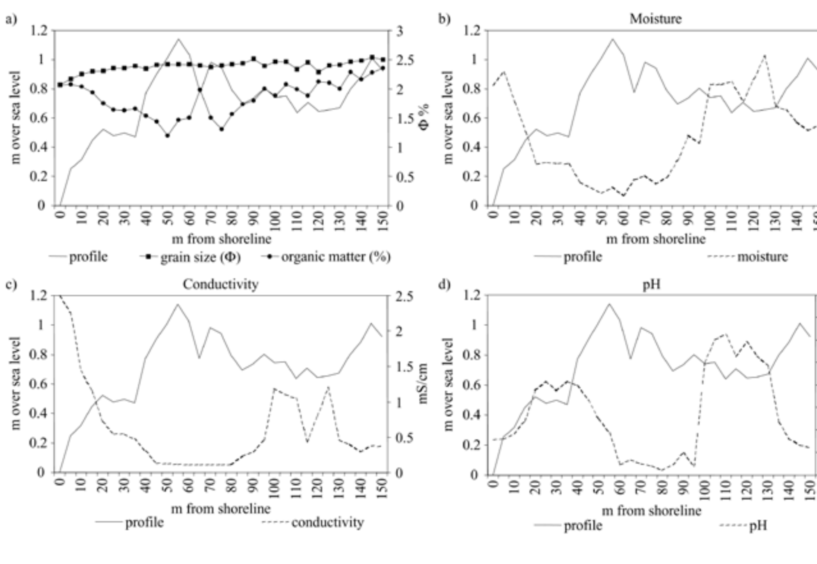
Figure 1. Groundwater characteristics registered in wells dug every 5 m starting from the shoreline are shown together with the transect profile throughout the one year period of study. For (a) water table levels and (b) temperatures months with similar trends have been grouped whereas mean annual trends are shown for (c) conductivity and (d) pH values.



b) *Soil characteristics*

The analysis of the transect profile showed a wide eu- and supralittoral (from shoreline limits to 45 m in width), a low vegetated dune (from 50 to 85 m wide and 1.10 m high) and a depression in the back dune zone from 95 m to 130 m that is flooded during heavy rains. Mean grain size of sand samples was calculated on the two transects and was more or less constant along the entire transect with a meanof 2.384 **Φ** and a tendency of finer grains towards land. Mean organic matter of soil calculated on 4 months (October, January, April and July) presented a clear variability along the transect reaching its highest value (2.35 %) at 150 m in the back dune area and its lowest one (1.2 %) at 50 m. To be noted are the lower values on the dune with only a slight increase at 65 m (Fig. 2a). Through monthly sampling of the substrate, parameters such as moisture, conductivity, and pH were also analysed. Annual mean moisture contents showed highest values towards the sea and in the back dune depression where the substrate was muddy (Fig. 2b). This area was entirely flooded in December, February, and March when sudden and heavy storms occurred. This was also in relation to the texture of the substrate (finer grain size) that had the tendency of retaining water. The analysis of the values of conductivity and pH in the different months showed similar trends and a mean annual trend was calculated for each parameter.

Figure 2. Substrate characteristics sampled every 5 m starting from the shoreline are reported throughout the one year period of study. Seasonal mean values are shown for (a) grain size and organic matter whereas annual ones are given for (b) moisture contents (c) conductivity and (d) pH values.



The pH of the soil presented variations according to the salinity of the substrate with more base values towards the sea and in correspondence to the depression of the back dune (Fig. 2c). Also conductivity showed highest values seawards and in the back dune depression where a salt crust sometimes could be found (Fig. 2d). The rainfall station at the sampling site (Cala Rossa) indicated a trend quite different from that registered at the climatic station of Grosseto. A peak in the precipitation was obtained in December followed by February whereas for the month of January the lowest values of the entire sampling season were obtained. No rain was recorded in July and August. The trend registered for the water table level followed the trend of rainfall at the sampling site showing its direct interdependence.

Assessment of the biotic components

a) *Faunal data*

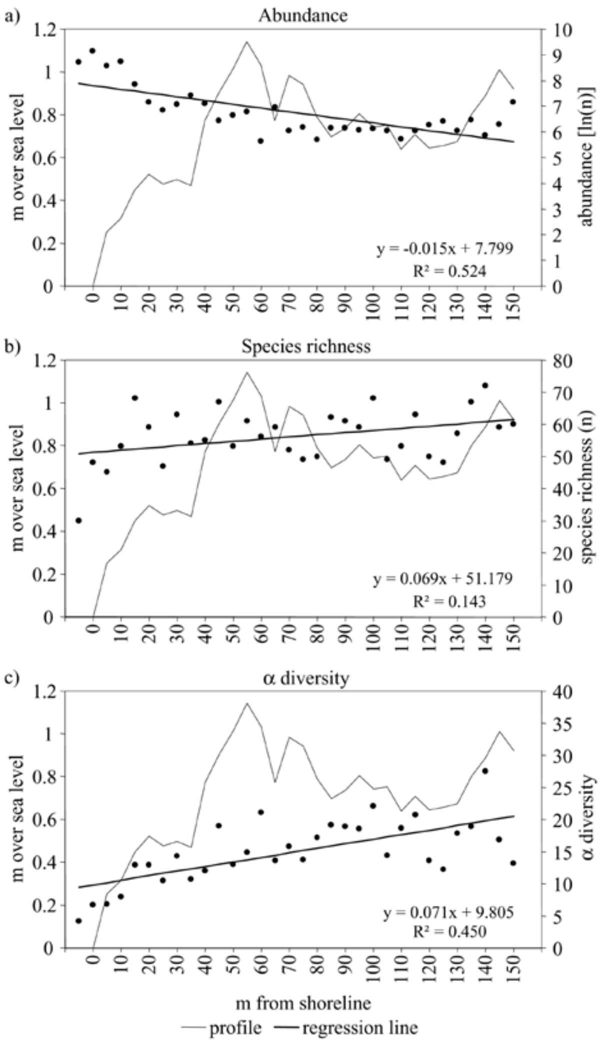
Calculating a mean annual abundance for each sampling distance a significant decrease in the abundance of the invertebrate population was recorded proceeding from sea towards land ($y=-0.015x + 7.799$ $R^2=0.524$ $p<0.001$) (Fig. 3a). A similar pattern also occurred in three out of the four seasons analysed separately (October: $y=-0.017x + 6.105$ $R^2=0.374$ $p<0.001$; January: $y=-0.015x + 4.986$ $R^2=0.356$ $p<0.001$; April: $y= -0.020x + 7.237$ $R^2=0.628$ $p<0.001$; July: N.S.). Instead for species richness there was a significant increase in number proceeding landwards when considering the annual pattern ($y=0.069x + 51.179$ $R^2=0.143$ $p<0.05$) (Fig. 3b) but no significant trends were obtained when analysing the different seasons separately with the exception of April where an opposite trend occurred ($y=-0.052x + 37.511$ $R^2=0.163$ $p<0.05$). In this month the highest number of species was recorded (n=226).

Table 1. Abundance, species richness, diversity indices and metres at which 50 % of the macrofaunal community changes are shown.

	Oct	Jan	Apr	Jul	Tot
n	8413	3270	24716	11181	47580
species	120	107	226	145	334
α diversity	19.83	21.21	34.35	23.51	48.48
J’	0.35	0.39	0.43	0.44	0.42
L	0.34	0.39	0.21	0.18	0.20
$1/\beta$ (m)	16.08	18.52	19.64	15.33	19.25

Alpha diversity index (Table 1) calculated on the total showed quite a high value and varied according to the four different seasons reaching its highest value in April (34.35). When the annual α-diversity values were analysed along the sea-line axis there was a significant increase proceeding towards land ($y=0.071x + 9.805$ $R^2=0.450$ $p<0.001$) (Fig. 3c). This pattern occurred also in all the seasons analysed with the exception of July (October: $y=0.068x + 2.471$ $R^2=0.199$ $p<0.05$; January: $y=0.059x + 3.154$ $R^2=0.153$ $p<0.05$; April: $y=0.053x + 7.293$ $R^2=0.332$ $p<0.001$; July: N.S.). Annual β-diversity value (0.052) indicated a change in 50% of the composition of the macroinvertebrate community every 20 m proceeding landwards. Only during July and October did the composition of the community change over a smaller stretch of coast (15 m – 16 m in the two months respectively).

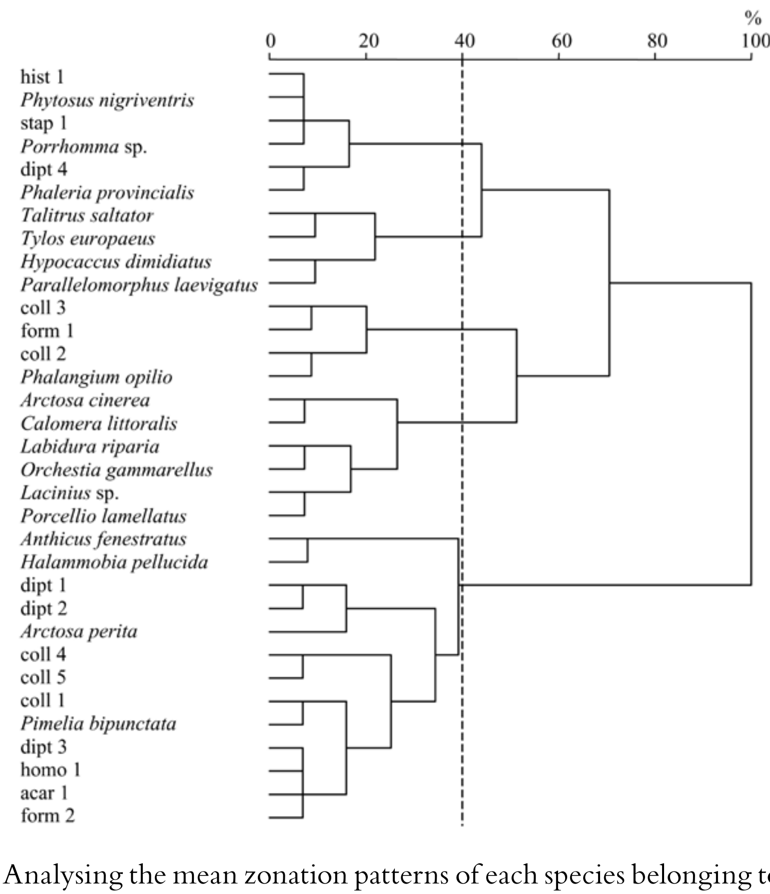
Figure 3. Simple regression analysis of log-transformed abundance (a), species richness (b) and (c) α diversity with distance from the shoreline are shown together with the regression equations and correlation coefficients.



Pielou's evenness index showed an annual value of 0.042, a value not particularly high due to the presence of crustacean species that were few but very abundant numerically. This was confirmed also by the Simpson's dominance index that showed the presence of highly abundant species especially for autumn and winter months.

Considering a dissimilarity level of 40 % cluster analysis grouped macroinvertebrates into 5 clusters (Fig. 4).

Figure 4. Hierarchical cluster analysis of macroinvertebrate species according to the chemical and physical parameters of the substrate (moisture, pH, conductivity, organic content, mean grain size) is shown.



Analysing the mean zonation patterns of each species belonging to the different clusters it appears clear that species belonging to the first cluster were typically eulittoral species (crustaceans such as *Talitrus saltator, Tylos europaeus*, carabids *Parallelomorphus laevigatus* and histerids *Hypocaccus dimidiatus*). These were followed by species more linked to the supralittoral such as the tenebrionid *Phaleria provincialis* or to the organic debris occurring in this area (staphylinids *Phytosus nigriventris,* histerids and dipterans). The third and largest cluster grouped typical psammophilous dune species (*Pimelia bipunctata, Anthicus fenestratus*) or species strictly related to a certain type of vegetation cover or debris (tenebrionids *Halammobia pellucida,* dipterans, collembolans, ants, and spiders). Only *Arctosa cinerea* and *Porrhomma* sp. appeared to be zoned on the dune but had been associated to different clusters (in clusters 4 and 2 respectively). Species belonging to clusters 4 and 5 were generally zoned in the back dune depression without showing a clear distinction in the zonation patterns of the two groups. The amphipod species *Orchestia gammarellus* belonged to group 4 and was typically linked to the saltmarsh environment. This species presented a clear distribution pattern in the back dune area ranging from 105 m to 150 m and never overlapped with the zonation pattern of *Talitrus saltator,* a typical intertidal species which colonised dunal areas and reached 85 m during winter months. Simple linear regression of the macroinvertebrate population with the environmental parameters showed that abundance was positively correlated with conductivity and negatively with mean grain size parameter and vegetation biomass (Ln(abundunce)= 0.694 x conductivity + 7.395 $R^2=0.477$ $p<0.001$; Ln(abundunce)= -4.275 x M_z + 16.806 $R^2=0.299$ $p<0.01$; Ln (abundunce)= -1.174 x veg biomass + 7.306 $R^2=0.335$ $p<0.001$). Whereas species richness and α-diversity had negative correlations with conductivity and positive ones with mean grain size parameter and vegetation biomass (Species richness= -3.617 x conductivity + 52.734 $R^2=0.161$ $p<0.05$; Species richness= 34.868 x MZ – 25.623 $R^2=0.308$ $p<0.01$; Species richness= 6.954 x veg biomass + 52.792 $R^2=0.146$ $p<0.05$; Alpha diversity= -3.130 x conductivity + 11.988 $R^2=0.354$ $p<0.001$; Alpha diversity= 25.073 x MZ – 44.113 $R^2=0.382$ $p<0.001$; Alpha diversity= 6.595 x veg biomass + 11.760 $R^2=0.386$ $p<0.001$).

b) *Botanical data*

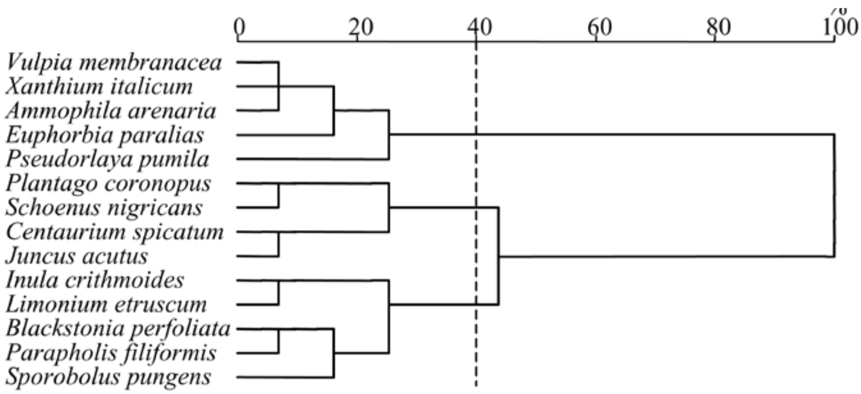
Sampling for plant biomass conducted in the four seasons along transect 1 showed that the highest mean values of plant biomass per m^2 occurred on the dune at 60 m where *Ammophila arenaria* was the dominant species and in the back dune area at 135 m where *Schoenus nigricans* and *Juncus acutus* were dominant. These were responsible for the high biomass (6.1 kg/m^2) found in this area. Water contents of plants was lowest on the dune as could be expected since this is the point where the water table reaches its greatest distance (about 1 m) from the beach surface, whereas higher water contents were obtained for the foredune and back dune areas. Along transect 2 the highest mean biomass values were obtained at 100 m (4.1 kg/m^2). In this case no significant difference was found in the water contents of the plants from the foredune to the back dune. In general in the two transects, on a total of 37 plant species that were sampled, 14 were the most abundant occurring in the sample quadrats more than 10 times (Table 2).

Table 2. Frequency of the plant species in each quadrat along their distribution range obtained using the presence/absence criteria.

Species	Transect 1		Transect 2	
	range (m)	frequency	range (m)	frequency
Ammophila arenaria	35-100	20	55-80	8
Blackstonia perfoliata	80-150	13	65-150	12
Centaurium spicatum	90-145	15	100-145	8
Euphorbia paralias	45-75	6	45-70	6
Inula crithmoides	100-140	29	65-150	44
Juncus acutus	105-145	11	90-150	13
Limonium etruscum	85-135	23	65-145	46
Parapholis filiformis	45-150	39	55-150	45
Plantago coronopus	65-150	14	95-150	12
Pseudorlaya pumila	40-95	12	65-75	3
Schoenus nigricans	90-150	30	80-150	32
Sporobolus pungens	35-140	44	45-150	57
Vulpia membranacea	45-80	7	50-80	11
Xanthium italicum	35-90	29	45-70	15

At a dissimilarity level of 40 % three groups were obtained with cluster analysis. The first group included plants typical of the sand-dune zone (*Vulpia membranacea, Xanthium italicum, Ammophila arenaria, Pseudorlaya pumila* and *Euphorbia paralias*) the second group those plants that occupied more elevated areas of the back dune(*Plantago coronopu, Schoenus nigricans, Centaurium spicatum* and *Juncus acutus*) and the third group those plants that were frequently found in the back dune depression (*Inula crithmoides, Limonium etruscum, Blackstonia perfoliata, Parapholis filiformis Sporobolus pungens*). The analysis of the zonation patterns (with 95% confidence limits) of the 14 most abundant plants along the two transects showed that mean zonations of the single plants had similar distributions in the two transects and thus were cumulated. The three groups indicated by cluster analysis corresponded to morphologically different areas of the transect (dune, back dune depression and elevated back dune areas). Considering the total number of plant species that occurred along the transects there was a decrease in species number proceeding landwards (40-80 m 27 species, 85-120 m 25 species 125-150 m 19 species) and this was associated to an increase in plant biomass that reached 13.4 kg/m^2 in the back dune. The overall ß diversity value for plant species showed a change in the community structure every 40 m whereas for the four seasons analysed separately, October presented the lowest ß diversity value (0.019) indicating minor changes in the plant community when proceeding from the sea towards land.

Figure 5. Hierarchical cluster analysis of plant species according to the chemical and physical parameters of the substrate (moisture, pH, conductivity, organic content, mean grain size) and to groundwater characteristics (pH, conductivity, water table depth from the ground surface) are shown.



Simple linear regression of the vegetation with the environmental parameters showed that species richness and plant biomass were negatively correlated with conductivity (Species richness= -4.711 x conductivity + 4.198 R^2=0.549 $p<0.001$; Plant biomass= -0.174 x conductivity + 0.319 R^2=0.123 $p<0.05$) and positively with mean grain size parameter (Species richness= 0.014 x ground water depth – 0.224 R^2=0.224 $p<0.01$; Plant biomass= 1.566 x M_Z – 3.211 R^2=0.147 $p<0.05$). Only species richness had a significant positive correlation with groundwater depth (Species richness= 29.971 x M_Z – 62.084 R^2=0.338 $p<0.001$).

Special attention was given to *Limonium etruscum* (Plumbaginaceae) an endemic plant of the coast of Grosseto. This species has a restricted distribution pattern generally associated with brackish water environments and today it can be exclusively found at the Maremma Regional Park in an area to the south of Collelungo. Therefore the population is exceedingly important both from a quantitative (abundance) and qualitative (genetic diversity) point of view. Measurement of the variation in abundance of *L. etruscum* along the two transect perpendicular to the shoreline was conducted in July 2006 and April 2007 and correlated with abiotic data of the substrate. The analysis of the distribution pattern of the species showed that a wider range occurred along transect 2 (from 65 m to 145 m) compared to transect 1 (from 85 m to 135 m), where the species was restricted to the back dune depression. In both transects the species decreased very sharply further inland. Also plant density differed along transects with density twice the size in transect 2 compared to 1 (mean number of individuals 107.5/m^2 in transect 2 compared to 63.2/m^2). Along both transects a positive correlation was found between the presence of *L. etruscum* and substrate water content (presence =0.08 water content - 0.34 $R^2=0.40$ $p<0.001$), whereas the abundance was positively correlated with soil conductivity (number individuals =86.51conductivity-9.44 $R^2=0.30$ $p<0.001$)

Discussion and Conclusion

The study conducted at the beach site in the Maremma Regional Park indicated a very healthy, dynamic and complex environment with well organised biotic components that rapidly changed perpendicularly to the shoreline. In general all sandy beach ecosystems are extremely dynamic environments (McLachlan & Brown, 2006) but some are relatively stable or in a dynamic equilibrium whereas others show detectable trends of changes. The site chosen for the study belonged to the latter case and was continuously changing because of the on-going progradation process of the beach. This phenomenon was strictly related to the strong erosion occurring upper north at the mouth of the Ombrone river where large sections of the beach had been destroyed. Osenberg & Schmitt (1996) referred that human activities may destroy certain environments but at the same time may supply new habitats. This is exactly what has been happening at the Maremma Regional Park in the last few decades. Human activities such as river bed quarrying and reforestation have greatly reduced the Ombrone River's sediment loads and have caused a strong erosion process at the apex of the river delta. As a consequence the area to the south of Collelungo that once was a marine bay (Cala Rossa) has progressively been filled up with sediments and a relatively new beach has been built. The wide eu- and supralittoral coupled with a flat slope has continuously increased and prevented the formation of a stable dune. In fact the dunes are low and are progressively advancing towards the sea as testified by the death of *Ammophila arenaria* plants that with time remain in the back dune areas. On the other hand the back dune is slowly invaded by plants of more consolidated areas such as *Juniperus oxycedrus, Juniperus phoenicea,* and *Pinus pinaster.* Furthermore, the dune is not a continuous formation but is interrupted in various points where sea water can enter during winter storms. These interruptions are not due to blowouts caused by the dominant winds but rather to the way the embryonic dunes have been formed. At the chosen site the back dune is characterised by a depression where a typical salt marsh vegetation cover (*Schoenus nigricans* and *Juncus acutus*) can be found. This area, characterised by a muddy substrate, is subjected to changes and can be flooded by sea water during storms or can be totally dried up and presents a solid salt crust at the surface during summer months. All these morphological features are visible indications of continuous changes occurring at medium-long period of time.

However the results of our one year monitoring period detected changes of the environmental characteristics also at a shorter time scale. As expected, variations in water temperatures and groundwater levels were generally associated to seasonal changes. The only exception was January, which showed water table levels similar to those of spring-summer months. This was related to the exceptionally dry weather conditions that had occurred in that particular month of winter 2007. In any case at the study site the water table could be quickly recharged as demonstrated by the high levels reached during the month of February indicating the possibility of a fast recovery. The capability of a quick recharge was due to the Uccellina hills that backed up the study area. To our surprise no salt water intrusion was recorded during the monitoring period as demonstrated by the conductivity values of the water table that always remained more or less the same in the different periods of the year. Decreasing values of conductivity, ranging from marine to freshwater values, were always detected in beach areas up to the base of the dune, whereas the dune proper and back dune were characterised by values just slightly higher than those considered suitable for crop irrigation. This means that in these two zones water quality (in particular salinity levels) remained the same all year round (at least at the groundwater surface from which our samples were collected) and provided suitable conditions for the resident vegetation. This result differs from the findings of Pranzini (1996) and Grassi & Netti (2000) who analysed the phenomenon along the coast of the Grosseto plain at a larger spatial scale. In fact these authors found evident salt water intrusion along the last section of the Ombrone river plain but this phenomenon was associated with human activities (such as excessive water pumping from wells or from the river that tend to withdraw sea water) more than to a natural phenomenon.

With regard to substrate features clear trends were identified. When proceeding landwards, beach areas were characterised by decreasing organic, moisture and salinity contents, dune areas by low salinities, moisture and pH values whereas the back dune depression by opposite environmental values. The presence of higher salinities in the depressed area was principally due to superficial sea water that invaded the zone during sea storms and dried up into salt layers during hotter months. Finer sand coupled with mud contents retained more water compared to other areas and permitted a typical salt marsh vegetation to be established. Here the vegetation was distributed according to its tolerance to the different environmental parameters. Species such as *Juncus acutus* and *Schoenus nigricans* were distributed differently from others such as *Limonium etruscum, Inula crithmoides* and *Sporobolus pungens* as was shown by cluster analysis. The former species were found in slightly more elevated areas whereas the latter in depressed areas where higher moisture conditions remained for longer periods of time. Furthermore, the endemic plant.

L. etruscum was shown to be tolerant to high salinities and to have a distribution pattern in relation to the presence of a muddy soil. The needs of these three factors combined together (high moisture contents, relatively high salinity and muddy soil) make this plant a very rare species. Arrigoni and Rizzotto (1985) described the species as new for science in 1985, but at that time the plant could be exclusively found in two areas along the coast (Maremma Regional Park and wetlands of Talamone). Today it has restricted its distribution pattern, and populations have been severely affected by habitat loss or misguided management strategies. In fact the population at Talamone was eradicated after the destruction of the wetlands when a parking lot for summer tourists was constructed directly over its environment. The population at the study site is thus extremely important as it represents the last existing population of the species. It is also very vulnerable because its presence is determined by a very delicate equilibrium between surface marine water invasion and freshwater coming from rainfall and/or from the water table. A slight modification of the beach's morphology (steeper slope or slightly higher dune) would lead to its possible eradication therefore it is important that scientists direct management planners towards adequate choices.

The annual α diversity value calculated for terrestrial macroinvertebrate species is one of the highest if compared to other similar environments (Colombini *et al.*, 2003) and indicates a very rich and diverse community which changes according to the season. ß diversity value indicated a change in 50% of the composition of the macroinvertebrate community every 20m proceeding landwards whereas for plant species ß diversity values showed a change in the community structure every 40 m and morphologically corresponded to the sand-dune zone, the saltmarsh zone and the maquis zone. Among the different environmental parameters analysed conductivity, grain size and plant biomass were most important in influencing the abundance, richness and diversity of the macroinvertebrate community. Species richness increased at increasing distances from the sea and was related to the complexity of the habitat. The increase in habitat diversity in association to the increase in community diversity is a common feature in sandy beach ecosystems and has already been reported for other localities (Colombini *et al.*, 2003; Chelazzi *et al.*, 2005). Plant richness and biomass increased with decreasing conductivity and mean grain size and only plant richness increased with increasing ground water depth. Generally speaking all elements of the system (biotic and abiotic) were strictly interlinked with each other and slight changes of certain parameters (slope, substrate salinities, grain size, etc.) immediately showed changes within the inhabiting flora and faunal communities. The peculiar features found at the study site give the possibility to certain species to survive and to flourish taking advantage of their ability to tolerate extreme environmental conditions. This was the case of the amphipod species *Orchestia gammarellus* inhabiting the back dune depression which used particular behavioural strategies slowing down nocturnal movements and taking refuge at the base of *Juncus acutus* plants to survive from desiccation during summer months. This species, typical of saltmarsh environments, has a hyper-hypo osmoregulation pattern and is capable of surviving over a wide range of diluted salinities (Moore & Francis, 1985; Morritt, 1988). Furthermore, in semi-terrestrial forms such as *O. gammarellus*, the area of the gills is reduced when compared to the aquatic forms such as *Gammarus* spp. (Moore & Taylor, 1984) and the gills are more solid. These changes reflect a need to regulate evaporative water loss while still permitting oxygen uptake. Morritt (1987) demonstrated that *O. gammarellus* had higher rates of water loss compared to those of *Talitrus saltator* and that it survived less under conditions of desiccation stress compared to the latter species. This is one of the reasons why *O. gammarellus* was unable to occupy vast areas of the study site and was restricted to the back dune depression. *T. saltator*, under favourable moisture conditions, was instead capable of reaching the back dune where it had the opportunity of foraging on a wider variety of organic items.

The overall characteristics of the study site indicated that the area was at the moment undergoing a low anthropogenic impact. This was mainly related to trampling by summer tourists and to the construction of small shacks made of driftwood and eradicated *Ammophila arenaria* plants that were used as shelters from the sun. The importance of this area due to the presence of rare or endemic species, such as the carabid *Eurynebria complanata* and the plant *Limonium etruscum*, has been gradually understood by Park authorities and the area has been designated an Integral Reserve and in the future will be entirely protected. However, the area is still endangered by human interventions upper north at the mouth of the river that aim to reduce beach erosion at the river mouth, to stabilise the beach of Marina d'Alberese and to protect the inland areas from salt water intrusion. To slow down the erosion process at the mouth of the river Park authorities have approved the construction of a inland revetment parallel to the sea line on the left bank of the Ombrone River that will soon become operative. This embankment will prevent sea water from reaching the saline low-lying grounds at the Ombrone river mouth during the occasional sea storms and save the pine tress of the old interdunes. Recently the Consorzio di Bonifica has reactivated the mobile sluice-gates of the Chiavica bridge at the mouth of the Essiccatore di Alberese channel (built the last century as a draining channel and connected to the Ombrone river). This will prevent marine water intrusion in the channel during sea storms whereas the saline waters occurring in the low-lying grounds will be pumped out towards the sea with the reactivation of the pumping system at the Idrovora S. Paolo. These interventions aim to prevent saltwater intrusion and the salinisation of the water table. Furthermore, there is the plan to install several submerged concrete groynes perpendicular to the shore line in the hope of recreating a local beach. The foreseen beach nourishment project at the moment has not been approved as it would have had sizeable impacts on several beach ecosystem components (Peterson & Bishop, 2005; Speybroeck *et al.*, 2006). According to the project it was calculated that 100,000 m^3 of sand would have been necessary for the operation and to obtain this quantity of sand, the equivalent of an area of beach of considerable dimensions (1000 m in length at a 1 m depth and 100 m in width) would have been extracted from the beach of Collelungo. According to our calculation (see ß diversity) this would have meant wiping out entire populations of beach-dune invertebrates and plants and would have disrupted the equilibrium of the entire ecosystem.

However, impacts of coastal armouring structures may cause significant habitat changes with attendant ecological changes. Miles *et al.* (2001) showed that wall structures alter the natural hydrodynamic of waves and currents and affect sand transport rates which in turn control the erosion-accretion dynamics of the beach. At the Maremma Regional Park the changes in the sea water currents caused by the submerged groynes at the mouth of the river will severely impact the beach dune ecosystem to the south of Collelungo. Consequently, there will be the loss of one of the best preserved coastal ecosystems and local endemic plants and animals will disappear. The erosion process at the mouth of the river will not be halted by these interventions and will probably occur in areas to the north of the Ombrone river mouth adjacent to those protected by engineering structures. It is thus clear that the main issues here seem to be the prevailing economic interest of recreating a beach for summer tourists rather than the protection and conservation of a unique beach dune ecosystem.

Acknowledgments

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THE MOROCCAN STUDY SITE

APPROCHE SPATIALE POUR L'ÉVALUATION QUANTITATIVE DES RESSOURCES EN EAU DANS LE BASSIN DE TAHADDART AU MAROC

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Résumé: Une démarche multidisciplinaire développée dans un SIG et faisant appel aux images de télédétection a été mise en place dans le bassin de Tahaddart. L'habilitation et l'intégration des données géographiques, l'homogénéisation des échelles, ainsi que le traitement et l'élaboration d'une base de données géographiques (BDG) ont facilité le travail d'analyse spatiale de la dynamique des ressources en eau dans ce bassin et ont permis ainsi de développer un modèle spatial du bassin hydraulique de Tahaddart.
La confrontation du modèle spatial à la situation actuelle de l'évaluation des ressources en eau, décrite par les données descriptives émanant des différents intervenants, a montré clairement que cette évaluation n'est que partielle. La demande en eau réelle n'est pas connue, les fournitures en eau potable et industrielle sont effectuées principalement en dehors du bassin hydraulique de Tahaddart et le bilan hydraulique n'est calculé que pour certains barrages.
Le principal résultat obtenu dans ce travail est la description quantitative des ressources en eau et l'établissement des relations de voisinage entre les différentes composantes de système offres – demande en eau. L'analyse spatiale opérée sur le modèle spatial a pu mettre en évidence les limites des méthodes actuelles d'évaluation des ressources en eau. Pour décrire convenablement et objectivement aussi bien l'offre que la demande en eau, il est nécessaire de réviser les méthodes actuelles d'évaluation et de planification des ressources, et de les renforcer par une approche spatiale de fédération et de recoupement des données émanant des différents acteurs et ce à tous les niveaux:

- l'observation des éléments définissant aussi bien l'offre que la demande en eau;
- l'organisation des données et leur intégration dans une plateforme normalisée en vue d'assurer leur partage entre les différents acteurs du secteur de l'eau;
- la prise de décisions suite à l'analyse statistique et spatiale des données;
- la présentation des résultats sous forme de cartes thématiques facilement actualisables.

Les principaux produits préparés à l'issue de ce travail sont contenus dans une base de données spatialisée concernant les ressources en eau du bassin de Tahaddart. Cette base de données est développée sur un logiciel de gestion des données localisée.

Introduction

Les ressources en eau sont soumises à des pressions considérables. Ainsi, l'activité humaine génère un nombre démesuré de contraintes et de para-

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mètres qui évoluent et changent dans le temps et dans l'espace, difficiles, voire impossibles à contrôler avec les méthodes actuelles de travail.

En pratique, la plupart des décideurs sur le territoire, disposent d'un nombre important d'informations géographiques. Toutefois, ces informations restent éparpillées et ne permettent pas de quantifier et de gérer adéquatement la ressource.

La rareté de la ressource d'une part, et le manque d'une vision intégrée d'autre part, imposent donc une exploration plus exhaustive du territoire qui permet l'amélioration de la connaissance des ressources en eau et l'évaluation de la demande réelle avec suffisamment de rigueur.

La demande en eau est souvent évaluée d'une manière fragmentaire et subjective en raison de la sectorisation et la séparation des tâches entre les différents acteurs du secteur de l'eau.

L'évaluation de l'offre est basée sur des méthodes empiriques d'évaluation quantitative des ressources en eau. Ces méthodes permettent d'établir des relations pluies–débits par le traitement statistique des séries chronologiques d'enregistrements: climatiques et hydrométriques. Cependant, aucune donnée sur le milieu naturel du bassin n'intervient dans cette évaluation. En outre, ces méthodes se basent sur des hypothèses de stationnarité en dépit des variations climatiques et des modifications du milieu naturel.

Malgré la réforme de la réglementation sur l'eau qui avait pour motif "les conditions actuelles de l'utilisation de l'eau ne sont plus celles qui prévalaient au début du siècle où les ressources en eau étaient beaucoup moins sollicitées que de nos jours" (SEE, 1995), les méthodes de travail n'ont pas été amendées depuis les études du plan directeur précédent concernant la zone d'étude, approuvé en 1993. Cependant, avec la disponibilité d'outils performants d'observation, d'analyse et de calcul et aussi de technologies novatrices de traitement de l'information, de nouvelles approches d'ingénierie et de gestion durable s'imposent.

Dans la présente recherche nous avons utilisé une approche spatiale pour l'analyse des données concernant l'évaluation quantitative des ressources en eau dans le bassin de Tahaddart au Maroc. En effet, la dynamique spatiale des ressources en eau ne peut être exprimée en chiffre et en lettre seulement. Il est évident que l'interrogation d'une base de données dûment structurée donne des réponses sous forme tabulaire. De même une représentation cartographique classique permettrait d'établir la relation de voisinage entre les ressources en eau et le milieu environnant. L'approche spatiale a pour but de restituer le modèle spatial du phénomène étudié. Ce modèle est formé de couches cartographiques d'informations associées à des tables de données. Le logiciel de traitement de données à référence spatial SIG permet de charger volontairement les couches d'informations à analyser, de façon à n'intégrer que les données spécifiques à l'aspect étudié.

L'objectif du présent travail est de préparer un modèle spatial de la zone d'étude qui a la capacité de:

- décrire la distribution spatiale des ressources en eau;
- localiser géographiquement les lieux d'utilisation des eaux par rapport aux ressources;
- préparer les éléments d'analyse des aspects liés à l'utilisation de l'eau, à la biodiversité et à la dégradation de la qualité des eaux;
- pour cela, nous avons adopté une démarche qui se base sur:
- la capitalisation des données sur le milieu naturel et sur les ressources en eau (régularisations, utilisations et qualité) en utilisant le SIG et la télédétection;
- la structuration des données et leur organisation sous forme d'une base de données géographiques (BDG) sous SIG;
- le traitement et l'analyse des données (offre, demande, tendances, conflits);
- l'enrichissement et la finalisation de la BDG par la rédaction de documents cartographiques concrétisant les résultats d'analyses spatiales effectuées.

Materiels et Methodes

Données utilisées

Données cartographiques

La carte topographique constitue un document synthétique et possède plusieurs informations thématiques (réseau hydrographique, sources et puits, espace minéralisé, aire de répartition des espaces végétaux, etc.).

Cependant les données enregistrées dans la carte topographique n'ont pas été mises à jour depuis les années 70 du siècle passé.

4 feuilles de la carte topographique au 1/50000 couvrent l'ensemble du bassin (El Manzla, Melloussa, Arba Ayacha et Souk Khemiss des Beni Arouss). Ces cartes ont été assemblées dans une mosaïque après leur géo-réferencement dans le système de projection marocain (Conique conforme de Lambert, zone 1-ellipsoïde de Clarke 1880).

La carte topographique, ainsi préparée, constitue le modèle géométrique de référence pour l'ensemble des travaux de la présente modélisation. Elle est également une source importante d'informations géométriques et géographiques: altitudes, distances, surfaces, villes, routes, activités diverses. Elle permet en outre de dériver les Modèles Numériques de Terrain et donc de générer la distribution spatiale des pentes et leur orientation, qui sont très utiles pour l'analyse et la compréhension des mécanismes de l'écoulement superficiel.

Nous avons également procédé à l'extraction du réseau hydrographique en couche vecteur, ce qui a permis sa hiérarchisation et la subdivision du bassin de Tahaddart en sous-bassins permettant une analyse plus exhaustive.

Données satellitaires

Les images satellitaires sont utilisées pour mettre à jour les informations disponibles, notamment celles relevées sur les cartes topographiques. Elles apportent des informations récentes, mais aussi des informations intermédiaires. Ceci permet de faire des évaluations de l'information à un instant donné, mais aussi de développer des approches diachroniques qui permettent de faire des analyses multi-dates. Ainsi, la mise à jour de plusieurs thématiques a été opérée, notamment : les plans d'eau et l'occupation du sol.

Pour ce travail, nous avons disposé de 3 images Landsat, mises à notre disposition à travers la base de donnée de l'Université de Maryland. Les images sont placées dans le cadron Landsat de Path and Row: *P201r035.*

La première image a été acquise le 07/05/1987, la deuxième le 06/03/1988 et la troisième le 20/08/1999.

La dernière image est très intéressante, car elle a été acquise à une date plus proche de la situation actuelle. Son acquisition pendant la saison estivale, caractérisée par la quasi-absence des cultures, permet de faire une meilleure discrimination de classes présentes dans le bassin, notamment les essences végétales. Disposant d'une bande panchromatique de 15 m de résolution, l'image de 1999 a été retenue pour la réalisation de la carte d'occupation des sols.

Les autres images sont importantes pour suivre l'évolution de toutes les classes, notamment l'évolution des surfaces d'eau et des zones humides. Il est possible d'enrichir le modèle par d'autres images intermédiaires ou des images plus récentes avec des meilleures résolutions pour affiner d'avantage le modèle.

Les images satellitaires ont permis également l'extraction de l'indice de végétation par différence normalisée (NDVI). Les cartes de classification du NDVI permettront de comprendre l'évolution du couvert végétal à différentes dates.

Données descriptives

Les données descriptives sont collectées à partir de plusieurs sources:

- des données synthétiques qui caractérisent le climat et l'hydrologie de la zone d'étude ainsi que la mobilisation et l'allocation des ressources qui sont disponibles sur le site web du Secrétariat d'Etat à l'Environnement (SEE);
- des données sur la demande en eau émanent des études réalisées par le département chargé de l'irrigation (DDGI et DAHA) et aussi de la synthèse de l'actualisation du plan directeur d'aménagement intégré des ressources en eau concernant la zone d'étude publiée sur Internet (ABHL, 2006).

Les données de base (séries d'enregistrements pluviométriques et hydrométriques) sont disponibles à l'agence de bassin hydraulique du Loukkos (ABHL) qui gère, entre autres, le bassin hydraulique de Tahaddart.

Les données accessibles sont utilisées par le présent travail pour alimenter les tables jointes aux différentes couches cartographiques d'information. Certaines de ces données ont permet de générer de nouvelles couches d'information, par exemple sur: la demande en eau potable, l'irrigation privée, les périmètres d'irrigation de la petite et moyenne hydraulique, les stations d'observation hydrométriques, etc.

Ces données sont également analysées pour comprendre le disfonctionnement des méthodes actuelles de travail et pour proposer la présente approche spatiale.

Données thématiques

Les données sur le milieu naturel: géologie, failles, forêts, nappes aquifères sont principalement extraites de données existante à l'échelle nationale: (carte géologique du Maroc, inventaire forestier national, carte des aquifères du Maroc).

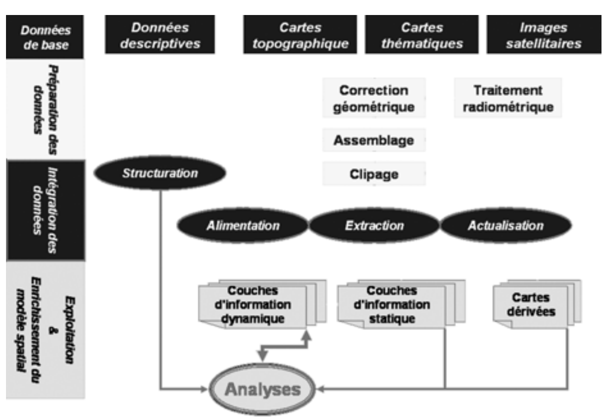
Ces données thématiques sont utilisées pour enrichir le modèle spatial de Tahaddart. Elles montrent le potentiel d'intégration et d'analyse par l'approche spatiale qui s'appuie sur les bases de données géographiques.

Montage du modèle spatial des ressources en eau de Tahaddart

Dans le présent travail, la modélisation spatiale est une approche de description de l'état des ressources en eau et de leurs différents usages. C'est ensuite une plateforme d'intégration de données émanant de différents acteurs. Mais aussi et surtout un outil d'analyse des données et de préparation d'éléments de décision sur l'eau.

Le modèle spatial des ressources en eau de Tahaddart est réalisé selon le processus décrit dans la Figure 1.

Figure 1. Processus de modélisation spatial.



Le montage du modèle spatial du bassin hydraulique de Tahaddart s'est fait selon 3 directives:

(i) compléter l'information sur les ressources en eau par l'intégration des données décrivant les différentes thématiques en relation avec les ressources;
(ii) offrir la possibilité d'assemblage de données sectorielles et d'analyses spatiales croisées;
(iii) constituer le noyau dur de l'approche spatiale pour la description quantitative des ressources en eau du bassin de Tahaddart.

Le modèle spatial du bassin hydraulique de Tahaddart est basé sur une BDG à couches multiples (réseau hydrographique, découpage administratif, demande en eau, carte topographique, images satellitaires, etc.). Ces couches sont structurées pour répondre aux besoins de description des ressources en eau dans ce bassin.

Les données descriptives sont collectées et renseignées sur les tables des couches d'information.

Les analyses spatiales effectuées sur la BDG ont généré tous les composantes du modèle spatial en question: modèle topographique, modèle du milieu naturel, modèle des écoulements, modèle des observations, modèle de mobilisation et modèle de la demande en eau pour l'alimentation en eau potable et industrielle (AEPI) et pour l'irrigation.

Modèle topographique

Cette composante regroupe tous les éléments de description géométrique de la zone d'étude tant en planimétrie qu'en altimétrie; principalement la carte topographique au 1/50000 (Fig. 2), les images satellitaires (Fig. 3), le modèle numérique de terrain, une vue 3D du bassin, la carte de classification des pentes, le découpage administratif, les limites de la zone d'étude, etc.

L'objectif de ce modèle est de fournir les références spatiales à l'ensemble des composantes du modèle et donc d'établir la relation de voisinage entre les différents éléments de description des ressources en eau.

Modèle du milieu naturel

Il regroupe les données qui peuvent avoir une influence sur l'écoulement superficiel et souterrain. Nous avons intégré dans ce modèle la carte des essences forestières, la carte géologique et les cartes des aquifères, en plus d'autres documents dérivés des images satellitaires ou de sources supplémentaires : l'occupation des sols, la carte des classes de NDVI, etc.

Ce modèle a été conçu pour qu'il reste ouvert et peut être implémenté et enrichi par d'autres données sur: la biodiversité, la qualité des eaux, les sources de pollution, etc.

Il permet, de fournir pour chaque point du bassin de Tahaddart, toutes les informations disponibles sur le milieu naturel.

Figure 2. A. Tableau synoptique de 4 feuilles de la carte topographique au 1/50000. B. Mosaïque des cartes topographiques couvrant le bassin de Tahaddart (limite de bassin découpé sur la mosaïque). Les coordonnées géographiques vont de 35.30 à 35.73 de latitude nord et de 5.56 à 6.00 de longitude ouest selon la projection géographique (Latitude/ Longitude; Sphéroïde WGS 84).

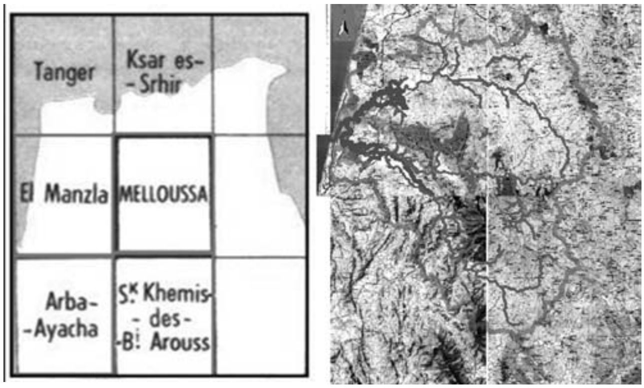
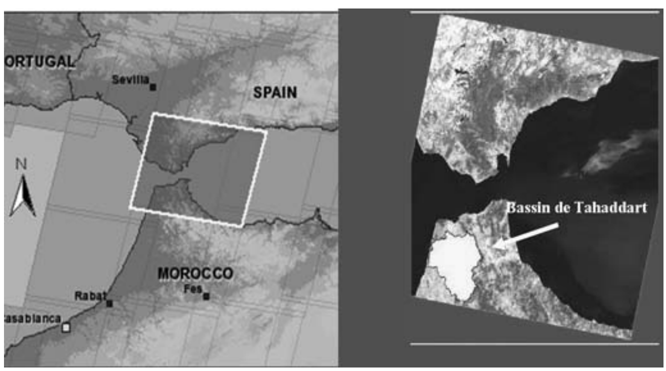


Figure 3. Localisation de l'image Landsat couvrant le bassin de Tahaddart Path 201 Row 035.



Modèle des observations

Il a été préparé afin qu'il puisse intégrer les données collectées et aussi les résultats des études statistiques menées sur ces données. Il a pour mission de préparer les éléments descriptifs qui alimentent les tables jointes aux différentes couches d'information, notamment les enregistrements hydrométriques et pluviométriques, ainsi que les mesures bathymétriques.

L'objectif de ce modèle est de maintenir les archives des observations du terrain en vue de les analyser sous SIG.

Modèle des écoulements

Il s'appui en grande partie sur les couches d'informations issues: du réseau hydrographique, des puits, des sources et des plans d'eau dans le bassin de Tahaddart. Ces couches sont extraites de la carte topographique. En outre, la table des données descriptives liée à la couche du réseau hydrographique a été codifiée. Chaque code correspond à un type d'information : type d'écoulement, appartenance à un sous-bassin, confluence avec un cours d'eau permanent. Le réseau hydrographique a été ainsi hiérarchisé et implémenté de la toponymie extraite de la carte topographique au 1/50000 (Fig. 4).

Ce modèle montre les lieux géométriques des surfaces d'eaux stagnantes, des écoulements superficiels et des indices d'écoulements souterrains (les puits et les sources). Il a pour objectif de montrer la répartition spatiale des ressources en eau dans le bassin de Tahaddart.

Modèle de mobilisation

Il s'intéresse aux équipements hydrauliques réalisés ou en projet: infrastructures hydrauliques, principaux barrages, ressources mobilisées et barrages à usage agricole.

Il a pour objectif de montrer l'emplacement des principaux réservoirs et leurs situations par rapport aux lieux de la demande et aussi aux sources de pollution.

Modèle de la demande en eau

Il englobe les données relatives à la demande en eau. Des couches d'information générées à partir des données descriptives sont consacrées pour chaque type d'usage: (i) demande en eau potable; (ii) demande en eau d'irrigation de la Petite et Moyenne Hydraulique (PMH); (iii) demande en eau de l'irrigation privée (IP).

Ce modèle a pour objectif de localiser les utilisateurs des eaux du bassin de Tahaddart. Il fourni les informations sur le type d'usage, l'origine de la ressource pour chaque usage et les chiffres disponibles sur les quantités demandées. Il permet en outre, de croiser les données officielles avec la réalité sur le terrain pour pouvoir les valider.

Matériel utilisé

Les cartes topographiques ont été géoréférencées sous un logiciel de traitement des données spatiales SIG approprié. Le traitement d'amélioration et d'extraction des indices à partir des images satellitaires et des cartes topographiques s'est effectué moyennant un logiciel de traitement d'images.

Toutes les couches d'information de base ont été numérisées. Les tables de données descriptives ont été conçues, développées et jointes à ces couches pour répondre à la méthodologie adoptée.

Le montage de la base de données géographiques, ainsi que les analyses spatiales qui ont généré les composantes de notre modèle se sont effectués sur un logiciel de traitement des données spatiales.

Résultats

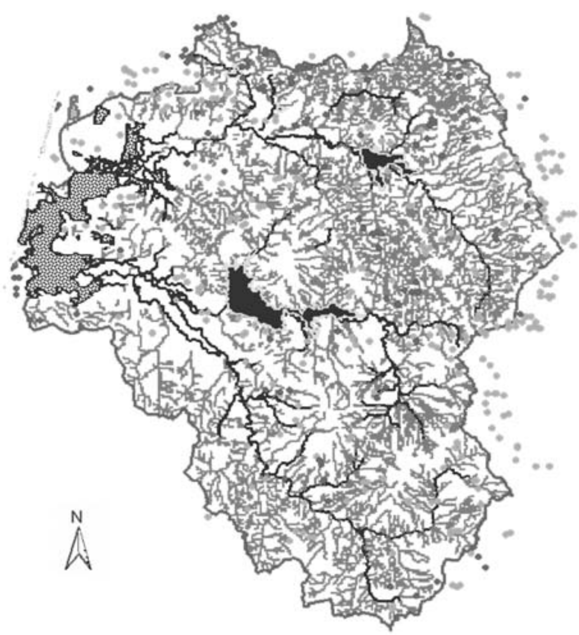
Les principaux résultats de ce travail sont:

- La mise au point du modèle spatial du bassin de Tahaddart;
- L'identification des ressources, usages, tendances et conflits concernant ce bassin;

Mise au point du modèle spatial du bassin de Tahaddart

Le modèle spatial réalisé a l'avantage de: (i) poser les aspects étudiés dans leur contexte géographique (lieu, voisinage, dépendance fonctionnelle, etc.); (ii) superposer toutes les couches d'informations disponibles; (iii) lier les cartes à des tables attributaires de données, formuler des requêtes et visualiser les résultats.

Figure 4. Systèmes d'écoulements selon le modèle spatial des ressources en eau dans le bassin de Tahaddart.



Ceci permet d'avoir l'ensemble de l'information disponible pour chaque point du bassin, d'améliorer la capacité d'analyse (analyse spatiale en plus de l'analyse ordinaire des données) et d'avoir la possibilité de développer des méthodologies et des modèles mathématiques basés sur les données localisées.

Le modèle permet également de superposer l'ensemble des composantes à des fins d'analyses spatiale et thématique.

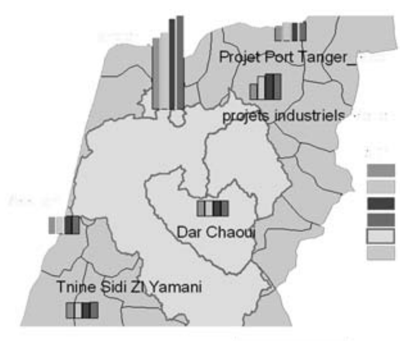
Identification des ressources, usages, tendances et conflits concernant le bassin

La demande principale en eau émane de la région du Tangérois (Fig. 5). En effet, le bassin de Tahaddart de 1110 km^2 de superficie, constitue le réservoir principal de l'alimentation en eau potable de la région du Tangérois 2155 km^2 de superficie et de population urbaine estimée à 735.000 habitants en 2005; 1.000.000 en 2020 et 1.200.000 en 2030 (ABHL, 2006). L'essentiel de la demande exprimée se situe à l'extérieur de la zone d'étude.

Les autres activités telles que l'irrigation, l'abreuvement du cheptel et l'alimentation en eau potable du monde rural (en dehors de la population dite branchée) sont supposées être satisfaites par l'utilisation des ressources locales.

La Figure 5 montre clairement que la demande n'a pas pour unité territoriale le bassin hydraulique, mais une unité du découpage administratif de la zone d'action de l'ABHL.

Figure 5. Projection de la demande en eau de la région du Tangérois.



La Figure 6 montre la répartition des périmètres d'irrigation de la zone d'étude. La demande en eau d'irrigation est estimée à 7 Mm^3/an.

Les Tableaux 1 et 2 présentent respectivement l'offre et la demande en eau. Nous remarquons que les volumes mobilisés actuellement sont estimés à 124 millions de m^3 par an et que la demande satisfaite par les ressources en eau du bassin de Tahaddart est officiellement estimée à 52,13 Mm^3 (eau potable seulement).

Figure 6. Répartition des périmètres traditionnels d'irrigation dans le bassin de Tahaddart. Superficie totale de l'irrigation saisonnière = 826 ha (17 périmètres d'une superficie de 5 à 683 ha). Demande en eau globale ne dépassant pas 7 Mm3/an (valeur estimée).

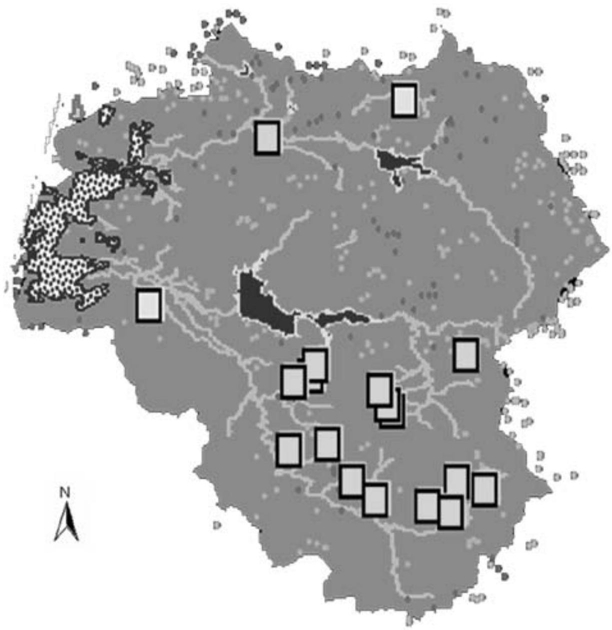


Tableau 1. Ressources mobilisées dans le bassin de Tahaddart (Source : DGH 1993).

Ouvrage	Oued	Apport moyen (Mm^3)	Volume utile de retenue (Mm^3)	Volume régularisé (Mm^3/an)
Ibn Battouta	El Kébir	56	40	26
9 Avril	Haricha	89	270	69
Prise de Bougdour	El Kébir	49	-	9,5
Prise de Hachef	Haricha	125	-	17,5
Nappe Charf El Akab				2

Tableau 2. Demande satisfaite par les eaux mobilisées dans le bassin de Tahaddart.

Type d'utilisation	Volumes demandés (Mm3)
Irrigation PMH	5,5
Irrigation privée	?
Eau potable exprimée	52,13
Eau potable non exprimée	?
Total	57,63 + ?

Selon les statistiques officielles (ABHL, 2006), le bilan hydraulique est positif et le bassin est excédentaire. Cette situation restera valable jusqu'à l'horizon 2030.

L'analyse des données descriptives a permis également de retracer la tendance offre-demande. En effet, la différence des dates de mise en service des deux barrages gérés par l'ABHL, exprime l'évolution de la demande. Ainsi avant 1977, la demande était satisfaite totalement par le pompage à partir de la nappe Charf Al Akab d'un volume ne dépassant pas 2 millions de m^3 par an.

La construction du barrage Ibn Battouta et sa mise en service en 1977 avait pour objectif de répondre à l'évolution de la demande de la ville de Tanger, et le barrage 9 avril 1947 a été mis en service en 1995 suite à une période de sècheresse de 16 ans (1979 à 1994). Il avait pour mission de faire face aux effets de la sécheresse et de fournir l'eau potable à l'ensemble de la région du Tangérois.

Actuellement, avec le développement socio-économique attendu de la région du Tangérois, d'autres barrages sont prévus pour satisfaire la demande à l'horizon 2030. Parmi les barrages prévus, des sites de barrages sont sélectionnés dans le bassin de Tahaddart (ABHL, 2006).

Les deux grands barrages présents dans le bassin sont utilisés exclusivement pour l'eau potable des grandes villes et des centres urbains de la région du Tangérois; une partie des périmètres irrigués est alimentée par les deux petits barrages à usage agricole; les autres activités sont alimentées par des ressources locales.

Les conflits d'usage ne se présentent pas à court terme notamment pour les raisons suivantes:

- Le partage naturel des ressources entre les usagers:
    - les barrages pour le transfert de la grande majorité de l'eau potable à l'extérieur du bassin;
    - les ressources locales pour les activités locales.
- La non existence de pollueurs qui entravent la qualité de l'eau relative à un usage particulier:
    - un seul foyer de rejet liquide à l'amont du barrage 9 avril 1947 qui reste jusqu'à présent très limité et n'affecte que peu ou pas la qualité de la retenue;
    - un seul foyer de pollution thermique relatif à la centrale hydrothermique de Tahaddart situé au niveau de l'estuaire;
    - l'irrigation n'est pas intensive et la pollution diffuse due aux intrants agricoles reste sans danger sur la qualité des eaux d'une manière générale;
    - les grandes agglomérations d'habitats et les quartiers industriels se situent en dehors du bassin versant de Tahaddart.

Cet état pousse à supposer que le bassin de Tahaddart constitue un modèle de bassin naturellement "sain". La qualité de l'eau est généralement bonne. Mais encore faut-il que les grands projets touristiques prévus dans la région du Tangérois ne touchent pas la qualité de cette eau.

Discussion

Le modèle spatial permet d'éclaircir les controverses concernant la planification et l'usage de la ressource en eau dans le bassin de Tahaddart. Il permet en outre de faire une évaluation des méthodes actuelles d'estimation de cette ressource.

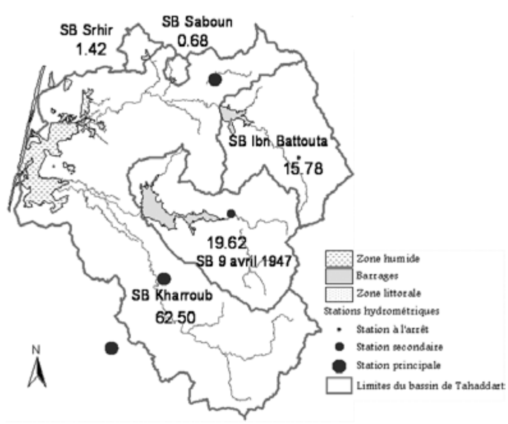
Représentativité du réseau d'observation

Selon les études du plan directeur (DGH, 1993), la densité des stations hydrométriques répond parfaitement aux normes internationales. Cependant, la Figure 7 montre que l'emplacement de ces stations à l'amont du réseau hydrographique ne permet pas de décrire correctement le régime hydrologique du bassin de Tahaddart. Pour les besoins de la planification, ces stations doivent assurer l'observation d'une superficie représentative du bassin étudié (70 à 80% de la superficie du bassin).

Les stations hydrométriques de la zone d'étude sont installées entre 1967 à 1970, avant la vision de la gestion intégrée des ressources en eau (fin des années 80). Le choix de l'emplacement des stations, près du réseau routier selon la carte topographique, ne donne pas forcément un réseau représentatif de l'hydrologie du bassin dans le cadre de cette vision.

Ce problème de représentativité entrave la connaissance des ressources en eau.

Figure 7. Répartition des stations hydrométriques dans le bassin de Tahaddart.



Taux de mobilisation des ressources en eau

Les ouvrages de mobilisation contrôlent l'écoulement dans la zone d'étude à raison de 37,5% seulement de la superficie du bassin de Tahaddart. Les eaux d'une superficie évaluée par le modèle spatial à 706,83 Km^2 (soit 62,5% de la superficie totale de ce bassin) ne sont que partiellement acheminées vers les stations de traitement et de production d'eau potable par le biais de deux prises de dérivation sans aucune capacité de stockage. Les eaux sauvages déversent directement dans l'océan en passant par la zone humide de Tahaddart. La Figure 8 et la Tableau 3 présente le détail de cette situation.

Figure 8. Taux de mobilisation des eaux superficielles dans le bassin de Tahaddart.

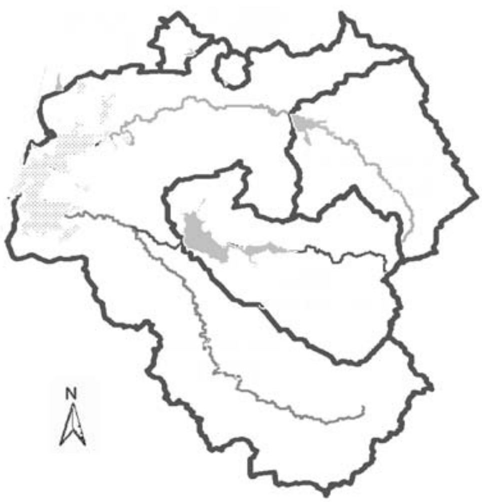


Tableau 3. Taux de mobilisation des eaux superficielles dans le bassin de Tahaddart.

NOM sous-bassin	Superficie (Km^2)	Pourcentage de la superficie totale
SB Saboune	7,66	0,68
SB Srhir	16,07	1,42
SB Ibn Battouta	178,47	15,78
SB 9 avril 1947	221,82	19,62
SB Kharroub + Mharhar	706,83	62,50
Total	1130,86	100,00

Le bilan hydraulique

Les termes du bilan hydraulique calculés par les méthodes actuelles (ABHL, 2006; DGH, 1993) se présentent de la forme suivante:

- l'offre n'est estimée qu'à partir des volumes d'eaux mobilisés par les barrages Ibn Battouta et 9 avril 1947, les eaux déviées par les prises

de Bougdour et Hachef, et le pompage à partir de la nappe Charf Al Aqab. Les autres barrages, les eaux sauvages des bassins Kharroub et Mharhar, les eaux souterraines exploitées à travers les sources et les puits ne sont pas pris en compte dans le bilan actuel;
- la demande prise en considération ne concerne que l'AEPI des villes de Tanger et des centres urbains de la région du Tangérois, ainsi que les zones des activités économiques actuelles ou en cours de réalisation. Les besoins du monde rural en eau potable et en irrigation n'ont jamais été comptabilisés.

Le modèle spatial proposé dans le présent travail montre donc, que le potentiel hydraulique réel n'est pas évalué d'une manière exhaustive. Il montre aussi que l'essentiel de la demande exprimée est située à l'extérieur du bassin. Ainsi, la demande estimée par les méthodes actuelles est en deçà de la demande réelle. En fait, dans les études du plan directeur actuel (ABHL, 2006; DGH, 1993), les prélèvements à l'amont des barrages ne sont pas comptabilisés dans les apports. Ils sont annulés en terme de bilan par la demande locale.

Le bilan ainsi établit dissimule la réalité sur le terrain. Nous considérons que la détermination du bilan hydraulique au sein de bassin hydraulique de Tahaddart doit être basée sur une meilleure connaissance de l'offre et de la demande en eau. Elle doit indiquer les volumes transférés vers les bassins limitrophes (exprimant la demande en AEPI de la région du Tangérois), et aussi signaler les parts des allocations à l'intérieur et à l'extérieur du bassin.

Conclusion

Les indices tirés du modèle spatial développé dans ce travail montrent la présence d'activités permanentes basées sur certaines ressources en eau locales non inventoriées. C'est le cas notamment de l'irrigation et du creusement des puits à proximité des agglomérations rurales.

Or, dans un contexte de rareté et selon la loi marocaine sur l'eau, le devoir des gestionnaires du secteur de l'eau est de rationaliser l'usage de l'eau en vue d'assurer la durabilité aussi bien de la ressource que des activités économiques. Toutes les ressources et tous les préleveurs sont concernés.

Le bassin de Tahaddart, situé au sud de la Méditerranée, est un exemple d'une gestion non efficiente des ressources en eau. Le modèle spatial mis au point dans la présente étude permet d'émettre des hypothèses sur la possibilité de mieux approcher l'appréciation du potentiel hydraulique et de la demande réelle dans ce bassin.

En effet, l'essentiel de la demande exprimée est située à l'extérieur du bassin; tandis que la demande réelle de la population et des activités économiques implantées au sein du bassin n'est pas complètement satisfaite par les études des plans directeurs. Ceci pose un problème dans la gestion de la ressource et contraint d'autres organismes à interférer par des actions complémentaires qui ne sont pas nécessairement coordonnées: lutte contre les effets de la sécheresse, actions de désenclavement des agglomérations rurales, actions de la lutte contre la pauvreté, etc.

Le diagnostic présenté par le modèle spatial, justifie d'abord le perfectionnement de ce modèle par le complètement et l'amélioration des données descriptives.

Il propose l'adoption d'une approche tenant compte des résultats de la présente étude pour procéder à la fédération et au recoupement des données émanant de l'ensemble des intervenants dans le secteur de l'eau.

En fin, ce modèle répond aux besoins en termes de méthodologies à développer et d'axes de recherches prioritaires à définir, notamment, la normalisation de la nomenclature de l'eau, l'établissement des conventions d'échange de données et la modélisation systématique des termes du bilan hydraulique du bassin.

Remerciements

Ce travail a été réalisé dans le cadre du projet WADI financé par l'Union Européenne 6ème FP Contrat INCO-CT-2005-015226. Nous remercions la coordinatrice générale, Professeur F. Scapini, et le coordonnateur local, Professeur A. Bayed du projet WADI.

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LES CHANGEMENTS RÉCENTS DANS LA COMPOSITION DU PEUPLEMENT D'OISEAUX D'EAU NICHEURS DU BAS TAHADDART (NORD-OUEST DU MAROC)

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Résumé: L'avifaune aquatique du complexe de zones humides du Bas Tahaddart a fait l'objet d'un suivi régulier durant les années 1970. Depuis, seule sa composante hivernale continue d'être suivie dans le cadre des dénombrements hivernaux d'oiseaux d'eau coordonnés par l'Institut Scientifique de Rabat.
Un suivi sur deux années (2006 et 2007) dans le cadre du projet WADI nous a permis de combler les lacunes dans nos connaissances sur les oiseaux d'eau nicheurs du Bas Tahaddart et de mettre en évidence les changements qui ont affecté ce compartiment depuis les années 1970.
Nous avons constaté, en particulier, que le peuplement d'oiseaux d'eau nicheurs du Bas Tahaddart a connu ces dernières décennies une nette amélioration, non seulement par la réhabilitation d'espèces ayant disparu du site ou par le renforcement des effectifs de celles ayant survécu, mais aussi par l'installation de nouveaux éléments reproducteurs qui étaient inconnus de la zone auparavant.
Alors que la majorité des zones humides marocaines subissent des contraintes négatives suite à une pression humaine croissante (drainage; empiètement des zones agricoles, industrielles et urbaines; fragmentation des habitats ; pollution; braconnage…) et à la succession de plusieurs années de sécheresse, quelques rares sites ont connu ces dernières années une nette amélioration de leurs valeurs écologiques, en particulier ornithologiques, suite à une dynamique locale positive.
C'est le cas du complexe de zones humides du Bas Tahaddart mais aussi de ceux du Bas Loukkos, des marais de Smir et de l'embouchure de l'oued Moulouya, ou encore celui du lac de barrage d'Al Massira, où des aménagements hydrauliques, routiers ou industriels ont participé à la réhabilitation ou à la création d'habitats écologiques favorables à la nidification d'un certain nombre d'espèces d'oiseaux aquatiques dont certaines sont considérées comme rares, menacées ou nouvelles à l'échelle du pays.

Introduction

Le premier suivi relatif à l'avifaune aquatique de la Péninsule Tingitane date des années 1970 (Pineau & Giraud-Audine, 1974; 1976; 1977; 1979). Excepté pour la population nicheuse de Grande Outarde qui a bé-

Felicita Scapini, Jean-Marc Boffa, Elisabeth Conrad, Louis F. Cassar and Mariella Nardi (editors), *Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socio-economic and environmental analysis of changes and trends to enhance and sustain stakeholder benefits*, ISBN 978-88-6453-015-4 (online)

néficié d'une étude spécifique ces dernières années (Alonso *et al.*, 2000; 2004; 2005; Hellmich & Idaghdour, 2002), seule l'avifaune aquatique hivernante a fait l'objet, depuis 1983, d'un suivi régulier dans le cadre des recensements hivernaux d'oiseaux d'eau coordonnés par le Centre d'Etude des Migrations d'Oiseaux (CEMO) de l'Institut Scientifique de Rabat au Maroc.

Nos prospections de terrain dans le cadre du projet WADI ont été axées essentiellement sur la recherche d'indices de reproduction des oiseaux d'eau durant les saisons printanières 2006 et 2007 (bien que nous ayons également programmé des missions en périodes d'hivernage et de migration) afin d'actualiser nos connaissances sur les espèces nicheuses du complexe de zones humides du Bas Tahaddart.

Ces prospections ont permis de mettre en évidence de grands changements jugés globalement positifs dans la composition du peuplement d'oiseaux d'eau nicheurs.

Nous exposerons succinctement ces changements, décrirons les habitats où les nouvelles espèces nicheuses ont été rencontrées et discuterons, à la lumière des changements positifs constatés aussi ces dernières années dans quelques rares zones humides marocaines, les causes les plus probables à l'origine des modifications qui ont affecté le statut nicheur des espèces concernées.

Matériels et méthodes

Le site du Bas Tahaddart est situé sur la façade occidentale de la Péninsule Tingitane (Figg. 1 et 2). Il présente une diversité remarquable d'habitats humides naturels et artificiels (plages, dunes littorales basses, sansouires, cours d'eau terminaux sous influence marégraphique, marais à émergents hauts, mares temporaires, affluents d'eau douce, salines).

Notons que les marais à émergents hauts, de très faible superficie, correspondent en fait à des affluents d'eau douce qui, du fait de leur faible débit, paraissent comme des plans d'eau stagnante où se développe une végétation aquatique à base de *Typha*.

Plusieurs missions de prospection ont été programmées au cours des années 2006 et 2007; la majorité de celles-ci ont concerné la saison de reproduction (missions mensuelles réalisées entre mars et juillet), période pour laquelle nous disposions de peu d'informations.

Les travaux de terrain, consistaient à relever, à l'aide de jumelles et de télescopes, la présence d'oiseaux d'eau présents dans les principales zones humides du complexe du Bas Tahaddart. Durant la saison printanière, tous les indices de reproduction sûrs (nids, œufs, poussins), probables (alarmes, parades, défenses de territoire, cantonnements) ou possibles (présence continue) ont été recherchés.

Figure 1. Localisation du complexe de zones humides du Bas Tahaddart ainsi que des autres sites mentionnés dans le texte dans la partie nord du Maroc.

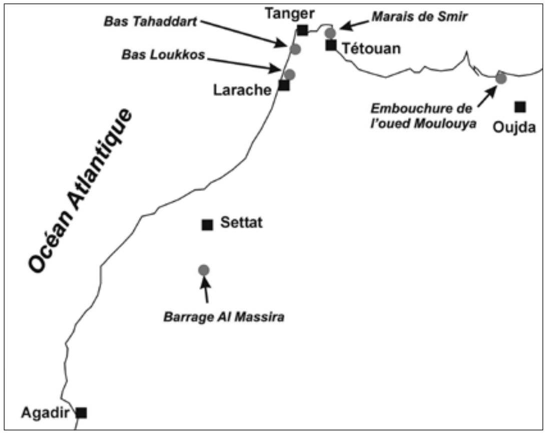
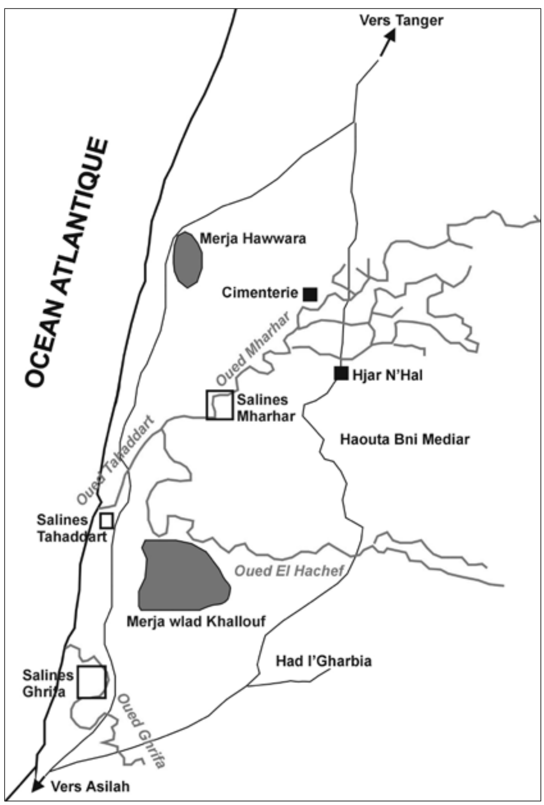


Figure 2. Présentation du complexe de zones humides du Bas Tahaddart et localisation des principaux secteurs prospectés sur le plan ornithologique.



Les données relatives aux diverses populations identifiées comme reproductrices au sein du complexe de zones humides du Bas Tahaddart ont été comparées à celles disponibles et synthétisées sur la région (Pineau & Giraud-Audine, 1979) afin de détecter d'éventuels changements ayant affecté la composition du peuplement nicheur d'oiseaux d'eau.

Résultats

Les prospections menées durant les printemps 2006 et 2007 ont permis de prouver la nidification de 21 espèces dans le complexe de zones humides du Bas Tahaddart (Tableau 1).

Pour deux autres espèces (Grèbe huppé *Podiceps cristatus* et Bihoreau gris *Nycticorax nycticorax*), un doute subsiste quant à leur statut de nicheur puisque leur présence continue durant toute la période de reproduction n'a pas été notée et qu'aucun signe de nidification sûre ou probable n'a été décelé.

Tableau 1. Liste des espèces d'oiseaux d'eau ayant niché dans le complexe de zones humides du Bas Tahaddart au cours des saisons de reproduction 2006 et 2007.

Espèces	2006	2007
Podiceps cristatus	?	
Tachybaptus ruficollis	X	X
Egretta garzetta	X	X
Ardea purpurea		X
Nycticorax nycticorax		?
Bubulcus ibis	X	X
Ciconia ciconia	X	X
Anas platyrhynchos	X	X
Circus aeruginosus	X	X
Circus pygargus	X	X
Rallus aquaticus		X
Fulica atra	X	X
Gallinula chloropus		X
Porphyrio porphyrio	X	X
Otis tarda	X	X
Tetrax tetrax		X
Himantopus himantopus	X	X
Recurvirostra avosetta	X	
Burhinus oedicnemus	X	X
Glareola pratincola	X	X
Charadrius alexandrinus	X	X
Sternula albifrons	X	X
Asio capensis	X	X
Nombre d'espèces nicheuses confirmées	17	20

Les Ardéidés arboricoles (Héron garde-bœufs *Bubulcus ibis* et Aigrette garzette *Egretta garzetta*) se sont reproduits au sein d'une importante colonie dominée par le Héron garde-bœufs et installée dans la partie nord du site sur un reboisement à base d'*Acacia*. C'est au niveau de cette héronnière que le Bihoreau gris a été observé. Nous n'avons toutefois pas pu nous assurer de sa reproduction.

Le troisième Ardéidé nicheur dans le Bas Tahaddart (Héron pourpré *Ardea purpurea*) a été identifié au niveau d'une Typhaie ayant recouvert un plan d'eau douce stagnant correspondant en fait à un affluent de l'oued Mharhar.

C'est également au niveau de ce marais que nous avons suspecté la nidification du Grèbe huppé *Podiceps cristatus* et confirmé celles du Grèbe castagneux *Tachybaptus ruficollis*, du Râle aquatique *Rallus aquaticus*, de la Foulque macroule *Fulica atra*, de la Gallinule-poule d'eau *Gallinula chloropus*, de la Talève sultane *Porphyrio porphyrio* et du Canard colvert *Anas platyrhynchos*.

Cette dernière espèce a niché aussi dans les petits marais temporaires de la vallée de l'oued El Hachef envahis par des Scirpes (comme d'ailleurs la Foulque macroule ou la Gallinule-poule d'eau) ou dans les salines des oueds Ghrifa et Tahaddart parmi la Salicornaie couvrant les cloisons de séparation des bassins. Notons que la Gallinule-poule d'eau fréquente également les *Phragmites*, *Typha* et *Scirpeus* des berges des petits affluents en amont des oueds Ghrifa, El Hachef et Mharhar.

Bien que nous n'ayons pas pu localiser les nids des Busards des roseaux *Circus aeruginosus* et cendré *C. pygargus*, la nidification de ces deux Rapaces est certaine dans le Bas Tahaddart étant donné leur présence continue et l'apparition à la fin de la saison printanière de juvéniles en compagnie d'adultes, très probablement leurs parents.

La Grande Outarde *Otis tarda* fréquente toujours le Bas Tahaddart et ses environs qui, ensemble, représentent la plus importante aire de nidification de l'espèce au Maroc; les effectifs sont toutefois en nette régression d'après les données recueillies dernièrement (Alonso *et al.*, 2000; 2004; 2005; Hellmich & Idaghdour, 2002).

Nos prospections du printemps 2007 ont permis de relever la présence d'un petit groupe d'Outarde canepetière *Tetrax tetrax* constitué d'un mâle et de deux femelles dont le comportement indique qu'il s'agissait très probablement de nicheurs dans la zone d'étude ou dans ses environs immédiats.

L'observation de plusieurs couples d'Oedicnème criard *Burhinus oedicnemus* cantonnés et alarmants au niveau des dunes de sable caillouteuses de la côte Asilah-Oued Ghrifa et de l'embouchure de l'oued Tahaddart, ainsi que le contrôle d'un nid avec deux œufs de la même espèce au niveau de la rive gauche de l'oued Tahaddart, attestent de la présence d'une petite population reproductrice appartenant à ce Limicole aux mœurs nocturnes.

Quatre autres espèces de Limicoles se sont reproduites dans le site. Deux l'ont fait au niveau des salines (Avocette élégante *Recurvirostra avosetta* et Echasse blanche *Himantopus himantopus*) alors que les deux autres (Glaréole à collier *Glareola pratincola* et Gravelot à collier interrompu *Charadrius alexandrinus*) ont niché, comme la Sterne naine *Sternula albifrons*, aussi bien sur les cloisons de séparation des bassins d'extraction de sel que le long de la portion de côte Asila-Oued Ghrifa au sein des dunes littorales basses et caillouteuses.

Signalons enfin que le Hibou du Cap *Asio capensis* existe toujours dans le Bas Tahaddart mais que ses effectifs doivent être très faibles. Nous avons relevé sa présence une seule fois dans des champs de céréales dans la partie amont de l'oued Ghrifa.

Tableau 2. Liste des espèces nicheuses retrouvées, disparues ou nouvelles dans le complexe de zones humides du Bas Tahaddart (2006-2007).

Espèces retrouvées	Espèces disparues	Espèces nouvelles
Bubulcus ibis	*Oxyura leucocephala*	*Tachybaptus ruficollis*
Ciconia ciconia	*Fulica cristata*	*Egretta garzetta*
Anas platyrhynchos (retour)		*Ardea purpurea*
Circus aeruginosus		*Tetrax tetrax*
Circus pygargus		*Rallus aquaticus*
Otis tarda		*Fulica atra*
Gallinula chloropus (retour)		*Porphyrio porphyrio*
Glareola pratincola		*Recurvirostra avosetta*
Charadrius alexandrinus		*Himantopus himantopus*
Sternula albifrons		
Asio capensis		

Discussion

Les données recueillies lors des prospections ornithologiques entreprises dans le cadre du programme WADI ont mis en évidence d'importantes modifications ayant affecté la composition du peuplement d'oiseaux d'eau nicheurs du complexe de zones humides du Bas Tahaddart.

Nous avons retrouvé 9 espèces (Tableau 2) parmi celles signalées comme reproductrices auparavant (Pineau & Giraud-Audine, 1979). Nous avons aussi retrouvé deux autres oiseaux (Canard colvert *Anas platyrhynchos* et Gallinule-poule d'eau *Gallinula chloropus*) qui avaient disparu complètement du site après assèchement, au cours des années 1950, de tous les plans d'eau douce dont celui de Charf Laakab (marais profond à émergents hauts) dont il ne reste plus aujourd'hui qu'une mare temporaire irrégulièrement mise en eau, la Daya Sghira.

C'est ce marais de Charf Laakab qui abritait des populations remarquables d'Erismature à tête blanche *Oxyura leucocephala* et de Foulque caronculée *Fulica cristata* et que nous n'avons donc plus retrouvées.

En revanche, nos recherches ont prouvé la nidification dans le Bas Tahaddart de plusieurs espèces inconnues jusqu'ici comme reproductrices. La majorité de ces oiseaux n'ont pu se reproduire qu'après réhabilitation ou même création d'habitats humides favorables.

En effet, le site du Bas Tahaddart présente actuellement plusieurs petits marais à émergents hauts dont la majorité sont de petite taille mais présentant des conditions écologiques minimales (émergents hauts, notamment) pour accueillir certaines populations nicheuses d'oiseaux d'eau (Grèbe castagneux *Tachybaptus ruficollis*, Héron pourpré *Ardea purpurea*, Canard colvert *Anas platyrhynchos*, Râle d'eau *Rallus aquaticus*, Foulque macroule *Fulica atra*, Talève sultane *Porphyrio porphyrio* et Gallinule-poule d'eau *Gallinula chloropus*).

Par ailleurs, l'installation plus ou moins récente de plusieurs salines dans le site du Bas Tahaddart a permis la nidification de l'Avocette élégante *Recurvirostra avosetta* (espèce nicheuse occasionnelle au Maroc) et de l'Echasse blanche *Himantopus himantopus*; elle a permis en outre de renforcer les populations préexistantes de Glaréole à collier *Glareola pratincola*, de Gravelot à collier interrompu *Charadrius alexandrinus* et de Sterne naine *Sternula albifrons*.

Il parait par conséquent clair que les changements constatés dans la composition de l'avifaune aquatique nicheuse du complexe de zones humides du Bas Tahaddart sont liés à des changements au niveau de l'hydrologie du milieu ayant permis la réhabilitation de certaines zones humides (marais à végétation émergente) suite à des aménagements routiers ou la création de nouvelles zones humides artificielles (salines).

Il est remarquable de constater que ces changements, globalement positifs ont eu lieu alors que la majorité des zones humides marocaines ont connu et connaissent des contraintes de différentes natures qui tendent à réduire leurs valeurs biologiques, en général, et ornithologiques, en particulier (Dakki & El Hamzaoui, 1998).

Précisons aussi qu'une évolution tout aussi positive a été constatée ces dernières années dans quelques rares zones humides marocaines, notamment l'embouchure de l'oued Moulouya (El Agbani *et al.* 2003), les marais de l'oued Smir (Amezian *et al.*, sous presse; Qninba *et al.*, en préparation), le complexe de zones humides du Bas Loukkos (Qninba *et al.*, 2008) et le lac du barrage d'Al Massira (Radi *et al.*, 2004, 2008; Thévenot *et al.*, 2004).

Ces changements positifs dans la composition de l'avifaune aquatique reproductrice, intervenus dans un contexte global défavorable, sont le fruit d'aménagements routiers (habitats humides réhabilités ou nouvellement créés par des digues ayant eu un effet de barrage), agricoles (rizières et systèmes d'irrigation), industriels (salines) ou hydrauliques (lacs de barrage).

Remarquons enfin que les modifications des milieux au niveau de quelques zones humides nord-marocaines, consécutives aux diverses actions humaines citées, ont eu lieu à un moment où plusieurs espèces d'oiseaux d'eau connaissent une expansion à l'échelle nationale (Héron pourpré *Ardea purpurea*, Butor étoilé *Botaurus stellaris*, Blongios nain *Ixobrychus minitus*, Nette rousse *Netta rufina*, Talève sultane *Porphyrio porphyrio*, Foulque caronculée *Fulica cristata*, Sterne hansel *Sterna nilotica*) ou régionale (Grande Aigrette *Casmerodius albus*, Ibis falcinelle *Plegadis falcinellus*, Goéland leucophée *Larus michahellis*, Mouette rieuse *Larus ridibundus*, Guifette noire *Chlidonias niger*) (Thévenot *et al*., 2003; BirdLife International, 2004; Qninba *et al*., 2008 et en préparation).

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ÉVALUATION DE LA BIODIVERSITÉ DES MACROINVERTEBRES AQUATIQUES DE TAHADDART AU MAROC: INTERÊT POUR LA CONSERVATION ET LA GESTION RATIONNELLE DES RESSOURCES HYDRIQUES

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Abstract: Macroinvertebrates are an important link in the food chain of aquatic species. They are a primary food source for several species of vertebrates. Moreover, they are known to be good indicators of aquatic ecosystems' health because of their great diversity and variable tolerance to pollution and habitat degradation.
Knowledge of the aquatic biodiversity of the ZCBVT, particularly that of macroinvertebrates, is essential to proposed strategies for water management and planning that are related to the rational use of water resources.
The number of taxa identified in the site amounts to at least 230, divided into 5 classes (gastropods, bivalves, crustaceans, arachnids and insects), 15 orders and 63 systematic families. An analysis of this aquatic biodiversity, of good biological quality in general, will be presented in its emerging hot spots, consisting of 47 species of high conservation value. These species are used to justify the importance of water resources of the site and guide the objectives of WADI project.
Last but not least, the ecological values of the site as well as priority habitats that need conservation are identified while threats and their effects on aquatic macroinvertebrates are emphasized.
Outstanding habitats include running waters in the watershed, particularly warm-water rivers and streams in the flat or mountainous areas and the large rivers of the lower course.
Water resource management measures that take the macro-compartment into account are then proposed.

Introduction

Les macroinvertébrés sont des hôtes des eaux courantes et/ou stagnantes où ils contribuent au flux d'énergie des réseaux alimentaires. De ce fait, ils sont l'un des éléments fondamentaux du fonctionnement des écosystèmes aquatiques et tiennent un rang important dans les équilibres biologiques et les chaînes trophiques s'y déroulant.

Comme les macroinvertébrés permettent la détection des dysfonctionnements provoqués par les pressions environnantes, ils sont utilisés pour évaluer l'état de biodiversité des écosystèmes aquatiques.

Dans ce travail, nous nous sommes proposés d'évaluer la biodiversité des macroinvertébrés des eaux douces et saumâtres du bassin versant et

Felicita Scapini, Jean-Marc Boffa, Elisabeth Conrad, Louis F. Cassar and Mariella Nardi (editors), *Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socio-economic and environmental analysis of changes and trends to enhance and sustain stakeholder benefits*, ISBN 978-88-6453-015-4 (online) © 2009 Firenze University Press

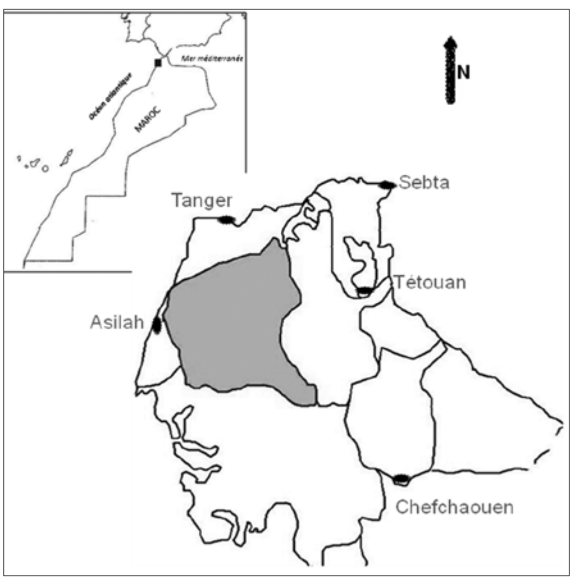
la zone côtière de Tahaddart (BVZCT) à partir des données existantes et de recherches complémentaires sur le terrain afin d'établir un état zéro de référence.

L'analyse et l'exploitation de l'inventaire des espèces patrimoniales a permis de définir le zonage géographique et les types d'habitats prioritaires pour la conservation de la biodiversité des macroinvertébrés de ce site. L'analyse des résultats permet de comprendre la place des macroinvertébrés dans le fonctionnement des ressources hydriques du site, d'identifier ses valeurs écologiques et les perturbations liées aux activités humaines qu'il subit.

Milieu Physique

Le Bassin de l'oued Tahaddart (Fig. 1) se situe sur la façade atlantique du Maroc. Sa limite nord commence à Charf El Akab à 15 km au sud de la ville de Tanger et sa limite sud se trouve au nord d'Asilah au niveau de l'oued Ghrifa.

Figure1. Situation de la région de l'étude, le BVZCT.



C'est un ensemble de collines basses dont l'altitude varie de 50 à 600 m avec une moyenne de 180 m. Le bassin versant couvre une superficie d'environ 2.740 km^2 et il est limité à l'est par les collines rifaines de Dar Zhirou et Hjar Enhal.

Le site est partagé entre deux bassins versants adjacents, séparés par la colline de "Haouta Bni Mediar", et dont les cours d'eau se joignent près de la côte pour former l'oued Tahaddart. Celui-ci est composé de deux grands affluents: El Hachef, retenu par le barrage du 09 avril 1947, et Mharhar, retenu par le barrage Ibn Battouta.

Sur le plan géologique, le bassin versant de l'oued Tahaddart est composé de grès numidiens, de marnes et de marnes calcaires.

Le bioclimat de la BVZCT est de type subhumide à hiver chaud ou tempéré. La pluviométrie est marquée par son régime méditerranéen. Les mois les plus secs sont juillet et août (<3 mm/mois) et les mois les plus humides sont novembre et décembre (125-135 mm/mois), avec une moyenne annuelle de 765 mm.

Méthodologie

La méthodologie proposée est basée sur l'analyse de données bibliographiques dressant un inventaire des espèces signalées dans ce site. De plus, des prospections de terrain ont été effectuées afin d'actualiser ces données et de compléter l'inventaire.

Choix des stations: Notre objectif étant l'étude de la macrofaune aquatique, le choix des stations a été guidé par leur répartition sur l'ensemble du réseau hydrographique, en tenant compte de leur variabilité thermique et hydrologique, l'échantillonnage des habitats représentatifs ainsi que par leur accessibilité.

Les prospections sont effectuées dans 18 stations réparties aussi bien au niveau de la zone cotière, le bas cours et le bassin versant de l'oued Tahaddart. La Figure 2 montre la localisation des stations prospectées. Les informations concernant les coordonnées géographiques, l'altitude, la hauteur d'eau et quelques paramètres mésologiques figurent au Tableau 1.

Figure 2. Localisation des stations du BVZCT.

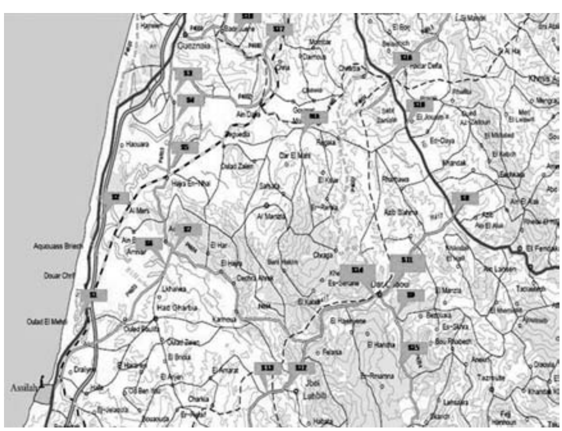


Tableau 1. Données mésologiques relatives aux stations du site de Tahaddart.

Code Station	Stations	Coord. Géo.	Al. (m)	Pr (cm)	C (µS/cm)	O (%)	pH	S (mg/l)	T (°C)
S1	Saline Oued Ghrifa	35° 31'219"N ; 05° 84'698"W	5	22,50	5560	5,00	6,00	22,00	25
S2	Saline Oued Tahaddart	35° 34'152"N; 06° 00'020"W	10	15,00	7032	4,20	6,00	31,20	26
S3	Marécage Cimenterie	35° 33'852"N; 05° 72'168"W	4	40,00	350	14,20	8,00	1,50	24
S4	Oued Bjada	35°39'218"N; 05° 56'801"W	3	15,00	850	10,10	8,50	0,60	22
S5	Oued Mharhar	35° 36'878"N; 05° 55'134"W	6	35,00	737	9,97	9,05	0,40	22,3
S6	El Kholj	35° 33'661"N; 05° 54'923"W	10	40	360	11,55	10,06	0,2	23,1
S7	Oued El Hachef	35° 33'071"N; 05° 55'206"W	5	20,00	350	7,01	8,81	0,20	21,2
S8	Oued Hmatoune	35° 34'868"N; 05° 38'572"W	90	3,00	772	17,97	8,67	0,40	22,7
S9	Oued Ankouda	35° 31'270"N; 05° 41'969"W	80	2,50	588	6,51	8,80	0,30	20
S10	Oued Ouljat Ech chat	35° 39'142"N; 05° 41'262"W	60	4,00	628	7,36	8,98	0,30	21,4
S11	Oued El Oulja	35° 32'042"N; 05° 41'280"W	60	7,50	640	4,10	7,83	0,30	22
S12	Oued jbel Habib	35° 28'198"N; 05° 48'223"W	40	7,50	428	16,13	8,46	0,20	17,7
S13	Oued El Kebir	35° 28'077"N; 05° 49'268"W	20	15,00	334	6,56	8,71	0,20	19,5
S14	Oued Haricha	35° 31'793"N; 05° 42'564"W	60	0,25	618	5,26	8,71	0,3	20
S15	Chemâa	35° 28'631"N; 05° 40'830"W	40	40	472	15,54	8,66	0,2	20,3
S16	Oued Sghir	35° 40'579"N; 05° 42'231"W	40	20	850	6,32	8,67	0,5	18,3
S17	Oued Aïn Laâsel	35° 41'477"N; 05° 50'061"W	30	15	920	6,4	8,75	0,5	22,9
S18	Lac Barrage Badriouène	35° 42'569"N; 05° 52'718"W	34	50	732	9,83	8,5	0,4	22

Al = Altitude; Pr = Profondeur de l'eau; C = Conductivité; O = Oxygène dissous; S = Salinité; T = Température.

Echantillonnage de la faune: La méthode utilisée a été adoptée par plusieurs auteurs notamment Ramdani (1986; 1988) et Himmi (1991; 2007). Le mode opératoire consiste à traîner un filet à plancton en soie à bluter de 0,10 mm de vide de maille (diamètre de l'ouverture 25 cm et profondeur 45 cm) relié à un manche de 1,20 m. Les coups de filet sont effectués de la même manière afin de pouvoir comparer les stations. Tout support supposant héberger une faune est placé dans le filet ou frotté à la main, de telle sorte que toute sa faune soit détachée et introduite dans le filet sous l'effet du courant.

Conservation et tri: Les échantillons prélevés sont transvasés dans une bassine en plastique, débarrassés des gros débris de végétaux in situ puis conservés dans de l'alcool à 70°. Au laboratoire, les contenus des bocaux sont d'abord triés à l'œil nu et /ou sous loupe binoculaire afin de séparer les différentes familles.

Identifications: La détermination des spécimens récoltés est réalisée en faisant appel à des ouvrages spécialisés dans l'identification des macroinvertébrés en général (Tachet *et al.*, 1986), des descriptions originales, des clés européennes ou marocaines et ceci pour les Mollusques, Annélides, Crustacés, Culicidés (Aguesse *et al.*, 1982; Lafont, 1983; Dethier, 1985; Dethier et Haenni, 1986; Ramdani *et al.*, 1987; Himmi *et al.*, 1995; Saoud *et al.*, 1995; Ghamizi, 1998). L'inventaire a été complété à l'aide des travaux de Gheit (1994), El Alami *et al.* (2000), Aguilar et Dommanget (1998), Jacquemin et Boudot (1999), Belqat (2002), Bennas *et al.* (2001), Bennas (2002) et Trari *et al.* (2002, 2004).

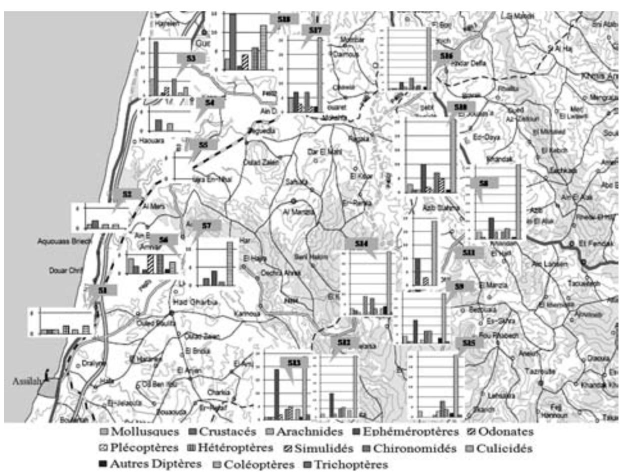
Résultats

Inventaire global: L'inventaire exhaustif des macroinvertébrés aquatiques des eaux douces et saumâtres du BVZCT (disponible sur demande) a permis d'estimer l'importance des écosystèmes/habitats du BVZCT. La liste répertoriée comprend au moins 229 espèces et sous-espèces, réparties entre 5 classes (Gastéropodes, Bivalves, Crustacés, Arachnides et Insectes), 16 ordres, 68 familles et 139 genres. Le groupe des Arthropodes domine largement la composition faunistique du peuplement d'invertébrés aquatiques avec 220 taxa répartis entre 61 familles (presque 96%), alors que les Mollusques constituent moins de 5% avec 10 espèces réparties en 7 familles.

Cet inventaire montre la prédominance classique des Insectes qui constituent presque 83% de la faune de Tahaddart avec 51 familles, 110 genres et 191 espèces et sous-espèces. Ceci représente presque 17% du total des Insectes des eaux continentales enregistré par Dakki (1998). Notons que le groupe dominant est celui des Coléoptères (11 familles), suivi par les Diptères (9 familles), puis les Ephéméroptères (6 familles), les Odonates (7 familles), les Hétéroptères (8 familles), les Trichoptères (3 familles) et les Plécoptères (2 familles).

Les Crustacés représentent plus de 12% avec 22 genres comprenant 27 espèces réparties entre 10 familles alors que les Arachnides avec 1 espèce représentent moins de 0,5%.

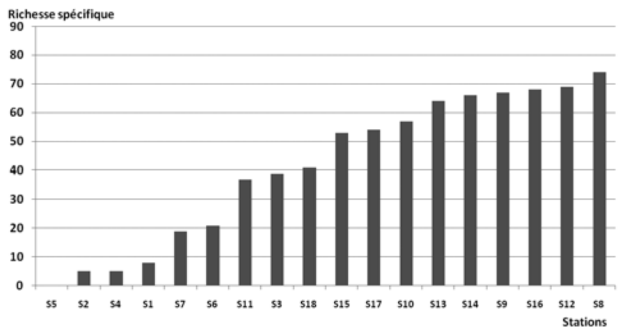
Figure 3. Richesse spécifique des stations prospectées dans le BVZCT.



L'analyse de la Figure 3 permet de faire ressortir que la station la plus riche en espèces est S8 avec presque 75 taxa, suivie par S12, S16, S9, S14, S13, S10, S17 et S15 avec respectivement 69, 68, 67, 66, 64, 57, 54, 53 taxa. Notons la faible richesse spécifique de S11 avec 37 espèces par rapport aux autres stations à proximité. Ceci est très probablement dû à l'impact de la pollution du cours d'eau par les déchets du village en amont. Par ailleurs, la richesse spécifique des deux habitats stagnants ne dépasse pas 41 espèces pour S18 et 39 pour S3.

Les stations les moins riches sont les salines S1 et S2 et S4 qui ne dépassent pas 8, 5 et 5 espèces respectivement.

Figure 4. Répartition spatiale des différents groupes de macroinvertébrés dans le BVZCT.



Notons l'absence totale de faune au niveau de S5. En effet, c'est une station où le substrat est riche en limons qui a fait qu'il y ait une absence de la macrofaune ne trouvant pas d'habitats adéquats pour se développer.

Une analyse de la répartition stationnelle des différents groupes rencontrés (Fig. 4) montre la nette dominance des Coléoptères au niveau des habitats d'eaux courantes, principalement celles situées au niveau de bassin versant. En effet, au niveau des oueds Hmâtoune et Sghir, le nombre de taxons est d'au moins 42. Les Ephéméroptères viennent en seconde place surtout au niveau de S13 où 19 espèces sont rencontrées. Les Hétéroptères puis les Odonates sont présents avec des effectifs d'espèces variables au niveau des différents habitats, mais notons leur richesse spécifique au niveau de S14.

Les autres groupes sont représentés avec des richesses plus faibles et sont répartis d'une manière variable au niveau des différents écosystèmes prospectés. Par contre au niveau des deux habitats stagnants, ce sont les Crustacés qui dominent avec une quinzaine de taxons au moins.

Espèces patrimoniales: Au moins 47 espèces ont été inventoriées comme patrimoniales (Annexe 1). L'inventaire comprend 17 taxa considérés comme rares et 12 taxa vulnérables. 8 autres espèces présenteraient un faible degré de vulnérabilité. Les espèces menacées sont estimées au nombre de 8.

Annexe 1. Liste des espèces patrimoniales: Endémisme, statut de conservation et degré de menaces.
1- M : Espèce menacée ?M : Espèce probablement menacée
2- R : Espèce rare; ?R : Espèce probablement rare; V: Espèce vulnérable; V- : faible degré de vulnérabilité
3- EN : Espèce nord-africaine; EMO : Espèce de Méditerrannée ouest; EM : Espèce marocaine

Espèces patrimoniales	Statut de menaces[1]	Statut de conservation[2]	Biogéographie (Endémisme)[3]
Phylum Mollusca			
CL. GASTROPODA			
O. Pulmonata			
Fam. Planorbidae			
*Planorbarius metidjensis(*Forbes, *1838)*			EN
Phylum Arthropoda			
CL. CRUSTACEA			
O. Ostracoda			
Fam. Diaptomidae			
Hemidiaptomus maroccanus Kiefer		R	EMO
CL. INSECTA			
O. Ephemeroptera			
Fam. Baetidae			
Acentrella almohades	?M	V	EMO
Baetis punicus		?R	EMO
Baetis maurus			EMO
Baetis meridionalis		?R	
Centroptilum luteolum	M	R	
*Cheleocloeon dimorphicum (*Soldán et Thomas, *1985)*		V	EN
Procloeon bifidum	M	R	
Procloeon concinnum		R	EMO
Pseudocloeon neglectus		V	EMO
Fam. Heptageniidae			
Ecdyonurus rothschildi		?R	EMO
Epeorus sylvicola		V	
Rhithrogena gr. sowai sp.1	M	R	EM
Fam. leptophlebiidae			
*Choroterpes (*Ch.*) volubilis*		R	EM

Espèces patrimoniales	Statut de menaces[1]	Statut de conservation[2]	Biogéographie (Endémisme)[3]
O. Heteroptera			
Fam. Corixidae			
*Parasigara transversa (*Fieber, *1848)*			EMO
Trichocorixa verticalis		?V	
Fam. Gerridae			
*Aquarius cinereus (*Puton, *1869)*			EMO
Gerris brasili			EMO
Fam. Veliidae			
Velia ioannis			EN
Velia noualhieri Puton (1889)		R	EMO
O. Diptera			
Fam. Simulidae			
Greniera fabri Doby & David, *1959*		R	EMO
Metacnephia blanci Grenier & Theodorides, *1953*		R	EMO
O. Coleoptera			
Fam. Dytiscidae			
Graptodytes aequalis Zimmermann, *1918*		R	EMO
Fam. Helophoridae			
Helophorus (Rhopalhelophorus) obscurus algiricus Mulsant, *1844*			EN
Fam. Hydraenidae			
Hydraena africana Kuwert, *1888*	M	R	EM
Hydraena (Hydraena) allomorrpha Lagar & Fresneda, *1990*		V-	EMO
Hydraena (Hydraena) bisulcata Rey, *1884*		V-	EMO

Choroterpes (Ch.) atlas		V	EN
Choroterpes (Eu) lindrothi	M	R	EN
Fam. Oligoneuriidae			
Oligoneuriopsis skhounate	M	R	EMO
O. Odonata			
Fam. Aeschnidae			
Aeshna cf mixta Latreille, *1805*		V	
Fam. Coenagriidae			
Ischnura graellsi Rambur, *1842*			EMO
Fam. Gomphidae			
*Paragomphus genei (*Sélys, *1841)*		R	
Fam. Platycnemididae			
Platycnemis subdilatata Sélys, *1849*		?V+ C27	EN
O. Plecoptera			
Fam. Perlodidae			
Hemimelaena flaviventris (Hoffm.) Pictet			EMO
Hydraena (Hydraena) capta d'Orchymont, *1936*		V-	EMO
Hydraena (Hydraena) hernandoi Fresneda & Lagar, *199*		V-	EMO
Hydraena (Hydraena) rigua d'Orchymont, *1931*			EN
Limnebius evanescens Kiesenwetter, *1866*		V-	EMO
Limnebius fretalis Peyerimhoff, *1913*		V-	EMO
Limnebius furcatus Baudi, *1872*		V	
Limnebius maurus Balfour-Browne, *1978*		V-	EMO
Ochthebius (Ochthebius) lanarotis lanarotis Ferro, *1985*	M	V	EM
Fam. Hydrochidae			
Hydrochus aljibensis Castro & Delgado, *1999*		V-	EMO
Fam. Hydrophilidae			
Laccobius (Hydroxenus) revelierei Perris, *1864*		V	
O. Trichoptera			
Fam. Rhyacophilidae			
Rhyacophila munda McLachlan		V	EM

Habitats remarquables: L'analyse des préférences écologiques des espèces patrimoniales de macroinvertébrés aquatiques précédemment inventoriées permet d'identifier les habitats remarquables à des fins de conservation au niveau du site d'étude.

Les habitats remarquables qui ont montré une importante richesse en espèces patrimoniales sont les rivières/ruisseaux chauds en zone plate ou en montagne (CCL), à écoulement lent, eurythermes (Tableau 2). Ces habitats peuvent s'assécher en été mais sont régulièrement remis en eau en période pluvieuse. Ils sont souvent riches en végétation. Les grands cours d'eau du bas cours lents, larges et chauds (CT, CFL, CCF) abritent également une importante faune remarquable. Les autres habitats (Merja, lac de barrage, …) généralement stagnants, plus ou moins profonds, de grande taille, chauds en été et peu froids en hiver n'abritent pas un nombre important d'espèces.

La grande richesse de ces habitats remarquables en faune rare, vulnérable et/ou menacée, malgré qu'elle représente un faible pourcentage par rapport au peuplement global, permet de proposer leur protection et conservation.

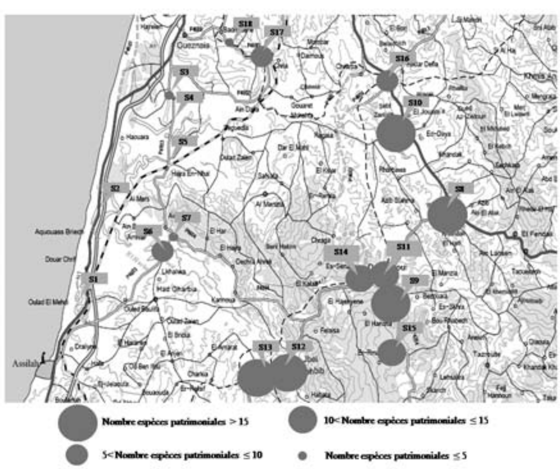
Une cartographie des espèces patrimoniales recensées dans la zone permet de localiser les secteurs du site à forte valeur écologique et présentant une sensibilité extrême (Fig. 5), notamment les cours d'eau de Jbel Lahbib et Oued El Kébir, ainsi que les cours d'eau de Hmâtoune, Ankouda et Ouljat Ech Chat qui abritent une biodiversité importante en espèces patrimoniales (N>15 espèces).

Tableau 2. Préférences écologiques de la faune du BVZCT: Nombre de taxa par type d'habitat.

	Types d'habitats							
	DD	LB	AB	MD	CCF	CFL	CT	CCL
Taxa patrimoniaux	1	1	1	1	5	17	24	36
Taxa rares	0	0	0	1	1	6	6	12
Taxa vulnérables	0	0	0	0	2	7	10	16
Taxa menacés	0	0	0	0	1	3	3	3

DD: Dayas d'eau douce
LB: Lacs de basse plaine
AB: Lacs de barrages
MD: Merjas d'eau douce
CCF: Grandes rivières de plaine
CFL: Ruisseaux lents de montagne
CT: Ruisseaux temporaires
CCL: Cours d'eau chauds et lents

Figure 5. Répartition des espèces patrimoniales au niveau des habitats du BVZCT.



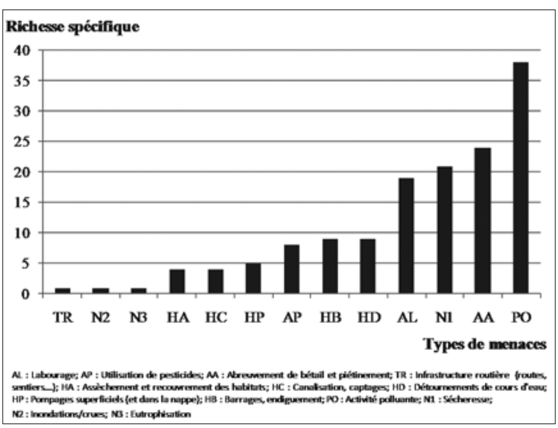
Menaces: Vu sa proximité de certaines villes (Asilah, Tanger et Tétouan), le BVZCT est le siège d'une croissance démographique au niveau de certains douars environnants. Les activités agricoles et d'élevage, les perturbations hydrologiques ainsi que la pollution domestique autour des agglomérations rurales accentue considérablement les effets de la sécheresse qu'a connue le Maroc ces dernières années.

Les sources de menaces sur les macroinvertébrés aquatiques du BVZCT, principalement les espèces patrimoniales appartiennent à 13 types de menaces (Fig. 6). En général, les pertes d'habitats aquatiques dans ce site sont dûes à 3 grandes catégories de menaces: l'agriculture et l'élevage avec les pertes en habitats que génère le labourage des terres humides. L'utilisation des pesticides, malgré ses méfaits, aurait moins d'impact que la forte densité du pâturage et les piétinements au niveau des différents points d'eau du site. Les perturbations hydrologiques sont surtout causées par les détournements des cours d'eau, le creusement des puits ou encore l'endiguement ou la mise en place de barrage pour augmenter les réserves hydriques pour la période estivale.

L'analyse de cette figure permet de faire ressortir que la principale menace qui guette les espèces et leurs habitats au niveau de ce site est la pollution qui affecte l'habitat de plus de 35 espèces patrimoniales, suivie par l'impact des activités d'élevage et de pâturage subie par plus d'une quinzaine d'espèces. La sécheresse qu'a connu notre pays ces dernières années a fait que les ressources hydriques connaissent une exploitation accrue pour les besoins de l'agriculture, des ménages, etc.

Les dysfonctionnements hydrologiques interviennent dans une moindre mesure et constituent des menaces de moindre importance.

Figure 6. Nombre d'espèces patrimoniales subissant des menaces dans le BVZCT.



Les conséquences des différentes menaces, que subissent les écosystèmes aquatiques de ce site, se manifestent par la fragmentation, la transformation et la perte d'habitats ou encore l'altération de leur qualité physicochimique, voire biologique.

Discussion

D'une manière globale, sur le plan biogéographique, la biodiversité de la faune des eaux continentales marocaines est relativement appauvrie, comparée à celle des pays d'Europe, d'Asie et de l'ensemble du Maghreb (Dakki, 1998). Ceci est démontré dans le BVZCT à l'instar du bassin de Sebou étudié par Dakki (1986), Dakki (1998), Belqat (2000), El Alami El Moutaouakil *et al.* (2000), Bennas *et al.* (2001) et Dakki et Himmi (2008).

Les raisons de cette pauvreté sont encore mal connues dans leur totalité, bien que plusieurs hypothèses aient été avancées à ce sujet, mettant en cause à la fois l'évolution paléobiogéographique (insularité, sécheresse fini-tertiaire, fluctuations climatiques quaternaires, etc.) et récente (impacts humains et sécheresses répétées) des eaux continentales du pays (Dakki, 1986). Par ailleurs, la faible variété intragénérique fait que la disparition d'un taxon monospécifique risque d'éliminer de la faune locale toute la représentativité du genre.

La comparaison de la faune aquatique de ce site (Tableau 3) à celle de l'ensemble des eaux continentales marocaines, en se basant sur l'étude nationale de biodiversité (Dakki, 1998) montre que le BVZCT a enrichi cet inventaire de 23 familles au moins. Ainsi le BVZCT compte presque 15% de la faune citée dans cette étude nationale. De même 16 des 37 ordres cités dans cette même étude se rencontrent dans le BVZCT, soit presque 50%. 63 familles systématiques au moins parmi celles recensées par Dakki (1998) sont récoltées au niveau du site de Tahaddart, soit 34%.

Tableau 3. Comparaison régionale et nationale de la biodiversité des macroinvertébrés aquatiques du BVZCT.

	Familles	Genres	Espèces
BVZCT	63	139	229
Bassin Loukkos	81	12	192
Bassin Sebou	107	312	648
Maroc	187	622	1531
BVZCT/Maroc (%)	34	22	15

Une comparaison avec la faune continentale du bassin de Sebou (Dakki et Himmi, 2008) révèle que le BVZCT comprend quelque 35,3 % des taxa répertoriés à Sebou.

Par ailleurs, la richesse spécifique est plus importante (229 espèces) par rapport au Complexe de zones humides du bas Loukkos (Himmi, 2005) où 192 taxa seulement ont été récoltés et par rapport à la merja de

Sidi Boughaba (156 espèces) tel que cité par Ramdani (1981). Ceci est probablement dû au fait que les prélèvements n'ont concernés que la partie littorale du bassin hydrologique, les eaux courantes du bassin versant n'ayant pas été prospectées.

Notons que lors de la campagne de prélèvement du printemps 2007, aucun Ephéméroptère n'a été prélevé au niveau des stations S12, S14 et S15. Ceci est probablement dû à la diminution de la qualité des eaux inhérente aux déversements d'eaux usées à partir des agglomérations avoisinantes (village Tleta de Jbel Lahbib et Village Dar Chaoui) qui ont fait que les habitats écologiques de ces 3 localités sont devenus inhospitaliers pour ce groupe malgré la présence de Plécoptères qui sont en principe plus sensibles.

Les Plécoptères sont des bioindicateurs de premier ordre qui sont polluosensibles et donc constituent avec les Trichoptères et les Ephéméroptères les groupes les plus sensibles aux polluants. La présence de ces trois groupes dans certaines stations, notamment S8, S9, S10, S11, S12, S13, S15 et S17 prouve à priori une bonne qualité des eaux de ce site et des habitats adéquats à ces insectes. Leur valeur écologique réside dans le fait qu'ils indiquent, par leur présence, un milieu aquatique non perturbé par une importante activité humaine.

La richesse spécifique élevée de ces habitats particuliers ainsi que l'importance des espèces patrimoniales qui s'y développent leur confèrent une valeur écologique certaine. Les impacts subis par ces écosystèmes seraient en faveur de la prolifération d'une faune aquatique ubiquiste au dépend de certaines espèces à grande valeur écologique et qui disparaissent progressivement du milieu. En effet, les macroinvertébrés aquatiques sont très sensibles aux changements des paramètres physico-chimiques des eaux dans lesquelles ils se développent. Certains peuvent disparaître dans un milieu pollué et d'autres profitent de la matière organique pour leur cycle de développement.

Les modifications hydrologiques au niveau du BVZCT, telles que la mise en place des salines au dépend de la sansouire au niveau de S1 et S2, les assèchements et les labourages provoquent le morcellement, l'isolement et la perturbation voire la disparition des habitats naturels par pompage, drainage et aménagement pour les besoins d'irrigation et d'utilisation pour l'agriculture.

D'autre part, l'évolution démographique au niveau des Douars aux alentours de Jbel Lahbib, Dar Chaoui et Hakama a fait que l'absence d'une gestion adéquate des déchets solides et liquides de ces agglomérations entraîne un changement de la qualité physico-chimique des eaux des différents habitats écologiques et entrainent des modifications de leur fonctionnement hydrologiques. La qualité biologique des habitats aquatiques et leur biodiversité se trouve ainsi affectée. C'est le cas des écoulements parfois bloqués par les déchets solides au niveau des stations S10 et S13 (CCL et CFL).

Notons qu'au niveau du site, l'agriculture et l'élevage ne sont pas intensifs et l'impact des pesticides semble peut influant.

Par ailleurs, la mise en place d'une infrastructure routière avec construction d'une autoroute avec aqueduc et échangeurs au niveau du site participe à de nombreux processus physico-chimiques et biologiques affectant également les écosystèmes environnants. De même, l'abaissement du niveau hydrique voire l'assèchement des milieux accéléré par les captages, détournements, endiguements et pompages excessifs ajoutés à la sécheresse suite aux aléas climatiques entraîne généralement une diminution des possibilités de survie des espèces à cause de la perte de leur habitat écologique.

Malgré le fait que les stations S8, S14 et S16 présentent des richesses spécifiques très importantes, elles abritent moins d'espèces patrimoniales. Ceci est dû à des perturbations, parfois locales, qui causent la diminution de la richesse spécifique, voire la disparition de certaines espèces à valence écologique étroite, vu leurs exigences vis-à-vis du milieu.

En effet, la pollution élimine les espèces très sensibles, qui sont généralement des espèces remarquables et intervient également au niveau des changements d'habitats en causant en cas extrême leur perte définitive.

Conclusions

Le but principal de cette étude est d'évaluer la diversité des macroinvertébrés des eaux douces et saumâtres du BVZCT, de définir les habitats prioritaires et de proposer des mesures pratiques de gestion pour la conservation de la biodiversité des macroinvertébrés de ce site et de développement local du BVZCT.

Malgré les différents usages hydrologiques des ressources en eau, une réglementation des captages d'eau pour son usage en agriculture devrait être mise en place avec une dépollution des cours d'eau en aval, surtout concernant l'oued Mharhar. Ceci permettra de rétablir les équilibres écologiques au niveau de cette partie du bassin. De plus, il est impératif de prévoir une gestion rationnelle des rejets liquides et solides.

Par ailleurs, un suivi de la qualité des eaux/produits toxiques (métaux lourds, produits chimiques, pesticides) qui risquent de nuire à la biodiversité des macroinvertébrés est préconisé afin de pouvoir expliquer l'évolution de la qualité biologique des différentes ressources hydriques du bassin.

Enfin, un effort de sensibilisation auprès des communautés autochtones usagères des ressources hydriques du site doit être fait ainsi que des campagnes d'information concernant l'importance des ces ressources pour la population locale et la biodiversité qu'ils abritent et son rôle dans le maintien des chaines trophiques.

Le contexte naturel et humain de la conservation de la biodiversité du BVZCT peut présenter des obstacles majeurs qu'il faudra affronter de façon stratégique et soutenue, d'autant plus que les contextes juridique et institutionnel ne sont pas très favorables. Même dans le cas d'une mise en place d'un arsenal juridique en faveur de la protection de la biodiversité, il reste très difficile à appliquer, vu la multiplicité des instances de gestion des eaux continentales dans notre pays.

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TENTATIVE D'APPLICATION DE LA DIRECTIVE CADRE SUR L'EAU DE L'UE POUR LES EAUX DE TRANSITION DE L'OUED GHRIFA: ÉVALUATION DE LA QUALITÉ ÉCOLOGIQUE D'UN ESTUAIRE NORD-MAROCAIN

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Résumé: L'étude de la macrofaune benthique de l'Oued Ghrifa repose sur un échantillonnage trimestriel entrepris entre 2006 et 2007. La diversité taxonomique est caractérisée par la présence de 44 espèces qui se répartissent en 29 familles, tandis que la diversité fonctionnelle est caractérisée par la dominance des déposivores de surface et des détritivores. Sur le plan biocénotique, deux peuplements sont mis en évidence avec, à l'aval, un peuplement marin à *Urothoe grimaldii* sur substrat sableux et, plus en amont, un peuplement estuarien à *Hediste diversicolor* sur substrat vaseux. La richesse spécifique diminue en s'éloignant de l'embouchure durant le printemps et l'été alors qu'elle reste comparable le long de l'estuaire pour les deux autres saisons. L'abondance est plus élevée en amont qu'en aval et la diversité H' est plus élevée en aval qu'en amont pour toutes les saisons avec des valeurs faibles (<3 bit) témoignant d'une certaine instabilité du milieu. L'état de la qualité écologique (EcoQ) de l'estuaire de l'Oued Ghrifa a été évalué par des indices (AMBI, BENTIX, BOPA, indice trophique ITI) qui sont pris en compte par la Directive Européenne Cadre sur l'Eau (DCE, 2000/60/EC). L'évolution saisonnière de EcoQ a été également effectuée en y intégrant d'autres descripteurs biologiques (richesse spécifique, abondance et indices de diversité et d'équitabilité). La macrofaune est essentiellement dominée par les espèces sensibles et tolérantes. Bien que l'évaluation de EcoQ soit effectuée à l'aide d'indices différents, ses tendances restent comparables. Les indices biotiques, et le AMBI en particulier, montrent un peuplement "normal" à "appauvri" en aval et un peuplement "déséquilibré" en amont de l'embouchure. Les valeurs obtenues permettent de qualifier le EcoQ de l'estuaire de l'Oued Ghrifa de "modéré" à "très bon". La saisonnalité ne semble pas avoir un effet évident sur le EcoQ.

Introduction

Les macroinvertébrés benthiques jouent un rôle primordial dans la caractérisation des écosystèmes côtiers et en constituent une composante clé en raison de leur importance mondialement reconnue dans les études se rapportant à la mise en valeur écologique des écosystèmes côtiers et marins. Les organismes benthiques sont considérés parmi les principaux acteurs dans le fonctionnement des écosystèmes marins et côtiers, un élément fondamental du réseau trophique et jouent des rôles significatifs dans la création et le maintien de la structure des habitats (bioturbateurs et organismes biogéniques) (Solimini *et al.*, 2006).

Felicita Scapini, Jean-Marc Boffa, Elisabeth Conrad, Louis F. Cassar and Mariella Nardi (editors), *Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socio-economic and environmental analysis of changes and trends to enhance and sustain stakeholder benefits*, ISBN 978-88-6453-015-4 (online)

Du fait de leur sédentarité, de leur sensibilité aux changements des conditions du milieu et à l'enrichissement en matière organique, les invertébrés benthiques constituent de bons intégrateurs des effets, surtout temporels, de divers stress environnementaux, qu'ils soient d'origine naturelle ou anthropique, dans les eaux côtières et de transition (Borja *et al.*, 2000; 2003a; 2003b). D'autre part, ces organismes sont susceptibles d'intégrer les fluctuations des conditions du milieu et les perturbations qui affectent à la fois la colonne d'eau et le sédiment (Dauvin, 1993). Les effets de telles perturbations peuvent, en définitive, être ressentis à différents niveaux de l'organisation biologique (individu, population, communauté) et le suivi des peuplements macrobenthiques s'avère pertinent dans le cadre de l'évaluation de la qualité de l'état écologique des écosystèmes côtiers.

Par ailleurs, et grâce à la connaissance de l'ensemble des espèces peuplant un milieu donné ainsi que de leur distribution, les biocénoses sont généralement définis par rapport à des conditions déterminées du milieu ambiant. Les notions de bioindicateurs et de "groupes écologiques" permettent ainsi d'évaluer l'état de dégradation d'un biotope donné en décelant les premiers signes de perturbation des peuplements (Borja *et al.*, 2000; Solimini *et al.*, 2006). Il s'agit alors de formuler par la suite un diagnostic de la situation, celui-ci étant essentiel dans la proposition de solutions permettant de préserver efficacement la biodiversité (Pearson & Rosenberg, 1978). L'ensemble de ces indices et de ces indicateurs doit constituer une approche à développer dans l'étude de la biodiversité de certains écosystèmes actuellement menacés.

Le diagnostic entrepris par la présente étude dans le cadre du projet WADI contribue à la connaissance de la structure des macroinvertébrés benthiques de l'estuaire de l'Oued Ghrifa, de leur variabilité spatio-temporelle dans cette zone de la côte atlantique marocaine et de la qualité de leur état écologique. Cet estuaire et sa macrofaune ont servi également comme site pour mesurer le niveau d'applicabilité de la Directive Cadre sur l'Eau de l'Union Européenne pour les eaux de transition des côtes marocaines.

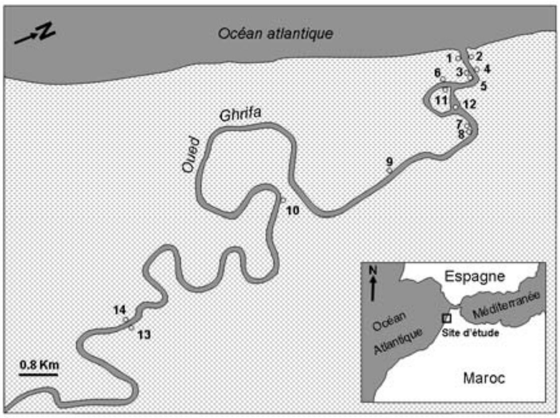
Matériel et méthodes

Site d'étude

L'estuaire de l'Oued Ghrifa (N35°31' W06°00') se situe sur la côte atlantique marocaine (Fig. 1) à une dizaine de kilomètres au nord de la ville d'Assilah et à quelque 25 kilomètres au sud de la ville de Tanger. C'est une zone humide constituée de salines et d'une steppe salée. Dans sa partie estuarienne longue d'environ 14 km l'oued serpente en de larges sinuosités dans une vaste zone de sansouire associée. L'estuaire de

Ghrifa occupe la partie sud du complexe du Bas Tahaddart (11.000 ha) qui fait partie des sites Ramsar (Convention internationale sur les zones humides) du Maroc.

Figure 1. Situation géographique de l'estuaire de l'Oued Ghrifa et localisation des stations d'étude.



Le climat est de type méditerranéen sub-humide. La saison humide et fraîche s'étend d'octobre à avril avec un maximum de précipitations en novembre-décembre (125-135 mm/mois). La saison sèche et chaude couvre la période mai-septembre et les mois les plus secs sont juillet et août (<3mm/mois). La pluviométrie moyenne annuelle est de l'ordre de 780 mm, mais il y a de fortes variations interannuelles avec des valeurs qui s'étalent entre 382 et 1437 mm/an. La température moyenne annuelle est de 17,4 °C avec des températures annuelles minimale et maximale de 13,3 et 21,7 °C respectivement. L'amplitude thermique moyenne est de 15 à 25 °C. La moyenne des minima du mois le plus froid est de 7,0 °C. La moyenne des maxima du mois le plus chaud est de 28,5 °C. L'hydrologie de la partie continentale de l'Oued Ghrifa est conditionnée par la pluviométrie, tandis que la zone estuarienne est davantage sous l'influence de la mer se traduit par la pénétration régulière de la marée dont l'influence semble se limiter au chenal.

Echantillonnage et analyse des prélèvements

L'échantillonnage de la macrofaune benthique des substrats meubles intertidaux a été réalisé dans 14 stations (Fig. 1) en juin, octobre et décembre 2006 et en mars et juin 2007. Au niveau de chaque station, un carré de 1 m de côté est tracé et à ses quatre sommets sont délimitées quatre surfaces unitaires de 1/16 m^2 chacune (25 cm x 25 cm) dans lesquelles la faune est prélevée à l'aide d'une bêche plate, jusqu'à une profondeur de 30 cm. Le tamisage est effectué sur une toile de

1 mm^2 de vide de maille. Le refus du tamis est fixé au formol dilué à 10%. Au laboratoire, les refus sont triés et la macrofaune isolée, identifiée et ensuite comptée.

Pour caractériser l'habitat sédimentaire, un échantillon supplémentaire de sédiment est récolté aux mêmes endroits que les prélèvements biologiques. L'estimation de la teneur en matière organique totale (MOT) du sédiment est effectuée par la méthode de la perte au feu (6 heures du four à 650°C). L'analyse granulométrique est réalisée sur une colonne de seize tamis (de 63 à 2000 µm). Les sédiments sont caractérisés par la teneur de chaque fraction et par la médiane granulométrique (Md). Les types sédimentaires sont identifiés par rapport aux principes de classification biosédimentaire de Chassé & Glémarec (1976). La salinité et la température de l'eau sont mesurées *in situ* dans les eaux du chenal à proximité des stations de prélèvements pendant les basses mers de vives eaux.

Analyse des données

L'analyse de la structure du macrozoobenthos est effectuée à l'aide des paramètres biotiques dont le nombre d'espèces (S), l'abondance (A) et les indices de diversité (indice de Shannon (H') et équitabilité de Pielou (J')). La recherche des interactions entre les stations et les saisons a été effectuée à l'aide d'une ANOVA à deux facteurs appliquée aux quatre paramètres biotiques.

La mise en évidence des communautés macrobenthiques s'est appuyée sur la MDS (non-metric multidimensional scaling), basée sur l'indice de similarité de Bray-Curtis. Les données de la matrice de similitude sont représentées par les abondances brutes transformées en log(x+1). Cette analyse multivariée a été réalisée à l'aide du programme Primer Statistic Package (Clarke & Warwick, 1994).

La qualité écologique de l'estuaire de l'Oued Ghrifa a été évaluée à travers l'utilisation d'un ensemble d'indices biotiques qui sont pris en compte par la Directive Européenne Cadre sur l'Eau, "DCE" (Borja, 2005) dont AMBI (AZTI Marine Biotic Index - Borja et al., 2000, 2003a,b), BENTIX (Simboura & Zenetos, 2002), BOPA (Benthic Opportunistic Polychaetes Amphipod index - Dauvin & Ruellet, 2007) et ITI (Infaunal Trophic Index - Word, 1980). Le calcul de ITT est basé sur la détermination des groupes trophiques relatives aux espèces de la macrofaune (Grall & Glémarec, 1997; Hily & Bouteille, 1999).

Résultats

Facteurs du milieu

L'habitat sédimentaire de l'estuaire de l'Oued Ghrifa présente trois sections qui se succèdent d'aval en amont: la première section (stations de

1 à 5) correspondant à la zone aval est occupée par du sable fin et moyen avec une médiane granulométrique variant de 126 à 350 μm (Tableau 1). Les apports continentaux contribuent à l'augmentation de la taille des grains dans cette zone, principalement en hiver. Plus en amont, se trouvent les deux sections suivantes. La deuxième section (stations 6, 11 et 12) est caractérisée par un habitat sédimentaire variant entre sable fin envasé et vase sableuse, tandis que la troisième section (stations 7, 8, 9, 10, 13 et 14) est dominée par des vases sableuses et vases fines. La médiane granulométrique n'y dépasse pas 180 μm. La teneur en matière organique totale (MOT) de la partie aval est faible par rapport à celle de l'amont avec des valeurs inférieures ou égales à 1,16% (Tableau 1). En amont, la MOT atteint un maximum de 6,20% en automne. Pour ces deux paramètres sédimentaires aucune saisonnalité n'est apparente. Toutefois, un gradient spatial aval-amont s'établi pour toutes les saisons pour la médiane granulométrique, en particulier.

Tableau 1. Valeurs minimales et maximales (min-max) des descripteurs sédimentaires caractérisant les substrats des zones amont et aval de l'estuaire de l'Oued Ghrifa entre juin 2006 et juin 2007. Md = Médiane granulométrique, PL= Pélites, SF= Sables fins, SGG = Sables grossiers et graviers, MOT = Matière organique totale.

		Juin 06	Oct. 06	Déc. 06	Mars 07	Juin 07
Md (μm)	Aval	164-218	126-236	179-350	161-186	176-203
	Amont	<63-180	<63-140	<63-162	<63-179	<63-160
PL (%)	Aval	39,73-86,50	32,65-74,66	16,46-64,86	62,97-86,40	48,00-69,07
	Amont	69,30-99,70	84,74-99,40	0,26-99,60	0,71-99,35	78,95-99,60
SF (%)	Aval	13,70-51,78	24,60-54,10	33,50-50,07	13,45-36,43	28,54-50,87
	Amont	0,14-30,28	0,24-13,58	0,25-16,64	0,16-30,44	0,21-20,24
SGG (%)	Aval	0,11-8,60	0,74-13,24	1,64-37,44	0,12-0,96	1,12-7,99
	Amont	0,15-1,13	0,23-1,68	0,15-1,02	0,25-2,55	0,06-0,81
MOT (%)	Aval	0,58-0,74	0,72-1,16	0,61-1,07	0,52-0,61	0,56-0,62
	Amont	0,63-5,00	1,10-4,92	0,89-4,19	0,66-6,20	0,61-5,42

La distribution de la salinité dans l'Oued Ghrifa est typique des milieux estuariens avec une saisonnalité apparente. Les fortes valeurs de salinité sont enregistrées en été (Tableau 2). La plus faible valeur moyenne de salinité est notée en hiver (forts apports d'eaux douces pendant cette saison humide), avec une grande variabilité spatiale (écart type élevé) (Tableau 2). La corrélation entre la salinité et la température est évidente pour les saisons, chaude et froide. Ainsi, à des valeurs moyennes élevées et faibles de salinité correspondent respectivement des valeurs moyennes élevées et faibles de température.

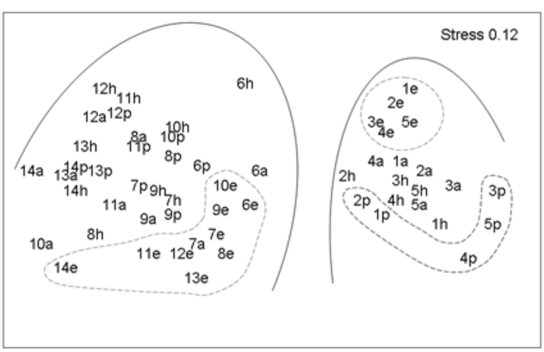
Tableau 2. Moyenne (± écart type) et valeurs minimales (Min) et maximales (Max) de la température (T °C) et de la salinité (S‰) de l'eau de l'estuaire de l'Oued Ghrifa entre juin 2006 et juin 2007.

Saison	Juin 2006		Octobre 2006		Décembre 2006		Mars 2007		Juin 2007	
S/T	S‰	T°C	S‰	T°C	S‰	T°C	S‰	T°C	S‰	T°C
Moyenne (± Std)	32,1 (±6,3)	23,2 (±2,7)	31,6 (±9,8)	19,6 (±1,6)	28,6 (±14,8)	12,7 (±1,3)	---	16,1 (±1,5)	37,3 (±2,9)	21,1 (±2,8)
Max	35,6	27,5	36,0	23,2	38,4	13,9	---	18,4	39,8	26,1
Min	19,0	20,0	18,2	17,3	1,0	9,4	---	13,2	30,8	18,4

Macrofaune benthique

L'échantillonnage de la macrofaune benthique de l'estuaire de l'Oued Ghrifa a permis de d'identifier 44 espèces qui se répartissant sur cinq groupes zoologiques. Elles se composent de 23 crustacés (neuf amphipodes, sept isopodes, cinq décapodes et deux mysidacés), 15 annélides polychètes, quatre mollusques bivalves, une larve d'insectes (*Dolichopodidae*) et un némertien (espèces confondues). Du point de vue quantitatif, les 4210 individus récoltés sont dominés essentiellement par les annélides polychètes avec *Hediste diversicolor* comme espèce leader, tandis que les crustacés sont dominés principalement par *Urothoe grimaldii* et *Haustaurius arenarius*.

Figure 2. Ordination par l'analyse MDS des prélèvements saisonniers effectués dans l'estuaire de l'Oued Ghrifa entre juin 2006 et mars 2007. e: juin 2006, a: octobre 2006, h: décembre 2006, p: mars 2007.

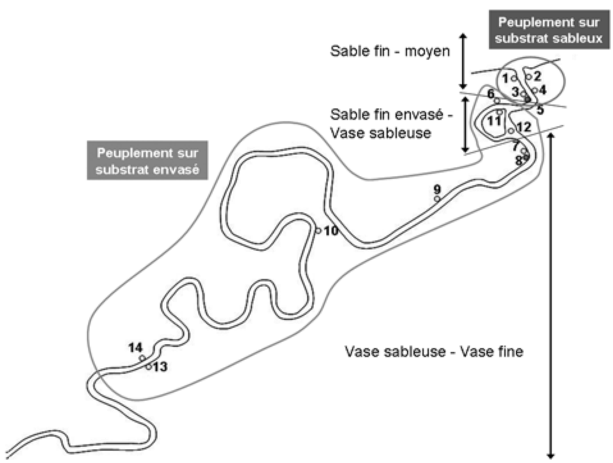


La Figure 2 illustre le résultat de l'analyse MDS où deux groupements majeurs de prélèvements forment deux nuages de points bien distincts. Le premier caractérise la zone aval (prélèvements des stations de 1 à 5) et le second représente la zone plus en amont (prélèvements des stations de

6 à 14). Ces résultats concernent les données obtenus pour chaque saison entre l'été 2006 et le printemps 2007.

La macrofaune benthique de l'estuaire de l'Oued Ghrifa s'organise alors sous forme de deux peuplements qui se succèdent selon un gradient aval-amont (Fig. 3). Le premier est installé sur un substrat sableux et est composé d'espèces marines colonisant une zone restreinte de l'estuaire, près de l'embouchure (moins d'un kilomètre), et qui est en contact direct avec l'estran sableux de la plage adjacente. Ce peuplement est dominé par le crustacé *Urothoe grimaldii* auquel se joignent *Bathyporeia pilosa*, *Eurydice pulchra*, *Eurydice affinis*, *Haustorius arenarius*, *Nephtys cirrosa*, *Pontocrates arenarius* et *Scolelepis squamata*. Le second peuplement, installé sur un substrat envasé (Fig. 3), est composé d'espèces laguno-estuariennes et est dominé par le polychète *Hediste diversicolor* auquel se joint le crustacé *Cyathura carinata*. L'effet de la saisonnalité se manifeste dans le résultat de l'analyse MDS, et tout particulièrement en été avec un groupement de prélèvements estivaux qui se distingue des autres prélèvements aussi bien pour l'aval que pour l'amont (Fig. 2).

Figure 3. Localisation des deux peuplements en relation avec les différents habitats sédimentaires identifiés au niveau de l'estuaire de l'Oued Ghrifa.



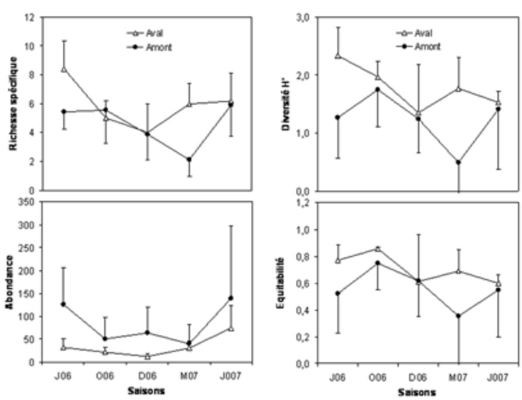
L'étude de la diversité de la macrofaune met également en évidence un gradient aval-amont. L'aval est exclusivement dominé par des formes marines, spécialement des crustacés amphipodes adaptés aux substrats sableux et à l'hydrodynamique marine élevée. En plus des amphipodes du genre *Bathyporeia* et *Urothoe*, il y a les représentants des genres *Pontocrates* et *Haustorius*, ainsi que les isopodes *Eurydice pulchra* et *E. affinis*. *Scolelepis squamata* et *Nephtys cirrosa* sont parmi les polychètes qui tolèrent bien l'instabilité sédimentaire dans cette zone. L'amont est caractérisé par la dominance quantitative des polychètes (*H. diversicolor* en particulier) et, dans un moindre degré, de l'isopode *Cyathura carinata*.

La variabilité spatiale montre que l'abondance A est plus élevée en amont qu'en aval pendant les cinq saisons (Fig. 4). La valeur élevée de l'écart-type témoigne d'une grande variabilité de ce paramètre au niveau de l'estuaire. Sur le plan temporel (Tableau 3), l'été reste la saison la plus favorable pour la macrofaune de l'estuaire de l'Oued Ghrifa dans laquelle la richesse spécifique S montre ses valeurs élevées en aval (Figure 4). En effet, le passage de l'été vers l'automne est marqué par une diminution de S et A la plus forte (Tableau 3). Le printemps est marqué par des valeurs de A et S moyennes les plus faibles par rapport à celles enregistrées durant les autres saisons (Tableau 3).

Tableau 3. Valeurs moyennes (± écart type) des paramètres biotiques de la macrofaune de l'estuaire de l'Oued Ghrifa récoltée entre juin 2006 et juin 2007. Les valeurs minimales et maximales sont indiquées entre parenthèses.

	Juin 06	Octobre 06	Décembre 06	Mars 07	Juin 07
Nombre d'espèces (S)	6,5 ± 2,1 (3-10)	5,4 ± 1,9 (6-9)	4,0 ± 1,8 (1-7)	3,4 ± 2,2 (0-7)	6,0 ± 1,9 (3-9)
Abondance (A)	92,0 ± 79,4 (11-237)	40,5 ± 38,9 (6-116)	42,1 ± 52,5 (2-162)	37,2 ± 34,9 (0-103)	114,2 ± 129,5 (4-445)
Indice de Shannon (H')	1,6 ± 0,8 (0,27-2,78)	1,8 ± 0,5 (0,67-2,72)	1,3 ± 0,6 (0-2,00)	0,9 ± 0,8 (0-2,47)	1,5 ± 0,8 (0,17-2,93)
Equitabilité (J')	0,6 ± 0,3 (0,17-0,98)	0,8 ± 0,2 (0,33-0,96)	0,6 ± 0,3 (0-0,96)	0,5 ± 0,4 (0-0,96)	0,6 ± 0,3 (0,28-0,95)

Figure 4. Variabilité saisonnière de la richesse spécifique, l'abondance, l'indice de Shannon et l'équitabilité au niveau des zones amont et aval de l'estuaire de l'Oued Ghrifa. J06: juin 2006, O06: octobre 2006, D06: décembre 2006, M07: mars 2007, J07: juin 2007.



Les valeurs de diversité H' sont plus élevées en aval qu'en amont, sauf pour l'hiver (Fig. 4). L'aval montre en moyenne des valeurs élevées en été et faible en hiver alors que l'amont présente des valeurs élevées en automne et faibles au printemps, ceci est à mettre en rapport avec la variabilité des paramètres, A et S qui montrent le même scénario. Les valeurs moyennes des deux indices H' et J' sont faibles et leurs valeurs maximales sont enregistrées en automne (Tableau 3, Fig. 4).

Les effets spatial (station) et temporel (saison), séparément et combinés, mis en évidence sont significatives pour l'ensemble des quatre paramètres biotiques (Tableau 4).

Tableau 4. Résultats de l'ANOVA à deux facteurs pour les effets d'interaction de la saison et du site sur les variables biotiques. ddl: degré de liberté.

Source de variation	ddl	Moyenne des carrés	F	p
Richesse spécifique				
Effet station	13	9,304	6,773	0,000
Effet saison	4	27,677	20,147	0,000
Effet station*saison	50	3,325	2,421	0,000
Abondance				
Effet station	13	4115,237	39,619	0,000
Effet saison	4	3515,889	33,849	0,000
Effet station*saison	50	744,009	7,163	0,000
Indice de Shannon				
Effet station	13	1,654	5,381	0,000
Effet saison	4	4,703	15,300	0,000
Effet station*saison	50	0,568	1,849	0,002
Equitabilité				
Effet station	13	0,376	3,820	0,000
Effet saison	4	1,359	13,815	0,000
Effet station*saison	50	0,193	1,960	0,001

Evaluation de l'état de la qualité écologique (EcoQ)

Les proportions des groupes écologiques en termes de richesse spécifique et d'abondance diffère d'une saison à une autre (Tableau 5). Les espèces sensibles (groupe écologique I) et tolérantes (groupe écologique III) dominent la macrofaune de l'estuaire de l'Oued Ghrifa respectivement. Les espèces opportunistes du 2ème ordre (groupe écologique IV) sont absentes tandis que celles du 1er ordre (groupe écologique V) sont présentes de façon très modeste par une seule espèce.

Tableau 5. Valeurs totales de la richesse spécifique et de l'abondance (S/A) des groupes écologiques de la macrofaune de l'estuaire de Ghrifa entre juin 2006 et juin 2007. GEI: espèces sensibles; GEII: espèces indifférentes; GEII: espèces tolérantes; GEIV: espèces opportunistes du 2ème ordre; GEV: espèces opportunistes du 1er ordre.

Groupes écologiques	Juin 06	Octobre 06	Décembre 06	Mars 07	Juin 07
GEI	15 / 149	13 / 157	9 / 61	9 / 116	14 / 381
GEII	5 / 26	3 / 32	3 / 12	3 / 72	4 / 20
GEIII	14 / 1044	14 / 374	7 / 547	5 / 258	9 / 1024
GEIV	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
GEV	1 / 69	1 / 4	1 / 5	0 / 0	1 / 9

Les valeurs des indices biotiques AMBI, BENTIX, BOPA et ITI sont comparables entre les saisons (Tableau 6). L'aval montre des valeurs AMBI très basses par rapport à l'amont contrairement à BENTIX. En se basant sur la classification de Borja *et al.* (2000, 2003a), l'estuaire est classé comme "non dégradé" à "moyennement dégradé" avec des peuplements macro-zoobenthiques entre "normaux" et "déséquilibrés". La variabilité saisonnière de BOPA est faible et les valeurs sont comparables entre l'aval et l'amont (Tableau 6) indiquant ainsi un milieu non pollué avec une absence presque totale des polychètes opportunistes et un taux faible de la charge organique. Les valeurs de ITI supérieures ou égales à 68 en moyenne (Tableau 6) coïncident avec une dominance des suspensivores-détritivores et indiquent des conditions benthiques normales avec un environnement qui est ni perturbé ni dégradé. Avec des valeurs proches à 0, les déposivores et en particulier ceux de sub-surface sont prédominants signifiant ainsi que l'environnement est fortement dégradé. Dans le cas de l'estuaire de l'Oued Ghrifa, ITI indique en général un milieu non dégradé avec une zone aval plus perturbée que la zone amont (valeurs plus faibles en aval qu'en amont).

Tableau 6. Valeurs moyennes (± écart type), minimales et maximales (min-max) des indices biotiques calculées pour les zones aval et amont de l'estuaire de l'Oued Ghrifa entre l'été 2006 et l'été 2007.

	Eté 2006		Automne 2006		Hiver 2006		Printemps 2007		Eté 2007	
	Aval	Amont	Aval	Amont	Aval	Amont	Aval	Amont	Aval	Amont
AMBI	1,32±1,24 (0,20-3,41)	2,75±0,82 (0,63-3,50)	0,08±0,06 (0-0,14)	2,73±0,58 (1,50-3,41)	1,08±1,31 (0,00-3,30)	3,30±0,32 (2,90-4,00)	0,15±0,15 (0,00-0,35)	3,08±1,32 (0,00-3,00)	0,28±0,44 (0,07-1,06)	3,21±0,36 (2,94-4,07)
BENTIX	5,11±0,77 (3,82-5,85)	2,58±1,21 (2,00-5,67)	5,96±0,08 (5,82-6,00)	2,87±1,21 (2,00-5,00)	5,17±0,94 (3,60-6,00)	2,24±0,35 (2,00-3,1)	6,00±0,00 (6,00-6,00)	3,52±2,20 (0,00-6,00)	5,82±0,28 (5,33-6,00)	2,40±0,64 (2,00-3,56)
BOPA	0,04±0,06 (0,00-0,15)	0,01±0,04 (0,00-0,12)	0 -	0,02±0,04 (0,00-0,08)	0 -	0,01±0,01 (0,00-0,03)	0 -	0 -	0 -	0,02±0,04 (0,00-0,10)
ITI	57,31±27,30 (26-92)	35,62±29,80 (14-100)	98,67±2,97 (93-100)	73,60±23,10 (40-100)	85,65±24,90 (42-100)	96,84±4,80 (89-100)	78,0±12,0 (63-91)	90,4±39,5 (0-100)	67,24±27,7 (37-100)	87,11±18,5 (55-100)

Discussion

Dans l'estuaire de l'Oued Ghrifa, les sédiments évoluent des sables fins à moyens aux vases fines dans selon un gradient aval-amont. Cette distribution sédimentaire est caractéristique des milieux estuariens (McLusky, 1981) et entre pour une grande part dans la détermination des peuplements de la macrofaune (Robineau, 1987; Marques *et al.*, 1993a; 1993b; Mannino & Montagna, 1997; Cherkaoui *et al.*, 2005). Dans les écosystèmes estuariens, le sédiment, en tant que facteur maître contrôlant et influençant la distribution de la macrofaune (Sanders, 1958; Rhoads & Young, 1978; Service & Feller, 1992), ne constitue pas un facteur limitant (Wolff, 1973). Dans les estuaires de Blavet et Scorff (France), la communauté de *Polydora ciliata* peut se rencontrer dans une large variété de conditions édaphiques (Le Bris & Glémarec, 1996), D'après Glémarec & Hily (1981), l'élément édaphique ne participe pas dans la répartition de la macrofaune benthique mais intervient plutôt dans les habitudes trophiques. Le sédiment est également considéré comme un indicateur fiable des impacts anthropogéniques sur les environnements côtiers et estuariens (Ridgway & Shummield, 2002) en raison de son impact potentiel sur les peuplements biologiques et ses capacités d'accumuler les substances et d'assurer une bonne intégration avec le temps.

Les variations de la salinité (entre 19 et 40) mis en évidence dans cet estuaire suivent aussi un gradient et permettent de qualifier le milieu de meso-polyhalin. Le sédiment et la salinité jouent un rôle clé dans la distribution et l'organisation de la macrofaune dans les écosystèmes de transition (Quintino *et al.*, 1989; Mannino & Montagna, 1997; Cherkaoui *et al.*, 2005).

L'estuaire de l'Oued Ghrifa est caractérisé par une macrofaune benthique peu diversifiée (44 taxa appartenant à 29 familles). Les crustacés (amphipodes et isopodes) dominent qualitativement la macrofaune benthique et les polychètes la dominent quantitativement. La dominance quantitative d'un nombre limité d'espèces (2-3 espèces) au niveau de l'aval de l'estuaire et d'une seule espèce au niveau de l'amont explique la faible diversité des peuplements de la macrofaune; ce qui les rapprocherait de ceux des milieux instables (Blondel, 1979; Thébault & Loreau, 2005). Cette faible diversité est à mettre en relation avec une faible diversité des habitats sédimentaires et une absence des herbiers au niveau de la zone intertidale de cet estuaire. Ceci, par conséquence, réduit notablement la diversité des habitats et limite en plus la variabilité tant spatiale que temporelle de la macrofaune. La structure macrozoobenthique de l'estuaire de l'Oued Ghrifa rappelle aussi celle du peuplement estuarien supérieur des vases de l'estuaire de la Seine (France), caractérisé par des densités élevées (104 ind./m^2), une richesse spécifique (8 espèces) et une diversité spécifique (1 bit) faibles (Desprez, 1981; Desprez *et al.*, 1983). Cependant, la richesse spécifique de l'estuaire est faible (≤ 6 en moyenne) par rapport à d'autres systèmes estuariens. Elle peut être aussi expliquée par la faible variété sédimentaire impliquant une probabilité plus faible d'observer des formes différentes de la faune. De même, Gentil et Dauvin (1988) ont évoqué le problème d'estimation du nombre total d'espèces vivant dans le peuplement qui pourrait être considéré comme un appauvrissement faunistique. Selon ces auteurs, il pourrait s'agir d'une grande diversité spécifique masquée, avec une grande richesse en espèces qui sont peu abondantes et dispersées et qui apparaissent rarement dans les échantillons. Au niveau de la baie de Vilaine (France), la richesse spécifique faible des sables fins envasés a été expliquée par l'action estuarienne (dessalure, turbidité liée au bouchon vaseux) et par l'action hydrodynamique des vagues (Le Bris, 1988; Le Bris & Glémarec, 1995). Ces deux actions y favorisent une instabilité sédimentaire, facteur qui est à l'origine d'un appauvrissement en nombre d'espèces (Maurer *et al.*, 1979).

La diversité H' reste relativement élevée en aval de l'estuaire de l'Oued Ghrifa au cours des saisons. Ce scénario est rencontré aussi dans plusieurs systèmes estuariens dont l'estuaire de Mondego, Portugal (Marques *et al.*, 1993a,b), l'estuaire de Nueces au Texas (Mannino & Montagna, 1997), l'estuaire de Schelde, Pays-Bas (Ysebaert *et al.*, 2003) et l'estuaire de Bou Regreg (Cherkaoui *et al.*, 2003). Sur le plan temporel, la richesse spécifique diminue en s'éloignant de l'embouchure durant l'été et le printemps alors qu'elle reste comparable le long de l'estuaire pour les autres saisons. Ceci nous laisse évoquer l'effet de la température durant ces saisons et qui s'accentue vers l'amont conduisant, dans certains endroits de l'estuaire, à la dessiccation totale de la vase. De plus, la prédation peut jouer un rôle dans ce sens là puisque ce phénomène coïncide avec une apparition remarquable du décapode *Uca tangeri* (attesté par grand nombre de terriers) en ces périodes. La densité est plus élevée en amont qu'en aval en raison de l'action hydrodynamique faible qui favorise l'épanouissement des différentes espèces, et tout particulièrement les formes déposivores et détritivores. La structure taxonomique représentée par un nombre d'espèces réduit traduit une faible structure fonctionnelle caractérisée par la dominance les groupes des déposivores de surface et des détritivores.

Les effets station, saison et combinés (station*saison) sont toutes significatives pour les paramètres biologiques de l'estuaire de l'Oued Ghrifa peuvent être le reflet de la nature instable des conditions environnementales entre les parties aval et amont de l'estuaire. Pourtant, les habitats sédimentaires qui changent notablement en fonction des saisons (d'après nos observations sur le terrain) affectent, pour une grande part, la structure biotique du macrozoobenthos.

La macrofaune benthique de l'estuaire de l'Oued Ghrifa s'organise sous forme de deux peuplements qui se succèdent selon un gradient aval-amont. Un peuplement marin en aval et un peuplement estuarien en amont, caractéristique des milieux de transition. Les espèces du peuplement marin sont adaptées aux substrats sableux et oligotrophes et à un niveau élevé de l'hydrodynamique marine. Les espèces *N. cirrosa* et *S. squamata* sont parmi les polychètes qui dominent ce peuplement et tolèrent bien l'instabilité sédimentaire dans cette zone. Ce peuplement peut être identifié à ceux des plages sableuses de l'Atlantique marocain (Bayed, 2003) et témoignent de l'intrusion d'espèces marines dans l'estuaire. Le second peuplement installé sur un substrat envasé, est composé d'espèces laguno-estuariennes adaptées à un taux élevé de matière organique et à des eaux mesohalines avec une action hydrodynamique moins accentuée. Il est dominé par le polychète *H. diversicolor* auquel se joint le crustacé *C. carinata.* Ce peuplement s'identifie à la Biocénose Lagunaire Euryhaline et Eurytherme avec des espèces communes et connues en général, comme typiques des sédiments meubles envasés, riches en matière organique. Il est aussi lié à la variété *Cardium edule–Scrobicularia plana* de la communauté de *Macoma balthica* dans le système de Thorson (1957). Les deux peuplements de la macrofaune identifiés dans l'estuaire de Ghrifa sont très proches de ceux qui colonisent l'estuaire de Tahaddart (une dizaine de kilomètres vers le nord) où la présence de l'herbier de zostères permet de subdiviser le peuplement de la zone amont en deux faciès (observation pers). De même, la comparaison du peuplement estuarien de l'Oued Ghrifa avec d'autres peuplements estuariens ou laguno-estuariens, montre qu'il présente certaines caractéristiques du peuplement de *Scrobicularia plana* de la lagune de Merja Zerga (Bazaïri *et al.*, 2003), de l'estuaire de Bou Regreg (Cherkaoui *et al.*, 2005), de l'estuaire de Mondego au Portugal (Marques *et al.*, 1993a; 1993b) et de Ría de Foz en Espagne (Junoy & Viéitez, 1990). Dans l'Oued Ghrifa, l'effet de la saisonnalité se fait sentir particulièrement en été, où un groupement de prélèvements estivaux se distingue des autres prélèvements aussi bien en amont qu'en aval. Ceci laisse penser au rôle de stimulateur joué par la température et la salinité durant cette période induisant ainsi des changements au niveau de la structure de la macrofaune (S et A élevées). La granulométrie en amont, en absence totale d'herbier, d'une part, et l'hydrodynamique marine dans l'aval (en tant que facteur contrôlant les conditions édaphiques), d'autre part, semblent être les facteurs clés qui structurent les deux peuplements de la macrofaune de cet estuaire atlantique. Contrairement à d'autres écosystèmes estuariens, la salinité ne semble pas jouer un rôle significatif dans cette distribution puisqu'il n'y a pas de zone médiane, entre l'aval et l'amont, caractérisée par un troisième peuplement intermédiaire, comme c'est la cas de l'estuaire de la Loire en France (Robineau, 1987), l'estuaire de Bou Regreg au Maroc (Cherkaoui *et al.*, 2005) et la lagune estuarienne de Óbidos en Portugal (Quintino *et al.*, 1989).

L'analyse des groupes écologiques montre la dominance des groupes écologiques I et III (espèces sensibles et tolérantes respectivement). En parallèle, il est à noter la présence discrète de certaines polychètes opportunistes comme *Heteromastus filiformis* et *Capitella capitata* et l'absence d'autres telles que *Scolelepis fuliginosa* et *Polydora ciliata*; espèces de caractère plus opportuniste quant à l'utilisation des ressources (habitat et nourriture) et indicatrices d'un état avancé de pollution et/ou de dégradation de l'écosystème (Pearson & Rosenberg, 1978). Ces dernières traduisent davantage des conditions de bon renouvellement de l'eau et l'évacuation de la surcharge en matière organique à la surface du sédiment. Elles témoignent aussi d'apports organiques modérés. Il s'agit globalement d'un écosystème où le brassage hydrodynamique dû aux marées, limite les effets d'enrichissement en charge organique (Salas *et al.*, 2004, Cherkaoui *et al.*, 2005). En outre, l'estuaire héberge une macrofaune euryèce tout à fait caractéristique de ces milieux et tolère bien les surcharges en matière organique.

A des EcoQ élevés au niveau de l'aval correspondent des valeurs élevées de la richesse spécifique, abondance, H' et J' contrairement à celles enregistrées en amont. Les valeurs des indices traduisant des EcoQ "mauvais" au niveau des stations qualifiées de marines (embouchure de l'Oued), sont essentiellement imputées au stress naturel dû à l'hydrodynamique marine relativement élevée dans cette zone. La saison ne semble pas présenter un effet sur l'état écologique de l'estuaire de l'Oued Ghrifa. Autrement dit, elle ne paraît pas avoir un effet évident sur le EcoQ puisque toutes les saisons montrent des états comparables. Il s'agit alors d'une caractéristique des milieux côtiers dynamiques (Bazaïri *et al.*, 2005). Dans notre cas, cette bioévaluation indique, un peuplement "normal" à "appauvri" en aval (milieu non pollué mais naturellement stressé) et "déséquilibré" en amont (milieu légèrement pollué) caractérisant un estuaire "non dégradé" à "moyennement dégradé". Bien que cette évaluation de l'état écologique soit effectuée à l'aide d'indices différents, les tendances de ses différents états restent comparables. En nous basant sur le résultat des indices AMBI, BENTIX, BOPA et ITI (en particulier l'aval pour cet indice), le EcoQ varie en général entre un état "très bon" et "modéré" sans que l'état "mauvais" ne soit décelé aussi bien pour l'aval que pour l'amont exception faite pour H' au printemps. Or les valeurs de H' témoignent d'un état écologique du milieu "pauvre" à "modéré". Ceci reflète l'absence de pollution ou de dégradation et la présence de certaines conditions de stress dans l'estuaire de l'Oued Ghrifa. L'indice ITI ne montre pas de discrimination évidente entre les stations de l'aval et celle de l'amont. BOPA indique bien l'absence des espèces opportunistes mais ne semble pas être suffisamment sensible pour distinguer entre EcoQ de l'aval (MOT faible) et celui de l'amont (MOT élevée). Par conséquent, AMBI semble être le mieux adapté pour décrire la situation écologique de l'estuaire de l'Oued Ghrifa. Ce constat dressé dans certains estuaires des côtes espagnoles (Borja *et al.*, 2003a; 2003b; 2004; Muxika *et al.*, 2003; 2005), l'estuaire de Mondego (Salas *et al.*, 2004), l'estuaire de Bou Regreg (Cherkaoui *et al.*, 2003, 2005) et dans les lagunes de Merja Zerga (Bazaïri *et al.*, 2005), de Smir (Chaouti & Bayed, 2008) et de Obidos au Portugal (Carvalho *et al.*, 2006), L'utilisation de H' est fortement recommandée (Salas *et al.*, 2004; Labrune *et al.*, 2006) lorsqu'il s'agit d'établir un état écologique basé sur un ensemble d'indices. L'utilisation combinée des indices biotiques en parallèle avec des paramètres de structure de la macrofaune (richesse spécifique et diversité) pourrait être utile dans la détermination de l'état de la qualité écologique des eaux de transition. De plus, cette approche peut répondre à toutes les exigences de la DCE (diversité et richesse spécifique ensemble avec la présence des taxa sensibles aux perturbations et taxa indicateurs de pollution ou indices biotiques) (Borja *et al.*, 2003b). Selon la DCE (Borja, 2005), les éléments de la qualité biologique relatifs au macrobenthos doivent tenir compte de la diversité H' et l'équitabilité et non seulement des espèces indicatrices (Salas *et al.*, 2004). De même, pour une bonne évaluation de l'état écologique, il serait alors judicieux de coupler l'analyse des groupes écologiques avec une analyse des groupes étho-écologiques (trophiques) (Bazaïri *et al.*, 2005; Ayari & Afli, 2008). Les indices ITI et FSI (Feeding Structure Index) (Hyland *et al.*, 2000) sont parmi les indices qui sont déterminés à partir des groupes trophiques sur lesquels est basée la structure trophique du macrozoobenthos mais ils ne tiennent pas compte de la diversité spécifique au sein de chaque groupe trophique. Cette diversité représente un bon indicateur de la résilience potentielle de l'écosystème (Bazaïri *et al.*, 2005).

Conclusion

Deux peuplements caractérisent la macrofaune benthique de l'estuaire de l'Oued Ghrifa, un peuplement marin en aval sur substrat sableux et un deuxième estuarien en amont sur substrat vaseux. L'attribution des espèces bioindicatrices à des groupes écologiques et trophiques a permis de calculer un ensemble d'indices biotiques. Ces derniers ont montré l'absence de signe de pollution et de perturbation témoignant ainsi d'un état écologique qui se balance entre "très bon" et "modéré" avec un peuplement qualifié de "normal" à "déséquilibré". Or les contraintes et impacts des différentes activités humaines qui se déroulent au sein de l'écosystème de l'estuaire de l'Oued Ghrifa représentent un risque potentiel et permanant pouvant conduire à la régression voire la disparition du cortège spécifique de la macrofaune. Ceci pourrait avoir un effet négatif sur le maintien de la biodiversité et la pérennité des peuplements benthiques en particulier. La nécessité d'établir des mesures de conservation s'avère être une étape préventive indispensable.

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RÔLE DES FEMMES ET DES HOMMES DANS L'UTILISATION ET LA GESTION DES RESSOURCES NATURELLES DANS LE BASSIN VERSANT D'OUED LAOU (NORD OUEST DU MAROC)

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Abstract: People in developing countries, especially those living in rural areas are usually highly dependent on natural and environmental resources for their livelihood. However, as a result of population growth and increase in poverty levels, considerable pressures are put on the environment, consequently affecting the very same resource base they depend on to earn a living. This study is intended to analyse the current situation and trends in terms of basic services, environmental goods availability and use in the Oued Laou river basin (northern Morocco), with a focus on water availability and use. These issues were investigated considering since the very beginning the different categories of inhabitants: as a matter of facts, some categories are more exposed to risks than others, because of their different links to the environmental goods. The consideration of these categories is particularly relevant in the case of a changing environment such as the Oued Laou River basin, in which people are experiencing a sudden change in environmental management and are under pressure by different development models at the time. The gender perspective was integrated within the study, as women represent an essential part of the system, they usually directly deal with local environmental goods, but at the same time have limited or no representation among decisional or powerful groups.

To fulfil the multiple aims of the study, we submitted a questionnaire to households chosen by quota sampling, in which the settlement in urban or rural environment, the main source of income and the gender represented the strata. The total sample included 52 households, for which and whenever possible interviews were carried out at the same time for the male and female heads of household.

A particular case included within the study was Fran Ali village, a rural area in which the main source of income is traditional pottery, an exclusive feminine activity and an issue which resulted to affect the perception of trends.

As an overall trend, our results highlighted a positive shift in school attendance between generations. Throughout the study we recorded just few traditions related to environmental goods conservation and use, with no difference between urban and rural areas, although a component of this result may come from the low level of acceptance of own traditions when compared to the external models proposed. Regarding the services, a difference was found between urban and rural zones in terms of water services and their costs. Water availability is not a problem at the whole basin level, but wastewater treatment is missing even in new urban zones. However, pollution is perceived as a problem only at the low basin level (Oued Laou). The analysis of work repartition between genders highlighted the number of duties carried out by women, both inside and outside the household, even if they have no voice at the *Jmaâ* (village council). Neither women nor

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men felt they are being represented at higher institutional level, and claimed for some Governmental attention. However, when asked, scarce propositions to improve the current situation emerged, with the positive exception of small scale local associations and support actions. From the data collected we derived that a key feature to improve the scenario can be capacity building on initiative taking and proper management of common goods (including cultural ones) beyond water availability.

Ce travail est dédié à la mémoire de Madame Fatiha Bou-Salah

1. Introduction

Le genre est défini comme étant la construction socioculturelle des rôles féminins et masculins et des relations entre les femmes et les hommes. Les rôles féminins et masculins se rapportent aux activités attribuées aux femmes et hommes dans la société et à la position que femmes et hommes y occupent respectivement. Ces rôles découlent des forces telles que la culture, la tradition, la politique et les besoins. Ils permettent de déterminer l'accès aux opportunités et aux ressources et imposent des attentes et des limites aussi bien aux femmes qu'aux hommes.

1.1. Historique de l'intégration des femmes et hommes dans le développement

L'évolution des grands courants de pensée concernant les femmes et le développement (Intégration des femmes au développement "IFD", Femmes et développement "FED" et Genre et développement "GED") montre qu'on se rend de plus en plus compte de l'évidence qu'un développement durable doit prévoir, sur une base d'égalité, la pleine participation des hommes et des femmes (PNUD).

Les stratégies établies dans le cadre de l'IFD prévoyaient des projets ou des composantes de projets concernant les femmes, l'accroissement de leurs revenus et de leur productivité et l'amélioration des moyens dont elles disposaient pour s'occuper du ménage sans s'attaquer aux causes fondamentales de la discrimination qui empêchent les femmes de participer pleinement aux sociétés dont elles font partie.

Vers la fin des années 1970 fut élaborée la formule FED afin de réparer les omissions de l'IFD. Selon cette formule, les femmes participent aux mécanismes de développement mais sur une base inégale. Les projets de développement intensifient les interventions dont les femmes sont l'objet (surtout les activités génératrices de revenus pour les femmes), sans pour autant améliorer leur accès aux ressources ou à la prise de décision (PNUD).

Durant les années 1980, l'approche GED a marqué un revirement d'attitude à l'égard d'un développement équitable et durable en se basant sur trois grands principes:

1) Hommes et femmes créent la société et la perpétuent, et conditionnent la répartition des tâches sans partager équitablement les bénéfices et les contraintes.
2) Femmes et hommes ont des rapports différents avec la société. Ils fonctionnent souvent dans des secteurs différents de la communauté et ont des priorités et des perspectives différentes.
3) Le développement se répercute de façon différente sur les hommes et sur les femmes, et les femmes et les hommes exercent une influence différente sur les projets. Les deux doivent participer à l'identification des problèmes et des solutions pour faire avancer les intérêts de la communauté.

L'approche GED cherche ainsi à assurer une répartition égale des possibilités, des ressources et des bénéfices entre les différentes couches de population que vise une intervention. L'utilisation de cette approche peut aider les organisateurs de projets à identifier des différences importantes entre les rôles et les responsabilités des femmes et des hommes et à se servir de ces informations pour rendre plus efficaces et durables les politiques, les programmes et les projets.

C'est une approche qui tire les conséquences du fait que les différences sociales basées sur le sexe découlent et s'enracinent dans les dynamiques sociales et sont donc transformables et jamais irréversibles. Partant de ces prémisses, l'approche GED met à l'ordre du jour la problématique d'un développement décidé et orienté par les femmes et par les hommes en tant que parties prenantes conscientes et responsables du présent et de l'avenir dans les dynamiques sociales, économiques et politiques. Afin de réussir ceci, on prend en compte les besoins pratiques et stratégiques des femmes et des hommes.

1. Les besoins pratiques correspondent à des préoccupations à court et moyen termes découlant des rôles respectifs. Ces besoins, liés aux activités quotidiennes et aux conditions matérielles dans lesquelles vivent les femmes et les hommes, ont un caractère immédiat et matériel et peuvent être satisfaits à court terme grâce à des solutions pratiques. Les besoins pratiques sont généralement évidents et bien identifiés par la population concernée et par les planificateurs. Exemples de besoins pratiques : besoins quotidiens en nourriture, énergie, eau, soins de santé primaire, accès à l'éducation primaire,…
2. Les besoins stratégiques se réfèrent aux questions de pouvoir et de contrôle ainsi qu'à la division du travail fondée sur le genre. Ces intérêts, ayant un caractère à long terme, peuvent inclure des changements dans la division sexuelle traditionnelle du travail, la répartition des responsabilités dans l'éducation des enfants, les droits légaux, la violence, les clivages sexistes au sein des institutions, le contrôle social de la santé de

la reproduction. De par leur tendance à s'inscrire dans le long terme, les besoins stratégiques de genre ne sont pas faciles à identifier. Les intérêts stratégiques diffèrent entre femmes, entre hommes et, entre femmes et hommes. Exemples de besoins stratégiques de genre : élimination de toutes les formes de discrimination dans le domaine culturel, financier, social, économique; égalité dans l'éducation/instruction; distribution juste du travail; allègement des charges et tâches domestiques.

Dans le cas du projet WADI, il s'agit, d'une démarche ou d'une approche pour la prise en compte de la situation, des besoins, des problèmes et des priorités des hommes, des femmes.

1.2. L'intégration systématique de l'approche genre

L'intégration de l'approche GED dans un projet commence avec une analyse genre. C'est une méthodologie de collecte et de traitement d'informations sur le genre, utilisant des données désagrégées par sexe en vue d'étudier la construction sociale des rôles de genre et comment le travail est divisé et valorisé selon le sexe. C'est un instrument indispensable à la fois pour comprendre le contexte local et pour promouvoir l'égalité et l'équité entre les sexes. L'emploi de l'analyse de genre, permet d'élucider les questions suivantes :

- les points de vue, les rôles, les besoins des femmes et des hommes dans la zone du projet,
- les rapports entre les femmes et les hommes en ce qui a trait à l'accès aux ressources, aux bénéfices et aux processus décisionnels, ainsi qu'au contrôle sur ces éléments;
- les obstacles socioculturels, les possibilités et les points d'appui pour réduire les inégalités entre les sexes et promouvoir des rapports plus égaux entre les femmes et les hommes;
- la capacité des institutions à établir des programmes visant l'égalité entre les sexes;
- les différences parmi les femmes et les hommes, ainsi que la diversité des contextes dans lesquels ils vivent, des rapports sociaux qu'ils entretiennent.

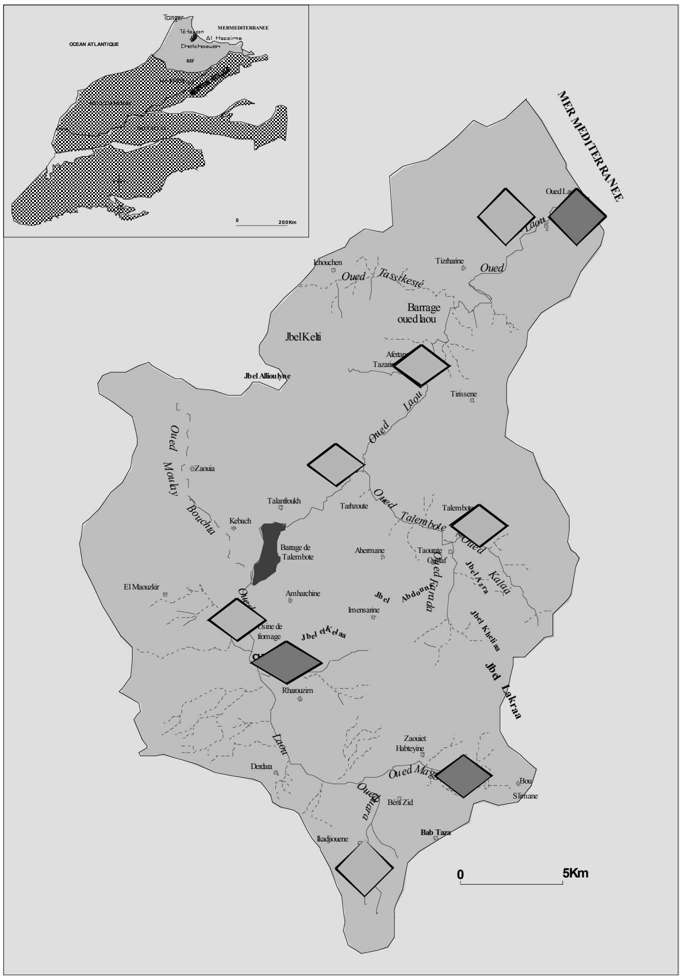
Quand tout ceci est pris en compte lors de la planification et mise en ouvre d'un projet, il sera considéré comme sensible au genre.

2. Méthodologie

2.1. Choix des populations cibles

Une étude préliminaire a permis de mettre en évidence 9 populations considérées comme représentatives du bassin versant d'Oued Laou (Fig. 1).

Figure 1. Localisation des villes et villages étudiés dans le bassin versant d'Oued Laou (Nord Ouest du Maroc). Les losanges gris représentent les milieux urbains (Oued Laou, Chefchaouen, Bab Taza) et les vides les milieux ruraux (Maggo Talambot, Fran Ali, Afertane, Khizana, Anjra).



2. La répartition altitudinale. Le bassin versant d'Oued Laou se caractérise par un net étagement en altitude. Les villages choisis doivent donc appartenir à des régions situées à différentes altitudes. Ils se répartissent au niveau de la plaine du Laou, le moyen Laou et le Haut Laou.
3. Types d'activités. Afin d'avoir une bonne représentativité des populations du Laou, il a fallu pendre en considération les différentes activités existant au niveau de cette région, à savoir la pêche, l'agriculture, le pâturage et l'artisanat.
4. Facilité d'accès. Il s'agit d'une région accidentée et enclavée. Pour être choisis, les villages doivent être accessibles.
5. Selon la méthodologie couramment utilisée en socio-économie, un tiers des populations choisies dans l'échantillon sont urbaines, à savoir Chaouen, Oued Laou et Bab Taza. Le milieu rural est représenté par Fran Ali, Afertane, Talambot, Anjra, Majjo et Khizana.

2.2. Enquêtes

Le bassin versant de Oued Laou se situe dans une région où le *Cannabis* est une culture très répandue. Cette pratique est cependant interdite par les autorités marocaines; fait qui rend les populations de cette région assez sceptiques et méfiantes vis-à-vis de visiteurs externes quelque soit l'objectif de leur visite.

C'est principalement pour cette raison qu'avant chaque sortie sur le terrain, un contact doit être de préférence établi avec les autorités mais aussi avec des habitants de la région. Ce contact facilite les visites chez les familles et établit une certaine confiance entre les chercheurs et les personnes interviewées. Plusieurs personnes nous ont prêté leur aide, établissant ce lien de confiance qui nous a permis de rendre visite à différentes communautés et d'obtenir les informations nécessaires.

La fiche définitive, adaptée à la situation du Bassin Versant d'Oued Laou au Nord du Maroc, après avoir testé sur le terrain de fiches préliminaires, comprenait quatre parties principales: le profil de la famille (nombre de membres, niveau d'éducation, la source principale de revenu); accès aux services (éducation, autre formation, santé, assainissement, électricité, sources d'énergie); la répartition des activités entre les hommes et les femmes (à l'intérieur du foyer et à l'extérieur); la perception des tendances (relativement aux aspect socioculturels, conservation du paysage et de la ressource en eau, traditions, problèmes et solutions proposées). Pour chaque famille (l'unité d'échantillonnage) nous avons posé les mêmes questions au chef masculin et féminin de la famille. En plus, pour éviter tout biais dans l'analyse gendre pouvant être due à l'influence réciproque des interviewées, les questions ont été posées par deux interviewers différents au même temps à l'homme et la femme (WADI, 2007.)

Annex 1. La fiche définitive des enquêtes.Annex 1. La fiche définitive des enquêtes.

Approche Gender dans le Bassin Versant de Oued Laou/Faculté des Sciences de Tétouan/ Wadi 6° FP, INCO-CT2005-015226

Fiche N° : Lieu : Date :
Personnes réalisant l'enquête :
Nom de la famille :

1. Situation

1.1. Statut :

Membres constituants la famille :

Mari ☐ Femme ☐ Enfants ☐ Grand parents ☐ Autres ☐

…………………………………………………………………………………………………..

Statut de la femme

Chef de famille ☐ Marié ☐ Veuve ☐ Mari migrant ☐

………………………………………………………………………………………………

Niveau d'éducation

Analphabète ☐ Lire et écrire ☐ Primaire ☐ Secondaire ☐ Autres ☐

………………………………………………………………………………………………

Niveau d'éducation des enfants

Analphabète ☐ Lire et écrire ☐ Primaire ☐ Secondaire ☐ Autres ☐

Sources de revenu

Agriculture ☐ Commerce ☐ Pêche ☐ Fonctionnaire ☐ Artisanat ☐ Autres métiers ☐

…………………………………………………………………………………………………...

1. 2. Accès aux services

-Education : Msid ☐ Primaire ☐ Autres ☐

Proximité / Distance (heures de marche)

-Santé : Médecine traditionnelle ☐ Centre santé ☐ Hôpital ☐

Proximité / Distance (heures de marche) : ………………………………………………………………………….

-Avez-vous bénéficié d'une formation sur les utilisations de l'eau ? Oui ☐ Non ☐

Organisme ayant assuré cette formation : ONG ☐ Gouvern. ☐ Autres ☐

-Appui des services agricoles/ Pêche/ Forêt : vulgarisateurs /rices/ : Oui ☐ Non ☐

-Formation professionnelle

Poteries ☐ Bambou ☐ Broderies ☐ Tissage ☐ Autres ☐

-Crédits : Oui ☐ Non ☐ Nom de l'organisme ayant octroyé le crédit ………………………….

Destination du crédit : ……………………………………………………………………………………

-Electricité :

Disponibilité à la maison : Oui ☐ Non ☐
Lampe à gaz ☐ Panneaux solaires ☐ Bougies ☐ Autres ☐

-Sources d'énergie : Cuisine et chauffage

Butane ☐ Bois ☐ Charbon ☐ Electrique ☐

-Type d'habitation : Moderne □ Traditionnelle □

Assainissement :

Déchets ménagers : ……………………………………………………………………………………………………

Eaux usées :………

Route et type de Transport :

Sentier □ Piste □ Route □

…………………………………………………………………………………………………..

1.3. Accès aux ressources

-Eau :

Disponibilité à la maison : Oui □ Loin de la maison □

H. de marche ………..Moment ……………Quantité………………Nombre/jour……

1. Source □ **2**. Puits □ **3**.Oued □ **4**. Seguia □

Eau gratuite □ Payante □

Boisson…………Nettoyage et Hygiène ……………..Irrigation ……………….Bétail……

-Propriété de la terre: Propriétaire □ Locataire □ Exploitant □

Parcelle : <0,5 H □ Parcelle : 0,5 H < P< 2 H □ Parcelle >2 H □

Nombre de jours de Labour : ……………………………………………………………………………………

-Types de cultures pratiquées:

1. Céréales □ 2. Cultures Maraîchère □ 3. Arboriculture □

4. Légumineuses □ 5. Cultures Fourragère □

Consommation …………………………………Commercialisation ………………………….

-Types d'élevages :

1. Bovins □ 2.Ovins □ 3.Caprins □ 4. Apiculture □ 5.Petits élevages □

Consommation ……………………………Commercialisation ……………………………….

2. Répartition des rôles et activités entre les hommes et les femmes.

2. 1. A l'intérieur du foyer

	Femme	**Homme**
Repas		
Linges, vaisselle, ménage		
Elevage enfants		
Peinture interne et externe		
Autres activités		

Approche Gender dans le Bassin Versant de Oued Laou/Faculté des Sciences de Tétouan/ Wadi 6° FP, INCO-CT2005-015226

2. 2. A l'extérieur du foyer

Type d'activité	H	F
Approvisionnement en eau potable		
Approvisionnement en eau de vaisselle		
Ramassage du bois pour feu		
Approvisionnement et		
commercialisation des produits :		
Agriculture		
Labour		
Nivellement à la sape		
Semis		
Epandage d'engrais		
Epandage de fumier		
Irrigation		
Fauchage/ Récolte		
Transport		
Transformation/ conservation		
Stockage		
Commercialisation		
Nettoyage des grains et mouture		
Choix des cultures à cultiver et des élevages à pratiquer		
Elevage		
Bovins		
Caprins/ Ovins		
Apiculture		
Petits élevages		

3. Evolutions et Tendances des ressources naturelles

Changement de paysage (Historique) ………………………………………………………………..

Consommation En diminution □ plus important□

Facteurs à l'origine de la diminution de la ressource eau :

Pollution □ Sécheresse □ Plus grande demande □ Autres □

Impacts des changements constatés sur la vie de la population :

4. Potentialités

Traditions de préservation des ressources naturelles héritées et pratiquées (économie de l'eau) :

-Savoir faire exemple collecte et utilisation des eaux de pluies : …………………………………………………………………………………………

-Sont t-ils encore pratiqués et transmis à qui et comment ?

…………………………………………………………………………………………

Approche Gender dans le Bassin Versant de Oued Laou/Faculté des Sciences de Tétouan/ Wadi 6° FP, INCO-CT2005-015226

-Organisations traditionnelles de gestion de l'eau (exp. Jamaa) (participation de la femme et de l'homme dans les décisions de la Jmaa) :

5. Contraintes rencontrées dans la gestion et l'utilisation de l'eau

6. Besoins et priorités des femmes

Les femmes peuvent elles communiquer leur problèmes et besoins à la Jmaa ?

Attitudes des populations vis-à-vis des programmes initiés par l'état dans le domaine de la gestion et de la conservation des ressources naturelles (services de l'eau, agriculture et forêts, …).

Les femmes sont elles informées des programmes ? Oui ☐ Non ☐

Si cela répond à leurs intérêts, besoins et priorités ?

7. Propositions de solution pour améliorer la situation :

Quelles améliorations peuvent être apportées par les femmes ? et comment elles voient l'apport des services publics :……………………………………………………………………………………………………....

2.3. Analyse des données

Après l'adoption du modèle définitif, les fiches de terrain ont été dépouillées et les résultats ont été introduits dans une base de données. En conséquence des critères de choix des familles par des méthodes non probabilistiques (voir le paragraphe 2.1): nous avons utilisé le "quota sampling" qui est l'équivalent non-probabilistique du "strata sampling". Les strata ont été changés car l'activité agricole a résultée transversale dans tout le contexte rurale. Le quota se référés ainsi à l'ambiance rurale/urbain, à la principale source de revenu (Fran Ali étant un cas isolé pour la poterie), et à la dimension générique. La répartition du travail a été classée selon la méthodologie SEAGA (1993) pour l'analyse au niveau "terrain".

Le Multi Dimensional Scaling (software Primer, généralement utilisé pour l'analyse de la biodiversité) a été utilisé pour ordonner les données et obtenir une description du contexte. On a considéré séparément:

- les familles, en ce qui concerne le profile socio-économique de la famille et l'accessibilité aux services;
- le genre, en ce qui concerne la perception des changements, des problèmes et les proposition de solution.

Les résultats obtenus ont été représentes sous forme de dendrogrammes dérivés en se basant sur la similarité des réponses (matrice Bray-Curtis on données non transformées). Le programme n'analyse pas celles avec réponses manquantes, l'effectif des familles peut varier entre familles et genres.

3. Résultats

3.1. Composition de la famille

Le nombre de membres d'une famille en milieu rural varie de 2 à 14. En milieu urbain ce chiffre varie de 3 à 18 personnes. Les familles en milieux urbain et rural se composent généralement des deux parents, et plus souvent des grands parents et d'autres parents en milieu rural qu'en milieu urbain.

Le nombre d'enfants par famille est de 0 à 10 et ce aussi bien pour le milieu rural qu'urbain. Pendant que le taux d'analphabétisme est élevé aussi bien chez les femmes que chez les hommes (37/50 familles où les deux chefs de famille sont analphabètes), le taux d'analphabètes des enfants en âge scolaire est nul, les enfants ont soit un niveau primaire ou secondaire.

La femme est soit chef de famille, mariée, veuve ou (2/50 cas) à mari migrant. Toutes les femmes sont soit mariées soit veuves. Aucune femme n'est divorcée.

L'agriculture est le principal revenu en milieu rural sauf pour Fran Ali où la principale source de revenu est la poterie. À Oued Laou, l'activité de pêche s'ajoute à l'agriculture. Les produits sont rarement commercialisés, ils servent surtout à la consommation propre. Probablement cela est une des causes de l'absence d'associations d'agriculteurs

3.2. Accès aux services de base

Deux grands groupements, le milieu rural et le milieu urbain, se distinguent par la disponibilité des services de base dans le bassin versant d'Oued Laou (Fig. 2). L'environnement urbain consolidé depuis plusieurs centaines d'années (Chaouen et Bab Taza) se caractérise par un accès aux services relativement satisfaisant. Le village d'Oued Laou est un cas particulier et il est représenté dans les deux groupements. Il s'agit en effet d'un milieu semi urbain et la population y est loin d'être homogène. Il existe à la fois des familles urbanisées et d'autres vivant dans des conditions quasi rurales. L'accès et la disponibilité des services de base dans l'environnement rural sont diverses et fragmentées.

Il existe toujours un centre de santé à proximité, à une distance allant de 5 minutes à pied à 1 heure par autocar. Parfois il n'y a pas de médecin dans le centre de santé comme c'est le cas pour le village de Khizana. Les villageois sont alors obligés de se rendre à Bab Taza ou à Chaouen voire à Tétouan. En milieu urbain, il y a un hôpital à Chaouen. A Oued Laou et Bab Taza, ce sont plutôt des centres de santé. Hommes et femmes, dans le cas de complication doivent se rendre à Chaouen ou à Tétouan. Ils ont cependant accès à des services para sanitaires tels que les pharmacies, infirmiers pratiquants, etc. La médecine traditionnelle n'est pratiquement pas utilisée dans le bassin versant d'Oued Laou selon les dires des habitants.

L'eau est disponible dans les foyers des centres urbains où ce service est payant. En milieu rural, il est disponible dans 50% des foyers à Maggo et Talambot. Il s'agit soit de sources situées dans la maison, soit de tuyaux qui amènent l'eau depuis les sources sur des distances de plusieurs centaines de mètres. Dans le cas de Fran Ali, Afertane, Anjra et Talambot, il faut aller s'approvisionner à l'extérieur. L'eau prélevée des sources ou des cours d'eau est toujours gratuite. Parfois les villageois s'organisent pour la gestion de l'eau. Ils cotisent pour mettre en place des canalisations afin d'avoir l'eau au sein des maisons.

L'électricité est disponible dans les centres urbains et la plupart des milieux ruraux à l'exception d'Anjra et de Afertane. Dans tous les cas, elle est payante. A l'exception des centres urbains, tous les foyers des milieux ruraux utilisent à la fois le butane, généralement pour la cuisine et l'éclairage, et le bois pour le pain.

En milieu urbain, il n'y a pas de propriétaires de terre. En milieu rural la propriété des terres pose toujours des problèmes. Les terres sont héritées des parents et des grands parents, elles sont alors divisées en petites parcelles aux nombreux héritiers. Il s'agit de petites parcelles éparpillées, souvent éloignées des maisons. Lorsque les parents sont encore en vie, les enfants doivent souvent louer des terres pour cultiver et vivre.

A part deux cas isolés de personnes (une famille à Oued Laou et une autre à Khizana), il n'existe pas de personnes ayant profité de crédit. Par ailleurs les femmes et hommes questionnés ne souhaitent pas avoir accès à ce genre de service à cause de l'impossibilité de pouvoir faire face aux remboursements.

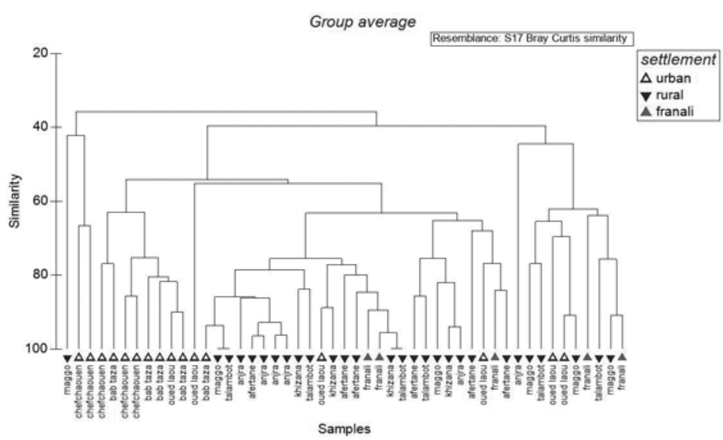
3.3. Accès aux services de éducation, formation professionnelle et formation sur les utilisations de l'eau

En milieu rural, il existe généralement un *msid* (école coranique simple) et une école primaire, à 5 minutes - 1 heure de marche. Les enfants ne poursuivent généralement pas leurs études et chez aucune famille rurale interviewée, il n'existe un enfant ayant atteint le niveau universitaire.

Les institutions scolaires, surtout de niveau secondaire et universitaire sont en général éloignées si bien que les enfants n'y ont pas accès. Les services sanitaires posent un problème crucial surtout chez les femmes en milieu rural. L'approvisionnement en eau est une dure tâche incombant aux femmes. Les sources sont en général éloignées et il faut parcourir de longues distances afin de s'en approvisionner.

La formation sur l'utilisation et la gestion de l'eau dans le bassin versant d'Oued Laou fait cruellement défaut. Il s'agit d'une zone où l'eau est disponible en grande quantité certes mais il existe des périodes de l'année où elle fait cruellement défaut. La ressource eau est à notre sens mal gérée et souvent gaspillée lorsqu'elle est en abondance, lors des saisons pluviale et printanière et dans les habitations situées en amont, près des sources. L'utilisation des tuyaux pour amener l'eau depuis les sources dans les maisons doit être mieux gérée ainsi que la répartition au sein d'un même village.

Figure 2. Dendrogramme raprésentant l'accès aux services de base en zone urbaine et rural. Claque symbole représente une famille interviewée, dont la provenance est indiqué en bas. Le cas de Fran Ali a été mis en évidence étant donné que la poterie constitute la principale source de revenu de la famille.



Seules les femmes ont accès à la formation professionnelle. Aucune formation sur l'utilisation ou la gestion de la ressource en eau n'a été mentionnée au cours de l'étude. Il n'existe pas non plus de formation pour la poterie, même à Fran Ali, où les mères de familles se chargent de l'enseignement aux enfants, ni de tissage ou *mendil*. Les rares formations dans les villages ou les centres urbains touchent à la couture moderne et à la broderie. Seules les femmes profitent de ces formations.

Seules les femmes se rendent aux cours d'alphabétisation. Apparemment, les hommes ne sont pas intéressés par ce service. Ceci pourrait être dû au fait que les monitrices sont des jeunes femmes. Il n'y a pas à notre connaissance de moniteurs masculins en milieu rural. Les classes mixtes ne sont pratiquement pas envisageables chez les adultes en milieu rural, dans le bassin versant d'Oued Laou ni ailleurs au Maroc.

3.4. Répartition du travail entre hommes et femmes

Les Tableaux 1 et 2 montrent clairement que la femme évolue dans deux espaces différents, un espace domestique ou privé et un espace public. Chacun de ces espaces comprend trois types d'activités, à savoir des activités vitales (domestiques *sensu stricto*), des activités économiques correspondant à un rôle productif de biens et services, et des activités sociales (ayant trait à la vie communautaire). Les activités de la femme liées à l'espace domestique sont de nature vitale et revêtent peu d'aspect social (telle l'éducation des enfants). Elles se caractérisent par leur pénibilité, répétitivité et diversité. Etant vitales, elles sont donc invisibles et constituent un travail non nommé, non reconnu et par conséquent non valorisé.

Les femmes participent également, à l'extérieur de foyer, de manière très active à l'agriculture et à l'élevage. Le travail est réparti de manière très inéquitable.

Tableau 1. Répartition du travail des hommes (H) et les femmes (F) lié au foyer, dans le bassin versant d'Oued Laou (0=néant).

Tâches liées au foyer	Urbain	Rural
Repas	F	F
Linge, vaisselle, ménage	F	F
Education des enfants	F	F
Peinture interne et externe	F (parfois un ouvrier H)	F
Approvisionnement en eau potable et de vaisselle	0	F
Ramassage du bois pour feu	0	F

Dans le bassin versant d'Oued Laou, la femme assume un rôle important à tous les niveaux, notamment pour l'éducation des enfants, les tâches ménagères et tâches extérieures. Son principal revenu économique est également conditionné à son travail. Les femmes assument en général le rôle de chef de famille, fait qui ne lui est souvent pas reconnu et c'est à l'homme que revient le mérite. Parfois, l'homme est absent de la maison (ex. périodes de récolte *Cannabis*) et c'est elle qui assume toutes les responsabilités au foyer. Dans le cas de Fran Ali, beaucoup de femmes restent à la maison pour fabriquer les articles de poterie et s'occuper de leur foyer. L'homme a l'unique souci de vendre les articles et est souvent installé soit à Tétouan soit dans une autre ville durant toute l'année.

Tableau 2. Répartition du travail des hommes (H) et des femmes (F) en dehors du foyer dans le bassin versant d'Oued Laou (0= néant).

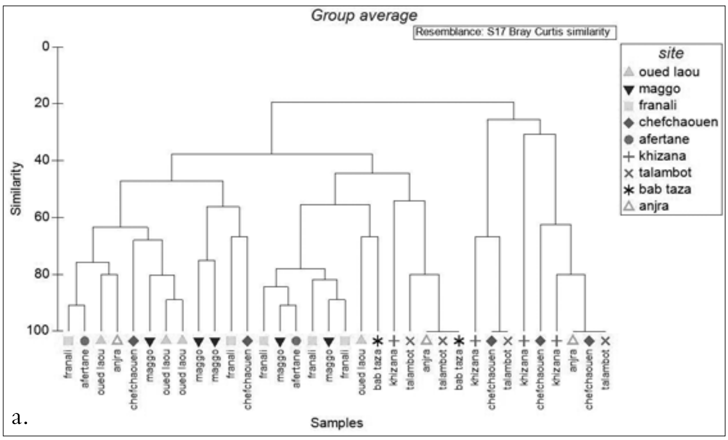
Tâches	Urbain	Rural
Labour à l'araire, nivellement à la sape, semis, épandage d'engrais et de fumier, irrigation, fauchage	0	H
Collection	0	F
Transport	0	FH
Séchage, battage, etc.	0	F
Nettoyage des semences	0	F
Stockage	0	F
Commercialisation	0	FH
Distribution du fourrage aux animaux	0	FH
Transport des semences au moulin	0	FH
Choix des cultures à cultiver	0	FH
Pâturage	0	FH
Faire le Souk	FH	FH

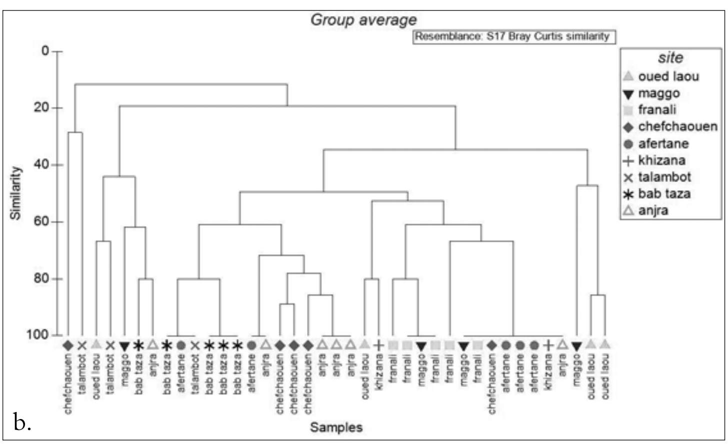
3.5. Normes culturelles et traditions de préservation des ressources naturelles

La médecine traditionnelle est apparemment quasi inexistante dans le bassin versant d'Oued Laou, en milieu rural autant qu'en milieu urbain. Les réponses ont toujours été négatives à ce sujet. L'utilisation des plantes médicinale est aussi quasi inexistante à l'exception de quelques femmes qui nous ont dit utiliser certaines plantes telles que menta, *fliou* ou *zahtar*. Il est cependant surprenant de constater que médecine et pharmacopée traditionnelles sont absentes, surtout en milieu rural, dans des régions où l'accès à la médecine moderne n'est pas toujours chose aisée. Les réponses pourraient ne pas avoir été complètement sincères, les femmes craignant d'avouer l'utilisation de plantes par souci pour l'image présentée à des gens étrangers et des femmes et des hommes 'modernes'.

Le savoir faire est transmis aux jeunes (urbain 50%), rural (plus de 50%). Dans le cas de réponse positive seul 50% des questionnés ont précisé le genre de savoir faire en question. Il s'agit de la fabrication de plats de cuisine (mets, fromage, petit lait, lait caillé), stockage des eaux de pluie, utilisation des *séguias*, poterie, tissage, *mendils*. Les traditions sont de moins en moins appliquées et transmises aux jeunes et ce, aussi bien en milieu rural que dans les centres urbains. Le seul village où une activité traditionnelle telle que la poterie s'est maintenue de génération à génération est celui de Fran Ali, probablement, grâce à son intérêt économique. La plupart des personnes questionnées (hommes et femmes) ont affirmé qu'ils souhaitent préserver les ressources naturelles dont ils disposent (forêt, eau, sol, faune, etc.). Les cultures traditionnelles telles que certains types de céréales de même que l'arboriculture sont en train de disparaître, laissant place à la culture du cannabis beaucoup plus rentable.

Figure 3. Dendrogrammes basés sur les aspects socioculturels, la sauvegarde du paysage et de la ressource en eau, les traditions, les problèmes et les solutions proposées. Les données sont séparées par gendre: hommes (a) et femmes (b). Chaque symbole représente une personne, avec des symboles différents selon la localité de provenance, indiqué en bas.





Il n'existe presque pas d'organisation traditionnelle dans le bassin versant d'Oued Laou. Apparemment la seule organisation traditionnelle connue et la *Jmaâ*, qui parmi se fonctions a la gestion du sol et des eaux pour l'irrigation. Parmi les localités considérées, la *Jmaâ* est toujours présente à Oued Laou, Fran ali, Maggo, Afertane, Anjra, Khizana, Talambot (c'est-à-dire dans tous les zones rurale set dans une zone urbaine récente). La gestion de l'eau, dans les localités connectées au réseau hydrique, a été indiquée par tous les interviewés être faite par l'ONEP.

Dans le bassin versant, la femme est mal représentée et n'a même pas droit de s'adresser directement à la *Jmaâ*, Elle doit le faire via l'homme. En tant que partie prenante, la femme joue un rôle fondamental sans cependant avoir accès à la décision qui reste réservée aux hommes. En ce qui concerne la perception des problèmes dans l'espace, les hommes semblent avoir une vision détachée de celui-ci (Fig. 3a). Les femmes, elles ne font pas de différence entre urbain et rural, mais il existe cependant une structure spatiale montrant que les femmes sont plus liées à leur milieu (Fig. 3b).

3.6. Perception de participation des hommes et des femmes dans la gestion des ressources naturelles

Dans les centres urbains, les problèmes liés à la ressource eau concernent surtout les prix exorbitants imposés par l'institution responsable de sa distribution. Dans le cas d'Oued Laou, il se pose de manière cruciale surtout pour les familles possédant des cultures irriguées. Les femmes doivent alors se rendre seules aux *seguias* éloignées et souvent très mal entretenues pour s'approvisionner en eau.

La majorité des personnes questionnées en milieu rural, aussi bien hommes que femmes, opinent que l'eau n'est pas un problème dans le bassin versant d'Oued Laou. Il s'agit d'une région assez bien arrosée, parcourue par de nombreux cours d'eau, où abondent les sources. Certains problèmes ont cependant été relevés. Ils concernent la pollution, l'éloignement des sources ou des cours d'eau, la retenue des eaux de sources par les habitants en amont, surtout durant les périodes sèches. Le régime hydrique de la région se caractérise également par une certaine irrégularité et entraîne en saison sèche, la non disponibilité de cette ressource. Les femmes ont toujours une plus vive nécessité vis-à-vis de l'eau que les hommes et se sentent plus concernées par les problèmes que peut poser la disponibilité de l'eau.

En milieu rural, le bois est une ressource indispensable dans tous les foyers. L'Administration des Eaux et Forêts interdisant les coupes de bois, il s'agit d'une ressource difficile à obtenir. Les femmes continuent cependant d'aller en forêt pour s'approvisionner de bois.

Les parcelles héritées sont généralement de petite taille, éparpillées et souvent très éloignées de la maison. A l'exception de Chaouen et Bab Taza où l'assainissement se fait (sans traitement aucun), pour tous les autres cas, les eaux usées vont directement à l'Oued ou dans les champs. Les rejets solides sont collectés par la municipalité à Chaouen. Dans tous les autres cas, ils sont rejetés directement dans la nature.

4. Discussion

4.1 Méthodologie adaptée au Bassin versant

Ce travail a permis l'élaboration d'une méthodologie adaptée au Nord du Maroc en général et au bassin versant d'Oued Laou en particulier. Bien que nous avons utilisé le niveau " terrain " de la méthodologie SEAGA, qui considère les différents aspects liés aux différentes échelles d'analyse, chaque site d'étude nécessite une adaptation ultérieure. Cela peut être réalisé surtout testant les questionnaires sur le terrain, pour trouver l'approche meilleure, qui peut faire sortir les problématiques et les besoins à identifier. Un rôle dominant dans l'interaction est joué par la confiance en l'interviewer. Dans tout cas, l'implication de chercheurs locaux et l'intégration de différentes contributions sont nécessaires pour recouvrir les aspects critiques du système à analyser

4.2. A propos de la méthodologie

En fait, il est difficile de distinguer les milieux urbains et ruraux dans le bassin versant d'Oued Laou. Le vrai centre urbain est la ville de Chefchaouen; mais aussi bien Oued Laou que Bab Taza sont en réalité des centres semi-urbains. Les résultats obtenus (fig.2) le montrent d'ailleurs, et les conditions dans lesquelles beaucoup de familles vivent sont en fait plus rurales qu'urbaines. En plus le village Fran Ali, bien que fortement caractérisé par une activité artisanale particulière, ne bénéfice d'aucun support, ni en ce qui concerne les infrastructures (d'après la figure 2 le profil des services étant homogène avec les zones rurales) ni en ce qui concerne la sauvegarde d'un artisanat traditionnel très caractéristique et principal source de revenu.

4.3. Statut de la femme dans la famille

Les données obtenues concordent avec celles de Khattabi (2004) pour le bassin versant de l'Oued Laou et avec celles concernant l'analyse du genre par rapport à la gestion de l'eau dans le bassin de la Méditerranée (Hamdy, 2005). En milieu rural, traditionnellement, les hommes une fois mariés demeurent toujours dans le foyer paternel pour fonder leur famille alors que les femmes quittent le domicile paternel pour rejoindre le mari. Cependant la tendance à fonder des foyers à deux (mari et femme) se fait noter de plus en plus dans le bassin versant d'Oued Laou. En milieu urbain, les familles tendent plus à l'indépendance et se composent uniquement des deux époux et des enfants (Chaouen et Bab Taza: 100%, Oued Laou 75% des familles interviewées). Parfois, certains membres de la famille, des cousins ou neveux, peuvent faire partie de la famille généralement pour des raisons d'étude.

Malgré le taux élevé d'analphabètes parmi les parents, il est satisfaisant de voir que les enfants sont généralement scolarisés et apprennent au moins à lire et à écrire. Cependant, les enfants ne poursuivent généralement pas leurs études et nous n'avons relevé aucun enfant ayant atteint le niveau universitaire dans l'échantillon. Les difficultés sont dues à l'éloignement des institutions d'éducation primaires, secondaires et universitaires mais aussi à des difficultés économiques qu'ont les parents à acquérir le matériel scolaire, les frais de déplacement ou d'hébergement et l'entretien des enfants dans les centres scolaires ou universitaires loin du foyer. Les filles sont plus affectées car elles souffrent de la tradition qui veut qu'elles doivent rester chez elles pour effectuer des tâches ménagères, se marier et fonder une famille. La plupart des familles craignent les médisances des gens si leurs filles sortent pour se rendre à l'école ou au collège et se font aborder par des garçons. Plusieurs familles empêchent leurs filles de continuer leurs études pour ces raisons. Ce problème a été relevé autant en milieu rural qu'urbain (Oued Laou et Bab Taza).

Il est surprenant de constater qu'aucune des femmes questionnées ne soit divorcée. Elles sont toutes mariées ou le cas échéant veuves. A en croire notre échantillon, le taux de divorce est très faible dans le bassin versant d'Oued Laou, surtout en milieu rural. Pour la femme, quitter le foyer conjugal pour revenir chez ses parents est contraire aux mœurs et traditions: la femme mariée doit rester chez elle et entretenir son foyer. Le manque de moyens propres l'empêchent également de vivre seule. Les hommes de leur part n'ont pas à avoir recours au divorce car ils peuvent avoir plusieurs épouses.

Le taux d'analphabétisme est élevé chez les femmes comme les hommes. Ceci s'explique par le fait que la plupart des institutions scolaires d'aujourd'hui sont des installations nouvelles et n'existaient pas il y a quelques années.

Une réticence a souvent été notée vis-à-vis des questions qui ont trait à l'aspect économique de la famille (propriétés, revenus, etc.). Les résultats obtenus ont donc été déduits d'autres questions concernant plutôt le type d'activité entrepris au sein de la famille et d'observations intégratives de terrain. En ce qui concerne la représentativité des femme dans les prises de décisions, la *Jmaâ* ne consens pas la participation féminine, bien que les femmes font la plus part du travail soit à l'intérieur soit à l'extérieur du foyer et, comme démontré par les données sur la perception séparées par genre, sont beaucoup plus en contact avec l'environnement par rapport aux hommes. Cependant ni les hommes ni les femmes ne se sentent représentés au delà des organisations traditionnelles, et encore moins aux niveaux plus élevés de participation. Parmi les propositions de solution des problèmes, c'est souvent la requête d'une représentativité majeure dans les institutions, ce qui peut être interprété comme un signal positif d'une volonté de changement au delà du niveau individuel.

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THE EGYPTIAN STUDY SITE

SUITABILITY ANALYSIS OF WATER QUALITY IN LAKE MARYUIT FOR ECONOMIC ACTIVITIES USING GIS TECHNIQUES

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Abstract: Lake Maryuit is one of the northern lakes in Egypt, located to the southwest of Alexandria city, and has been a source of fish in addition to providing other ecosystem services such as supporting wildlife habitat. The lake receives considerable amounts of waste water on a daily basis. Accordingly, water quality in the lake has deteriorated significantly with resultant impacts on the ecosystem functions of the lake.
Meanwhile, there is an urgent need to explore various available alternatives to reuse waste water in Egypt due to the increasing demand for water and limited supply. In this context, the paper in hand aims at assessing the suitability of water quality in three basins of Lake Maryuit for aquaculture and irrigation activities using suitability analysis through GIS techniques. The assessment involves examining two techniques of suitability analysis; namely computer-assisted overlay and weighed linear combination.
As a part of WADI Project sponsored by the EC, data on various variables of water and sediments in Lake Maryuit was acquired during field work conducted in March 2007. These variables can provide, to some extent, a comprehensive profile about the water quality in the lake and can consequently be used in assessing the suitability of water quality in the lake for some human uses.
The sampling points of various water variables, which were georeferenced, were used to develop a GIS for the water quality in the lake. The tabulated sampling points were used in generating a point feature class, which was in turn employed to create Digital Elevation Models (DEMs), each of them representing spatial variations in the level of one of the water variables within the lake vicinity. The developed DEMs were used in conducting suitability analysis of water quality in three basins in the lake, namely Main Basin, Aquaculture Basin and Southwest Basin, for aquaculture and irrigation activities. The employment of the two techniques produced contradicting results due to the nature of each technique. The outcome of the suitability analysis according to computer-assisted overlay technique indicated that the water quality in most of the lake is not suitable for aquaculture or irrigation. The weighed linear combination technique, meanwhile, showed that water quality in large proportion of the three basins is suitable for aquaculture activities and irrigation. However, computer-assisted overlay was found to be more appropriate for suitability analysis work involving threshold values.

Suitability analysis

Suitability analysis is an aspect of GIS with a wide range of application including urban, regional, environmental planning and management.

Felicita Scapini, Jean-Marc Boffa, Elisabeth Conrad, Louis F. Cassar and Mariella Nardi (editors), *Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socio-economic and environmental analysis of changes and trends to enhance and sustain stakeholder benefits*, ISBN 978-88-6453-015-4 (online)

Simply put, suitability analysis is an evaluation or a decision problem involving several factors where suitability of an object for certain uses is determined as a function of a number of factors. Generally, suitability analysis can be described as:

$S = f (x_1, x_2,\dots, x_n)$

where: S = Suitability measure

$x_1., x_2, \dots, x_n$ = Factors affecting suitability

Accordingly, suitability analysis constitutes an appropriate approach to combine (bring) these factors (together) in the evaluation or decision-making process (Mendoza, undated)

Among different groups of suitability analysis approaches, computer-assisted overlay and weighed linear combination are considered the most often employed. Computer-assisted overlay mapping is based on the concept of hand-drawn overlay techniques but instead of manually mapping, various variables are stored in digital form in the computer. The individual suitability maps can be analyzed, overlaid and combined in an overall suitability map.

Meanwhile, Weighed Linear Combination (WLC), which is one of the multi-criteria evaluation methods, is based on the concept of a weighted average where the analyst assigns the weight to each variable or factor representing the relative importance of this variable. Then a total score is obtained for each variable by multiplying the weight assigned for each variable and summing the products over all variables. Accordingly, the suitable areas are those areas having the highest overall score (Malczewski, 2004). The importance of this technique is revealed in those cases where the variables, used in analysis, have different value scales: ppm, Celsius degree, meter…etc. In such a case summing up the values of different variables will not lead to a meaningful result. Also, weighed linear combination technique is more appropriate when the employed factors are not equally important.

However, the implementation of some suitability analysis techniques without full understanding of the assumptions underlying these techniques may lead to not only inaccurate but also incorrect results (Malczewski, 2004).

This means that the application of different techniques gives different results. Therefore, the analyst, in the early stages, should carefully select the appropriate suitability analysis technique, to be employed. Moreover, the results of suitability analysis should be carefully interpreted in the shadow of the employed technique.

Case study

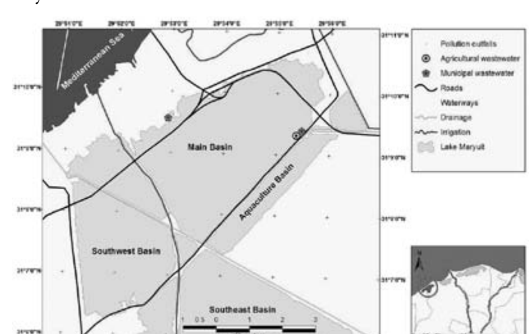
Lake Maryuit is located in north of Egypt southeast to the Alexandria city, one of the most heavily populated urban areas in Egypt. The lake is artificially subdivided into four basins; Main Basin, Aquaculture Basin, South West Basin, and South East Basin (Fig. 1). The Main Basin, which covers an area of about 20 Km^2, has been suffering from high levels of pollution. Currently, the main sources of pollution in the lake, particularly the main basin, are represented in:

West Treatment Plant Outfall, which discharges about 200,000 – 300,000 m^3/day of settled sewage into the lake.

El Qallaa Drain Outfall, which discharges about 400,000 m^3/day of agricultural waste water and sewage into the lake after primary treatment (El Sharkawi, 1999 and Kassim, 2005). In general, El Qallaa Drain is considered the major source of pollution in the lake (Samman *et al.*, 1988) (Fig. 1).

In addition to these two sources of pollution, previously for a long period, Gheit El Enab Outfall was discharging about 25,000-35,000 m^3/day of raw sewage and some industrial waste water into the lake. Since early 1990s, this quantity of waste water has been directed to the West treatment Plant (El Sharkawi, 1999). Also, about 25,000 – 30,000 m^3/day of industrial waste water used to be discharged into the Main Basin of the lake from Moharam Bey Industrial Complex. Such industrial waste water has high BOD, COD, oil and suspended solids. To keep the level of water in the lake constant, excess water is discharged into the Mediterranean Sea through El Max Pump station.

Figure 1. Lake Maryuit.



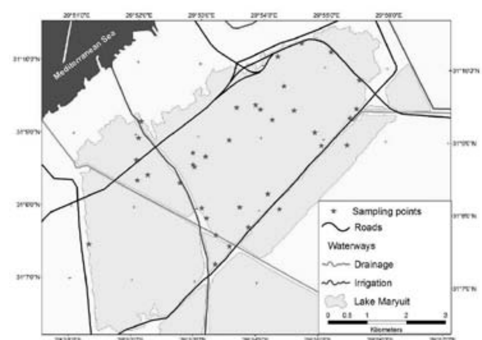
Lake Maryuit has for a long time represented a source of fish production in Egypt. Currently, some parts of the lake are used in aquaculture activities. The *Tilapia* species is of considerable importance in fisheries of Lake Maryuit as it represents about 90% of the total catch in the lake (Bakhoum, 1994).

Egypt has been listed among the ten countries that are threatened by want of water by the year 2025 due to the rapidly increasing population. Such a situation of water shortages necessitates seeking new supplies for agriculture activities, which consume about 86.3% of water supply in Egypt (Abdel-Shafy & Raouf, 2002). The application of waste water in irrigation purposes was one of the available alternatives adopted. This practice, which has increased over the past years is expected to continue in the future (Gaballah *et al.*, 2005). Such a situation necessitates the need for careful and in-depth assessment of the quality of the water to be re-used for human activities.

Data and methodology

The developed GIS is based on the most recent available topographic map of the lake and its surroundings, remote sensing imagery, and the data collected through field work in the lake. The base map of the lake and its surroundings was prepared based on topographic map scale 1:50,000 and a LandSat Enhanced Thematic Mapper (ETM+) image with a spatial resolution of 14.25 meter dated 17/06/2002. All of these sources were utilized in digitizing the base map of the lake.

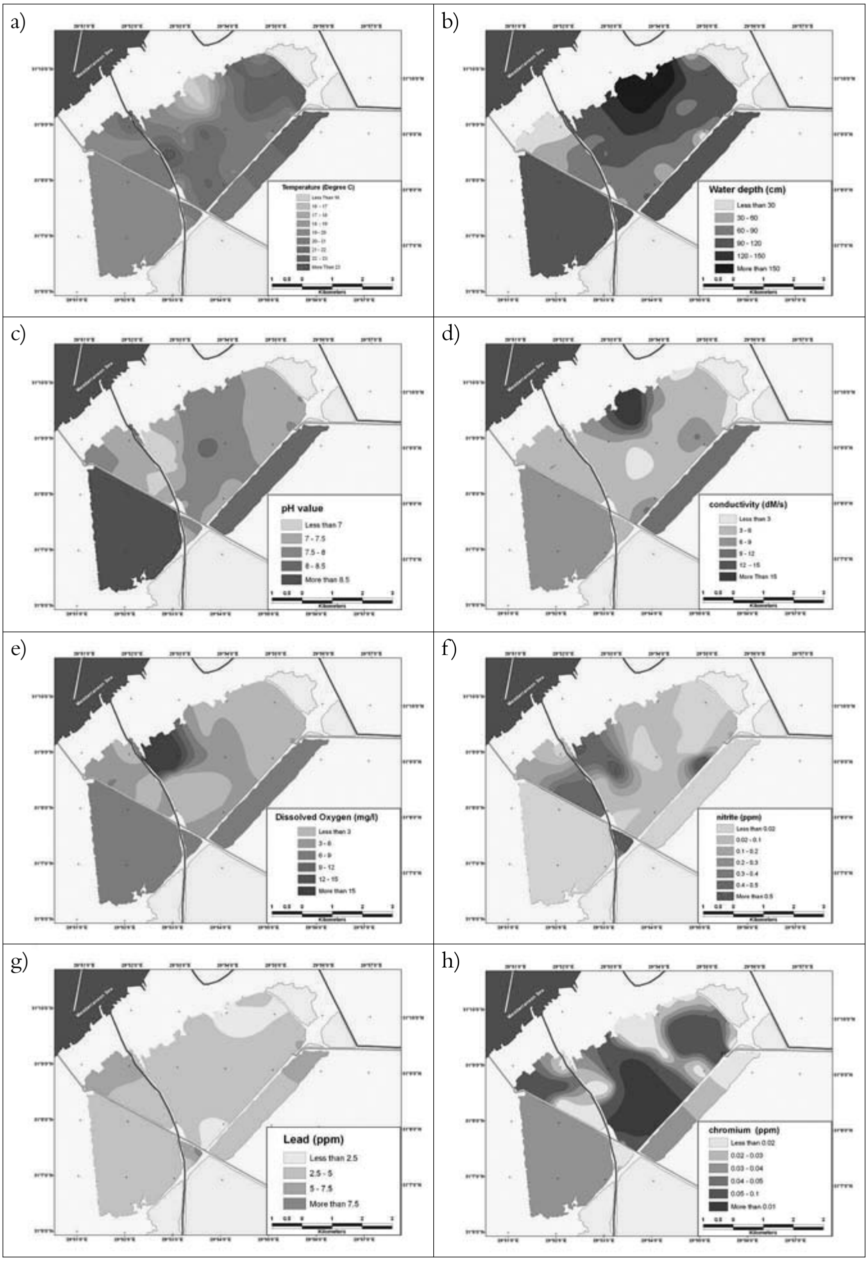
Figure 2. Sampling points location of water variables.



The data on various variables of water and sediment in the lake was collected through field work conducted within the framework of WADI Project , by teams of researchers from Barcelona and Italy in March 2007. The WADI project included Lake Maryuit as a case study.

In order to integrate the acquired data into the system, the sampling points had to be georeferenced, i.e. they have to be referenced to specific geographic location (Fig. 2). For that purpose, the coordinates of each sampling point were identified by GPS during the field work. Thereafter, sampling points were tabulated, where each sampling point has a number of fields representing records of various sampled variables in addition to two fields representing the coordinates of the sampling point in latitude and longitude. These coordinates were transformed into UTM (Universal Transverse Mercator) coordinates.

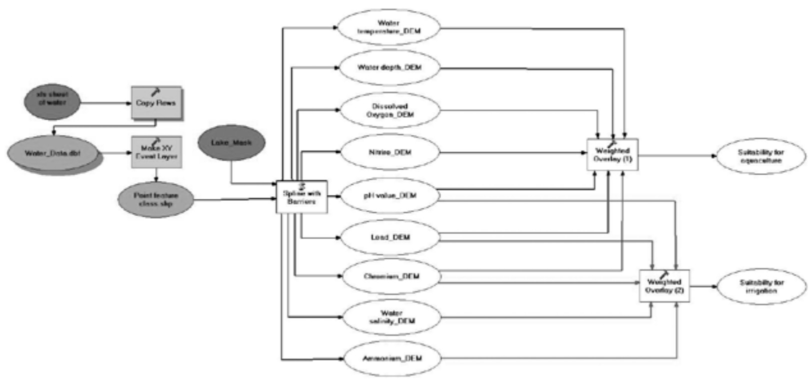
Figure 3. Digital Elevation Models (DEMs) for water variables.



Using ArcGIS Software, the tabulated data was used in producing a point feature class (layer) based on X and Y columns from tabulated data. The produced point feature class were was used in generating raster surface or Digital Elevation Models (DEMs) for each water variable representing the spatial variations for this variable within the lake body (see Figg. 3a, b, c, d, e, f, g and h).

As sampling points did not cover all the basins of the lake, the extent of the analysis was limited to those basins where sampling points exist. Accordingly the created DEMs were restricted to the Main Basin, the Aquaculture Basin, and the Southwest Basin. Also, sampling of some variables was conducted in some and not all sampling points, which meant that the values of these variables in some points were treated as missing value (disregarding or excluding sampling points with missing records) in creating DEMs. Finally, the generated DEMs were employed in conducting suitability analysis of water quality in the three basins of the lake for aquaculture and irrigation activities. Figure 4 illustrates the complete model of data handling and analysis.

Figure 4. Model of data handling and analysis using ArcGIS.



Criteria of assessment

The suitability analysis of the water quality in the three basins of the lake for aquaculture and irrigation was based on certain criteria. These criteria, which represent the main factors affecting the two uses, will be discussed in the following sub-sections.

Water quality for aquaculture

Fish production in closed and semi-closed water bodies such as Lake Maryuit is considerably affected by water quality, which is determined by certain variables such as water depth, water temperature, pH, dissolved oxygen, nitrite, chromium and lead. These variables, are thought to be the most critical variables affecting fish productivity, in particular tilapia, the main fish species in the lake (Table 1).

a. pH: pH is an indicator of the acidity or alkalinity of a water. Higher pH value exceeding 7 indicates water alkalinity while lower pH values less than 7 reveals water acidity. Generally, a safe level of pH for normal fish productivity is in the range of 5-9 and for maximum productivity the pH values should range from 6.5 to 8.5 (Phang, 1991). As for *Tilapia* species, to ensure high production, the optimum level of pH of water should range between 5-8.5 (Rachman and Adi, 2005).
b. Water temperature: Low or high temperatures pose serious stress to the fish and adversely affect their productivity (Lazur, 2000). In addition to direct impacts on fish productivity, water temperature affects fish productivity indirectly as the warm water is much less capable of holding oxygen gas in solution than cool water, which consequently may hamper fish production (Francis-Floyd, 2003). However, for *Tilapia* species, it was suggested that the optimum water temperature ranges between 26 - 30 °C (Rachman and Adi, 2005). Similarly, it was argued that the acceptable temperature range for *Tilapia* culture is 16 to 32 °C and is optimal at 25-29 °C (Asghar *et al.*, 2003). In conclusion, the growth of fish occurs in water temperature ranges between 16-30 °C.
c. Dissolved Oxygen: Dissolved oxygen is one of the most important water variables affecting fish production. Oxygen concentrations in water can drop quickly if water exchange is inadequate. Generally, it was argued that the optimum oxygen concentration should be above 5 parts per million (ppm) at all times for good growth (Lazur, 2000). For *Tilapia* species, the recommended optimum dissolved Oxygen level of water should exceed 3 mg/L (ppm) (Rachman and Adi, 2005).
d. Water depth: Fish productivity is directly correlated with water depth. This is mainly due to the negative correlation between depth of water and level of water enrichment or nutrient content (i.e. the more the water depth, the less the water visibility and algal production). This leads to better quality with higher oxygen content supporting fish production. In other words, the low depth of water and associated increase in nutrients usually signifies an increase in the ecosystem's primary productivity (i.e. excessive plant growth and decay), which leads to lack of oxygen and severe deterioration of water quality and reduction in fish populations. For the *Tilapia* species, it was recommended that water depth exceeds 200 cm to ensure maximum fish production;in the case of water depth less than 30 cm, fish production is hampered and becomes unfeasible (Rachman and Adi, 2005).
e. Nitrite: It is recommended for highest production of *Tilapia* that the Nitrite-Nitrogen (NO_2-N) concentration in water should not exceed 0.06 mg/L ppm (0.02 ppm of NO_2- form) (Rachman and Adi, 2005).
f. Heavy metals: Heavy metals are among those elements that are undesired in water bodies that are used for aquaculture activities. This is mainly due to the significant adverse impacts of heavy metals, and

their bioaccumulation, with attendant impacts on human heath. Accordingly, for fish production, very limited levels of heavy metals in water were suggested. For example, the tolerance limit is 0.1 mg/l of lead and 0.05 mg/l of chromium (Asghar *et al.*, 2003).

Table 1. Criteria of suitability analysis of water for aquaculture purposes.

Item	Recommended level
pH	5 - 8.5
Temperature	15 – 30 ppm
Dissolved Oxygen	> 3 ppm
Water depth	> 30 cm
Nitrite NO_2-	0.02 ppm
Lead Pb	0.1 ppm
Chromium CrO_4-	0.05 ppm

Water quality for Irrigation

Irrigation water varies in quality depending upon type and quantity of its content of salts, which exist in relatively small but significant amounts. Poor quality irrigation water results in a variety of problems ranging from salinity and water infiltration rate, to toxicity (Ayers and Westcot, 1985). Accordingly, the chemical and physical characteristics of the water body should be carefully assessed to identify the suitability of water for irrigation of food crops (Nazif *et al.*, 2006).

The irrigation water quality is generally determined by certain variables affecting crop production such as salinity, pH, nitrate (No^3), ammonium (NH^4), copper (Cu), chromium (CrO_4) and lead (Pb^2) (Table 2).

Salinity: Water salinity is measured by electrical conductivity reported in decisiemens per meter at 25°C (dS/m). High levels of salinity stunt the crop by reducing the availability of soil-water, slowing crop growth, restricting root development, and finally affecting the yield (Bauder and *et al.*, undated). Moreover, with higher levels of salinity, sodium and chloride toxicity are also likely to be evident. The recommended level of electrical conductivity in irrigation water ranges between 0–3 (dS/m) (Ayers and Westcot, 1985).

pH: Irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion. Generally, it is argued that the pH value of irrigation water is related to the kind of crops and the physical and chemical contents of the soil (Dökmen, 2004). However, it is recommended that the normal pH range for irrigation water is from 6.5 to 8.4 (Ayers and Westcot, 1985).

Nitrogen content (nitrate and ammonium): Despite most crops being unaffected by nitrogen levels above 30 mg/l, some sensitive crops, such as sugar beets, were reported to have lower sugar content and sugar purity with excessive nitrogen levels. Similarly, grapes, apricot, citrus are among the sensitive crops can be adversely affected by high levels of nitrogen, which can lead to a delay of fruit maturity and poorer quality of fruits. Also, high levels of nitrogen may stimulate growth of algae and aquatic plants in irrigation canals and drainage channels, which may increase maintenance costs for clearing vegetation from canals and drainage channels. The maximum recommended concentration of nitrogen in irrigation water is 10 mg/l for Nitrate-Nitrogen form (NO3-N) and 5 mg/l for Ammonium-Nitrogen form (NH4-N) (Ayers and Westcot, 1985).

Heavy metals: Many heavy metals such as iron, zinc and manganese are essential for plant growth at very low concentrations. Meanwhile, excessive amounts of heavy metals in irrigation water may have negative impacts on soil fertility. Moreover, some heavy metals have toxic impacts in high concentration (Dökmen, 2004). chromium is not recognized as an essential growth element,and it is recommended that the concentration of chromium in irrigation water should not exceed 0.10 mg/l. Such recommended concentration can actually be considered as conservative due to lack of knowledge on its toxicity to plants (Ayers and Westcot, 1985). High levels of lead concentration can inhibit plant cell growth.Therefore, the concentration of lead in irrigation water was recommended to be at maximum 5.0 mg/l (Ayers and Westcot, 1985; Dökmen, 2004). Concerning cooper (Cu), it was reported that Copper is toxic to a wide range of plants at certain levels.Accordingly, the maximum concentration of copper in irrigation water was recommended to be less than 0.20 mg/l (Ayers and Westcot, 1985; Dökmen, 2004).

In conclusion, it should be noted that, the suitability analysis of water for irrigation should be based not only on the total amount of salts existing in the water and their concentration but also on the type of salt and the potential problems resulting from such type of salt, which is determined by the types of cultivated crop.

Table 2. Criteria of suitability analysis of water for irrigation purposes.

Item	Recommended level
pH	6.5 – 8.4
Salinity	< 3 dS/m
Nitrate NO_3-	45 ppm
Ammonium NH_4-	6.5 ppm
Lead Pb	5 ppm
Chromium CrO_4-	0.1 ppm
Copper Cu	0.2 ppm

Results and discussion

The suitability analysis of water quality in the three basins of the lake for aquaculture activities was based on seven variables namely pH value, water temperature, dissolved oxygen, alkalinity, water depth, nitrite, lead, and chromium (Table 1), while the suitability analysis of water quality for irrigation was based on seven variables including pH, salinity, nitrate, ammonium, lead, copper and chromium (Table 2).

According to computer-assisted overlay technique, the developed DEMs, were used to extract individually those areas within the three basins that meet the recommended level of each criterion (Tables 1 and 2). The extracted suitable areas were converted into vector layers. This means that each of the produced vector layers represents areas that meet an individual criterion of assessment.

Thereafter, the produced individual vector layers ware overlaid (overlay intersect) to identify those portions of the three basins of the lake that meet all applied criteria having water variables within the recommended levels of all criteria i.e. suitable for aquaculture or irrigation.

According to weighed linear combination technique, each variable was scaled according to its suitability for aquaculture or irrigation according to different threshold limits or recommended maximum concentration of each variable. It was decided to apply an evaluation scale of 0 and 1 (0 for not suitable and 1 for suitable). Also, each variable was weighed or assigned a percentage influence weight according to its importance. The total influence for all variables must equal 100 percent.

Concerning suitability analysis of water quality for aquaculture, lead and chromium were given high weight compared to other variables involved in the analysis due to their significance (Table 3). The suitability of water for aquaculture is calculated according to the following equation:

$$S_{(a)} = \text{INT } \{(W \star 0.10) + (T \star 0.10) + (pH \star 0.10) + (D \star 0.10) + (N \star 0.10) + (Cro \star 0.25) + (Pb \star 0.25)\}$$

Where: $S_{(a)}$ = suitability of water for aquaculture
W = water depth,
T = water temperature,
pH = pH,
D = dissolved Oxygen,
N = nitrite,
Cro = chromium and lead
Pb = lead (Pb^2)

Meanwhile, in the analysis of water quality for irrigation, as copper (cu) and nitrate (No3) levels in different parts of the lake were found below the tolerance level i.e. within the recommended maximum concentration, they were excluded from the assessment. This means that the suitability analysis of water quality for irrigation was based on five variables. These variables were given an equal weight, 20% for each (Table 4). The suitability of water for irrigation is calculated according to the following equation:

$S_{(i)}$ = INT {(C ⋆0.20)+ (pH ⋆0.20) + (N ⋆0.20) + (Nh ⋆0.20) + (Cu ⋆0.20) + (Cro ⋆0.20) + (Pb ⋆0.20)}

Where: $S_{(i)}$ = suitability of water for irrigation
C = Salinity of water measured by electrical conductivity
pH = pH value
N = nitrate (No^3),
Nh = ammonium (NH^4),
Cu = copper (Cu),
Cro = chromium (CrO_4)
Pb = lead (Pb^2)

As the output raster from Weighted Overlay is integer, the final value would be 0 or 1, where 0 refers to an unsuitable area while 1 refers to a suitable area.

Table 3. The weight and the scale of the various criteria of water suitability for aquaculture.

Criteria	Weight	Scale Range	Scale Value	Remark
pH value	10%	< 5	0	Not suitable
		5 – 8.5	1	Suitable
		> 8.5	0	Not suitable
Water Temperature (°Celsius)	10%	< 15	0	Not suitable
		16 – 30	1	Suitable
		> 30	0	Not suitable
Dissolved Oxygen (mg/L)	10%	< 3	0	Not suitable
		> 3	1	Suitable
Water Depth (Cm)	10%	< 30	0	Not suitable
		> 30	1	Suitable
Nitrite (ppm)	10%	> 0.02	0	Not suitable
		< 0.02	1	Suitable
Lead (ppm)	25%	> 0.1	0	Not suitable
		< 0.1	1	Suitable
Chromium (ppm)	25%	> 0.05	0	Not suitable
		< 0.05	1	Suitable

Table 4. The weight and the scale of the various criteria of water suitability for irrigation.

Criteria	Weight	Range	Scale Value	Remark
pH	20 %	< 6.5	0	Not suitable
		6.5 – 8.4	1	Suitable
		> 8.4	0	Not suitable
Salinity (dS/m)	20 %	< 3	0	Suitable
		> 3	1	Not suitable
Ammonium (ppm)	20 %	< 6.5	0	Not suitable
		> 6.5	1	suitable
Lead (ppm)	20 %	> 5	0	Not suitable
		< 5	1	suitable
Chromium (ppm)	20 %	> 0.1	0	Not suitable
		< 0.1	1	suitable

The output of weighed linear combination technique divides the surface of the lake into two main categories; the first include those areas with (1) value indicating to those parts of the lake that have water quality suitable for aquaculture or irrigation and the second category include those areas with (0) value specifying those parts of the lake that have water quality not suitable for aquaculture or irrigation.

The application of computer-assisted overlay technique showed that water quality in all parts of the three basins is not suitable for aquaculture activities. Meanwhile, most of the lake water is not suitable for irrigation, whereas water quality in a very limited area of 0.2 Km^2 representing about 1% of the Main Basin was found to be suitable for irrigation activities (Fig. 5).

In contrast to computer-assisted overlay technique, weighed linear combination technique indicated that water quality in large parts of the three basins is suitable for aquaculture with an area of 22.90 Km^2 representing about 73.66% of the total area of the three basins. Also, those parts of the three basins where water quality is suitable for irrigation cover an area of 19.30 Km^2, representing about 62.90% of the total area of the three basins (Table 5).

According to weighed linear combination technique, water quality in all parts of Aquaculture Basin is suitable for aquaculture and irrigation activities (Figg. 6 and 7). This highlights improved water quality in Aquaculture Basin compared to other basins.

While water quality in all parts of Southwest Basin was found to be suitable for aquaculture activities (Fig. 6), only 3.96% of the basin area, in the south eastern corner of the basin, was found to be suitable for irrigation (Fig. 7).

Figure 5. Areas that have water quality suitable for irrigation according to computer-assisted overlay technique.

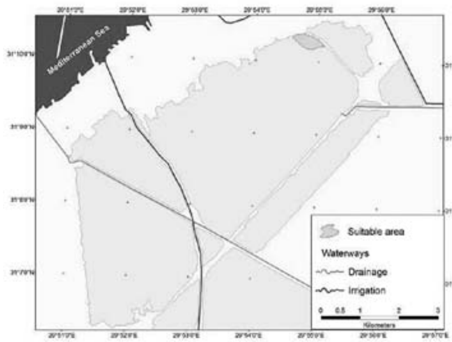
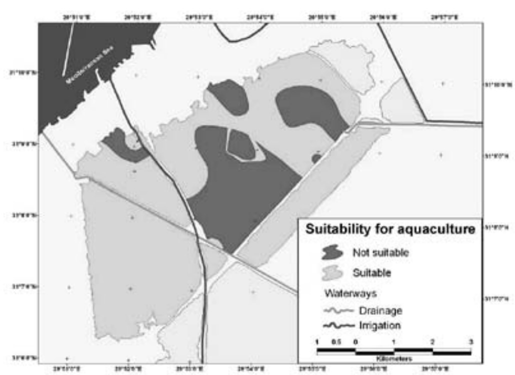


Table 5. Suitable area for aquaculture and irrigation activities according to weighed linear combination technique.

Basin	Total area of basin	Suitable area			
		Aquaculture		Irrigation	
		Area (m^2)	% of the basin area	Area (m^2)	% of the basin area
Main Basin	18,761,493	10,572,550	56.35	15,569,287	82.99
Southwest Basin	8,946,505	8,946,505	100.00	353,844	3.96
Aquaculture Basin	3,377,992	3,377,992	100.00	3,377,992	100.00
Total	31,085,990	22,897,047	73.66	19,301,123	62.09

Figure 6. Areas that have water quality suitable for aquaculture According to weighed linear combination.

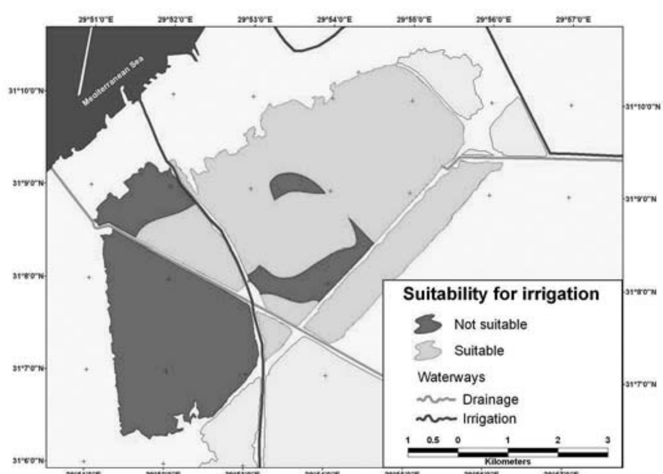


Also, it was found that water quality in 56.35% of the total area of Main Basin was suitable for aquaculture, while majority of the basin area (82.99%) had water quality suitable for irrigation activities.

However, those parts where water quality is not suitable for aquaculture activities were found to be primarily in Main Basin. This is mainly due to the deteriorated water quality in the basin as it receives, on a daily basis, about 200,000–300,000 m^3 of sewage and 400,000 m^3 of agricultural waste water mixed with sewage through West Treatment Plant and El Qallaa Drain, respectively. This is emphasized by the obvious spatial association between the distribution of those parts having water quality not suitable for aquaculture (Fig. 6) and the two sources of pollution (pollution outfalls) located in north eastern and northern parts of Main Basin (Fig. 1). Meanwhile, those parts that have water quality not suitable for irrigation are found mainly in Southwest Basin and in the western parts of Main Basin (Fig. 7).

It should be noted that despite many parts of the lake experiencing high concentrations of various variables, such as lead, chromium, and pH value, exceeding their recommended maximum concentration for aquaculture and irrigation activities, the implementation of weighed linear combination technique showed that water quality in a large portion of the three basins is suitable for aquaculture and irrigation. Actually, this is due to the nature of the weighed linear combination technique, which relies on an average weight of different variables involved in the assessment.

Figure 7. Areas that have water quality suitable for irrigation according to weighed linear combination.



This means that weighed linear combination technique is not appropriate in evaluating suitability based on threshold limits or recommended maximum levels where evaluation scales range between 0 and 1. Rather, such a technique is more appropriate in cases where degrees of suitability are intended to be identified based on a wider range of evaluation scale (e.g. 1 to 3 or 1 to 5… etc).

On the other hand, computer-assisted overlay technique identifies those areas that completely meet the applied criteria of analysis i.e. their variables are within the recommended maximum levels of all applied criteria. Consequently, computer-assisted technique is considered more appropriate where threshold limits or recommended maximum levels are used in suitability analysis, where evaluation scale ranges between 0 and 1. In such a case, each variable represents a limiting factor in the suitability analysis. Accordingly, computer-assisted overlay technique usually leads to more meaningful, reliable and reasonable results.

Conclusion

The developed GIS provided detailed information on various variables of water quality in three basins of the lake. Accordingly, the system was employed in conducting suitability analysis of water quality in different parts of the three basins for aquaculture and irrigation. Such a GIS is useful for future monitoring activities and support decisions concerning the management of natural resources in the Lake.

The suitability analysis, which covers three basins of the lake, namely Main Basin, Aquaculture Basin and Southwest Basin, employed two main techniques, namely computer-assisted overlay and weighed liner combination. The results of the suitability analysis identified those parts of the three basins that have water quality suitable for aquaculture and irrigation activities.

The implementation of the computer–assisted overlay and weighed linear combination showed different results. While the former showed that the water quality in most parts of the three basins is not suitable for aquaculture or irrigation, the later showed that water quality in large portion of the three basins is suitable for the two uses. Such a difference in the results of the two techniques can be attributed mainly to the nature of each technique.

However, it was found that computer-assisted overlay technique is more appropriate in those cases where threshold limits are relevant. This highlights the crucial role of the analyst in the success of suitability analysis in attaining meaningful as well as reliable results, through selecting an appropriate suitability analysis technique.

Those parts that were found to have water quality suitable for aquaculture and irrigation activities, according to weighed linear combination technique, refer to those parts that have a relatively (rather than absolute) improved water quality within the lake. Thus, water in these parts could not actually be used in these aquaculture or irrigation activities until several corrective measures are taken.

The most serious problem concerns the lead concentration in the water. Lead, in all parts of the lake, is higher than the recommended levels. Research in progress is determining the degree of bioaccumulation of this dangerous pollutant in fish in the lake.

The main source of the problem was El Qalla Drain with more than 400,000 m^3 of raw sewage discharged into the lake on daily basis. In this context, there is an urgent need to take action for rehabilitation and improvement of water quality in the lake to be suitable for some human uses.

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ECONOMIC VALUATION OF WETLAND ECOSYSTEM. CASE STUDY: LAKE MARYUIT, EGYPT

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Abstract: Lake Maryuit is one of the northern lakes in Egypt, located to the southwest of Alexandria city. The lake extends for 80 km along the North West coast of Alexandria and 30 km south and is divided into a number of basins by highways and railroads. It represents a very rich ecosystem providing a wide range of goods and services including for instance, fish in addition to other ecosystem services such as supporting wildlife habitat. However, the water quality in the lake has deteriorated considerably due to domestic and industrial wastewater being dumped in the lake on a daily basis as well as landfilling activities. This has led to considerable decline in the ecosystem functions of the lake and thus the goods and services produced.

This paper represents an effort first to review different ecosystem goods and services being produced by Lake Maryuit and then to estimate the economic value of the ecosystem goods produced by the lake in an attempt to show its real economic contribution. For that purpose a complete list of different ecosystem functions as well as the goods and services of the lake, was developed. The list included for example fish production and potential for developing recreational and tourism activities in the lake. Thereafter, the potential for employing different economic valuation techniques in an attempt to value such goods and services was assessed.

It was found, in this respect that the values of some of these services were quite difficult to estimate; for instance adjustments to the local climate of Alexandria city. Moreover, some valuation techniques were not applicable to the case of Lake Maryuit, for instance, travel-cost approach, as it requires that the site to be valued should be unique in that people would be travelling from different places to it so that a demand function for it could be derived, which is again not the case for lake Maryuit. Similarly, the hedonic-pricing method requires the presence of a free functioning market of real estates, and that records of these real estate values before and after pollution in the area (or alternatively in similar areas), that could thus be used as control cases, are available. Yet, none of these conditions were found to exist in the case of Lake Maryuit. It could be suggested, therefore, that this paper, in this context, could be seen as setting the basis for more comprehensive work on estimating the total economic value of the lake.

Furthermore, the paper in hand focused on estimating the value of environmental goods produced by the lake ecosystem, namely fish production. It was found in this respect that the total economic value of fish production from the lake, assuming 5%, and 10% discount rates, ranges between EGP 470,029,000 and 940,578,000. It is worth mentioning in this respect that these estimations undervalue the value of fish production from the lake, which could have been higher if optimum conditions in the lake, in terms of water quality and depth, were maintained.

Introduction

Wetlands are considered to be amongst the Earth's most productive ecosystems. They provide many, free of charge, yet valuable functions,

Felicita Scapini, Jean-Marc Boffa, Elisabeth Conrad, Louis F. Cassar and Mariella Nardi (editors), *Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socio-economic and environmental analysis of changes and trends to enhance and sustain stakeholder benefits*, ISBN 978-88-6453-015-4 (online)

including for instance, flood alleviation, groundwater recharge, retention of pollutants; products (such as fish, fuelwood, timber), rich sediments used for agriculture in the floodplains, tourist attractions and attributes like biodiversity, aesthetic beauty, cultural heritage and archaeology. They, accordingly, provide direct support to the livelihood of millions of people and provide goods and services to the world outside the wetland (Barbier *et al.*, 1997).

However, there still exist the view that wetlands are *wastelands,* resulting from ignorance or misunderstanding of the value of the goods and services available. This has led governments to perceive wetland potentials as only constituting alterations to the ecosystem, for intensive agriculture, industrial and/or residential uses. Furthermore, wetlands have been exposed to various forms of pressures including pollution, waste disposal and landfilling activities.

Economic value

Scarcity of resources, relative to human needs and wants, means that individuals have to make choices between different goods and services. Making such choices, for goods and services traded in the markets, is usually based on comparing their market prices with the satisfaction gained from their consumption. However, making choices concerning public goods, such as air and water, which are not traded in the marketplace and have no prices to guide choices, is rather difficult. In such cases, it is important to find ways for putting a value to these goods and services.

Generally, the total value of environmental goods and services is the sum of four sub-values including:

Direct value: is reflected in the market value of an environmental component (e.g. price of wood in the case of a forest).

Indirect value: reflects the functions performed by an environmental component and the indirect benefits that can be derived from it.

Optional value: is the value of reserving an environmental component for possible use in the future.

Existence value: the value of retaining an environmental component without any possible use in the present or the future.

The first three of the above values represent the use value of an environmental component, while the fourth represents the non-use value (see Table 1).

Use values are grouped according to whether they are *direct* or *indirect*; the former could involve both commercial and noncommercial activities, with some of the latter activities often being important for the subsistence needs of local populations in developing countries.

Regulatory ecological functions of wetlands may, meanwhile, have important indirect use values. For instance, storm protection may have indirect use value either in the form of savings in not having to construct man-made storm protection features or through reducing property damages.

Table 1. Classification of wetland economic value.

Total Economic Value			
Use values			Non-use values
Direct use value	Indirect use value	Option and Quasi-option value	Existence value
• Fish • Agriculture • Fuelwood • Recreation • Wildlife harvesting • Peat/energy	• Nutrient retention • Flood control • Storm protection • Groundwater recharge • External ecosystem support • Micro-climatic stabilisation • Shoreline stabilisation	• Potential future uses (as per direct and indirect uses) • Future value of information	• Biodiversity • Culture/heritage • Bequest values

Source: (Cited in Barbier *et.al.*, 1997).

Economic valuation is of tremendous importance in different contexts, for instance, appraisal of projects or programmes cannot be comprehensive or adequate without economic valuation of their environmental impacts. Also, setting national priorities for environmental policy is better informed if economic values of environmental resources impacts are known with some degree of certainty. Moreover, the entire objective of sustainable development could not be interpreted without some idea of the value of various environmental assets. This means that economic valuation can provide the potential for more cost-effective public choices, so that limited public funds can be spent to the community's best advantage.

In order to estimate the economic value of different environmental goods and services, economists have developed a number of valuation techniques. Each of these techniques has its advantages and disadvantages and cannot be employed generally to deal with every possible case (Pearce, 1993).

Economic valuation techniques

Economic valuation means simply eliciting measures of human preferences for or against changes in environmental conditions. It represents an essential step in incorporating environmental considerations into economic work. Wetland valuation means the quantification of the economic value of use of the wetland components, functions and attributes.

In this respect, there are a number of approaches that can be employed for economic valuation purposes, which can be laid in one of four categories, namely, direct and indirect observed approaches, and direct and indirect hypothetical approaches. Observed approaches involve the direct or indirect estimation of value from observations of market behavior, with the former including market valuation of physical effects, while the latter include travel cost, hedonic pricing, avoidance expenditures. Hypothetical approaches base their direct or indirect estimation of value, meanwhile, on responses to hypothetical valuation questions. The essence of these approaches as well as their applicability to the case of Lake Maryuit is discussed in the remaining part of this section.

a. Market valuation of physical effects (MVPE)

The most straightforward way of valuing an environmental resource or for that matter an environmental change in the value of that resource is to employ market valuation .i.e. prices. However, where the effect is on such a scale that can affect prices, an attempt should be made to predict the new price level. The use of actual prices would also be misleading if markets were seriously distorted by monopoly, price controls, protection, etc. In principle, where price changes occur, effects of on consumers' surplus should also be allowed for (Winpenny, 1991). Still, it could be suggested that MVPE is the most widely used and intelligible valuation technique, as it appeals to intuition and common sense and is easy to explain and justify (EDIWB, 1995).

Within the MVPE category, several techniques are available including:

Dose-response approach: which estimates the physical impact of an environmental change on a receptor, such as air pollution on material corossion, acid rain on crop yield (EDIWB, 1995).

Production function approach: according to this approach, environmental 'inputs' such as soil fertility and air and water quality can be related through econometric techiques to output, showing how output varies with changes in the various kinds of input.

Replacement cost method: it estimates the cost of environmental damage by using the costs which the injured parties incur in putting the harm right.

The MVPE could be employed, which is the case in this paper, to estimate the value of wetland goods traded in the market .e.g. fish production as well as plants used either as fuelwood or as animal fodder.

b. Hedonic Methods

Hedonic pricing methods are based upon the assumption that goods and services, including environmental ones, are usually defined in terms of their attributes. This means that the values of these goods and services are the sum of the values of the attributes which they contain (Day, 2001; Freeman, 1993). The hedonic pricing, in this respect, could be employed to assess the change in environmental attributes of real estate located around or nearby the lake. It is expected that their values have diminished due to lake pollution. However, this method requires the presence of a free functioning market of real estates, and that records of these real estate values before and after pollution in the area (or alternatively in similar areas), that could thus be used as control cases, are available. Yet, none of these conditions were found to exist in the case of Lake Maryuit.

c. Travel Cost Method

The Travel Cost method (TCM) depends on information about the amount of money and time people spend getting to a site to infer a value for that site. Although TC can in theory be used to value almost any non-market good or service, in practice, however, it is only used for the valuation of recreational sites such as parks and beaches. It can also be used to value changes in environmental quality at recreational sites, such as wetlands, such as changes in water and air quality (Boardman and Weimer, 1996; Dixon *et al.*, 1994). The site to be valued should be unique in that people would be traveling from different places to it so that a demand function for it could be derived, which is again not the case for Lake Maryuit.

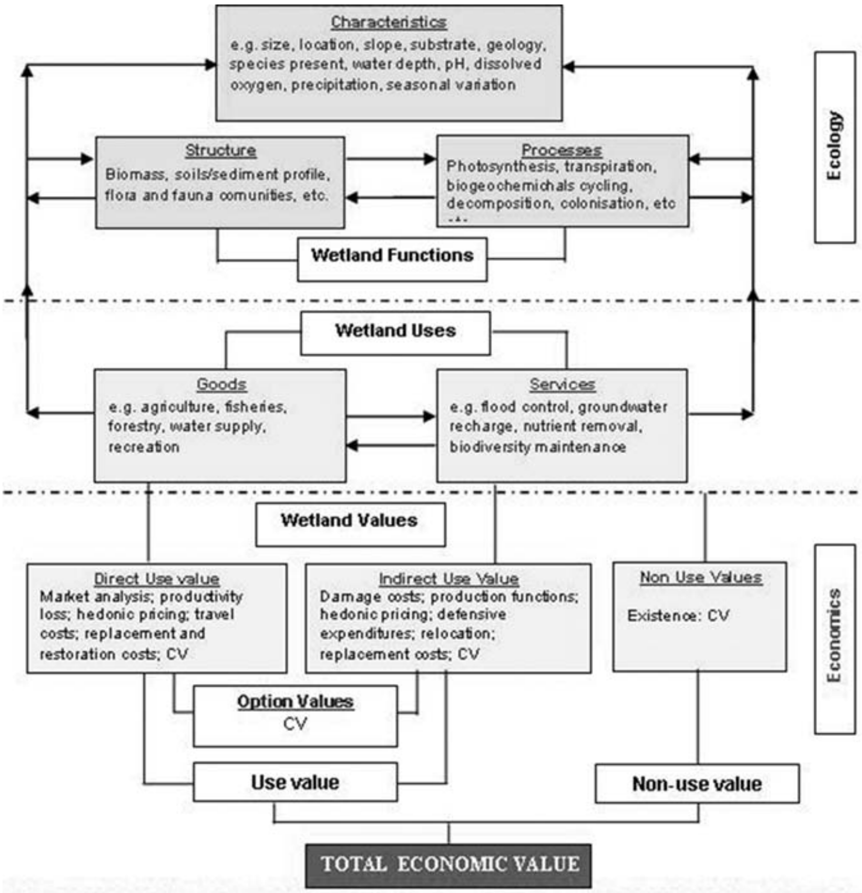
d. Contingent Valuation Method

The Contingent Valuation Method (CVM) is used to obtain values for non-market goods or services. It is a survey technique that attempts to elicit information about individuals' (or households') preferences for a good or service by asking a question or a series of questions about how much they value a good or service.

Using CVM involves three steps: a) designing and conducting a CV survey to elicit individuals' values for a good or service, b) analysis of Willingness to Pay (WTP) responses, and c) estimation of overall benefits or costs associated with existing conditions.

The most important concern when employing CVM is the high risk of receiving biased answers. Such potential bias includes: a) strategic bias, b) information bias, c) starting point bias, and d) hypothetical bias (Mitchell and Carson, 1989). The CVM approach could be employed to value the recreational value of the lake through a hypothetical scenario.

Figure 1. Coastal areas ecosystem dynamics and economic valuation of environmental goods and services. Source: Turner, 2000.



Case study

Study area description

Lake Maryuit, located in the north western coast of Egypt, extends for about 20 km between 31° 01 ′48″ and 31° 10′ 30″ North and 29° 49 ′48″ and 29° 57 ′00″ East. The lake is divided into four basins; namely, Main Basin, Aquaculture Basin, Northwest Basin, and Southwest Basin main basins (Fig. 2).

Economic value of fishing activities

In general, fishing is one the most dominant economic activities in the lake. The fisheries of Lake Maryuit were characterized, historically, by large fish production in terms of quantity and quality. There are, also aquaculture operations which occupy wide areas of the lake.

According to recent statistics, there are 2,073 fishing boats in the lake and 20,000 fishermen. Taking into consideration that the average family size is 4–5 persons, this means that about 100,000 inhabitants rely on fishing activities in the lake to earn their livelihood.

The deteriorating conditions in the lake could be attributed to a number of factors:

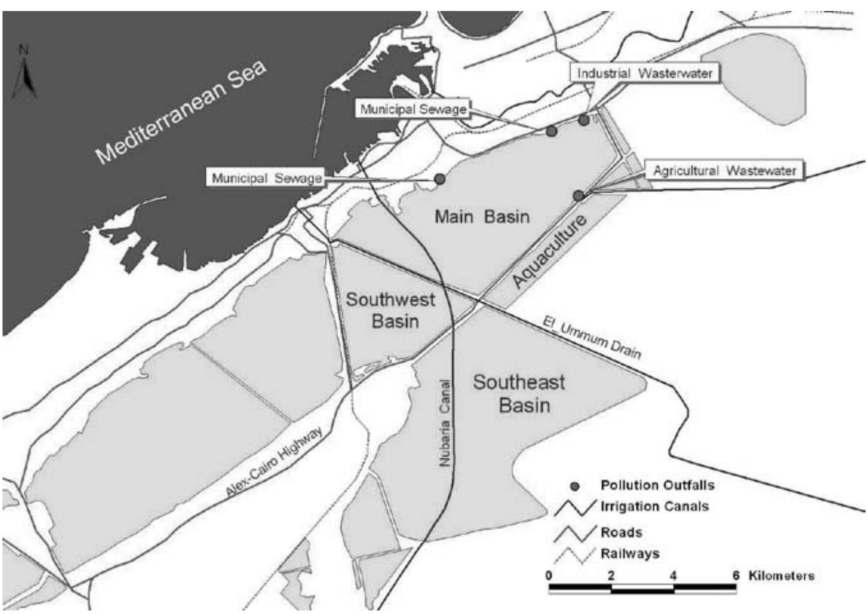
Low water level, enforced by the Ministry of Public Works and Irrigation, in order to use the lake as a contingency dumping place in case of irrigation water flooding in the vicinity.

Alexandria Municipal Wastewater Authority is dumping more than 300,000 m^3 of untreated municipal and irrigation wastewater, through El Qallah drain, in the main basin of the lake daily (Fig. 2).

Uncontrolled dumping of industrial wastewater located to the north of the lake.

Landfilling activities either illegally by individuals or by the Governorate or other Ministries, e.g. the Ministry of Housing and new communities, which landfilled parts of the lake to construct the international coastal road.

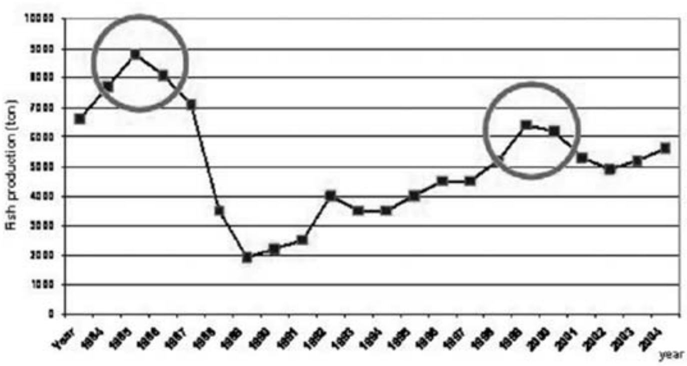
Figure 2. Lake subsections and pollution outfalls.



Concerning fish production from the lake, it has experienced considerable variation over the past two decades, i.e. since domestic wastewater, and afterwards illegal industrial wastwater, began being disposed of directly in the lake (Fig. 3). The lack began to display severe signs of environmental degradation including for instance; lack of oxygen, discolouration and algal blooms (EEA, 2006).

Fish production have reached a peak on two occasions, the first in 1986, where fish was trapped by pollution and in its attempt to avoid pollution was easily caught by fishermen. The second was in 1999-2000, when some low cost measures were taken to divert domestic wastewater from coming into the main basin. However, these measures were abandoned halfway due to conflicts between different governmental bodies and thus production started to decline again. In addition to the effects on quantities of fish caught, the quality of fish was also deteriorating as it became contaminated with various pollutants, the most serious of which are heavy metals (for more details see for example EEA, 2006; Saad, 2003).

Figure 3. Fish production (1984 – 2004). Source: Source: Fishery Resources Public Authority.



Market value of fish from the Lake

According to the market price of fish in 2005, the average price for a ton of fish was about L.E. 7500. The total market value of the fish production from Lake Maryuit in 2005 is about L.E. 42 million. This measn that the average annual value of fish production per acre is equal to L.E. 2545.

Market value of fish = Average price X Quantity = 7,500 X 5,600;
Total Market Value = L.E. 42,000,000;
Average annual value of fish production per acre = L.E. 2545.

Concerning the decline in lake area due to landfilling activities that took place between 1984 and 2002, it was estimated to be about 800 acres (Hassaan, in press). Additionally, some 1176 Acres are threatened to be dried up and lost as they were totally cut off from the lake system by the establishment of new roads crossing the lake body. This means a total loss of about 1976 Acres of the lake and consequently the loss of annual fish production, due to area decline, is estimated to be about L.E. 5,028,920.

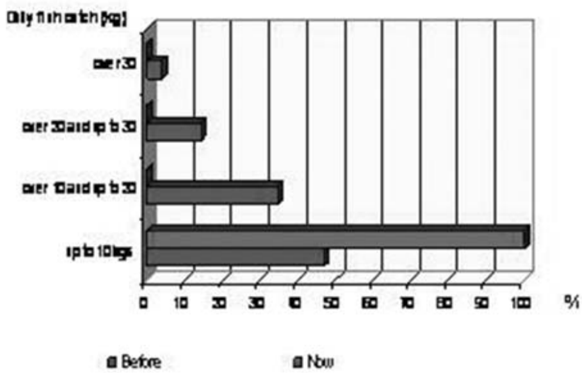
Lost annual fish production due to area decline = A X B
o Where:
A = Average annual value of fish production per Acre
B = Lost area between 1984 and 2002

Lost annual fish production due to area decline =

L.E. 2545 X 1976 Acre = L.E. 5,028,920

Such a decline in fish production was of concern to fishermen, in a survey conducted in 2007, who suggested that the average daily fish catch in the past ranged between 10 and 30 kg. Average daily catch nowadays, again as stated by the fishermen, did not exceed 10 kg despite the extra efforts they had to put into fishing.

Figure 4. Change in fish catch. Source: Field survey.



The total economic value of fish production from the lake, based on the above estimates, and assuming 5%, 7.5% and 10% discount rates, equals to EGP 84,000,000; 56,000,000; and 420,000,000, respectively. The present value of the foregone fish production due to landfilling and drying activities, assuming again 5%, 7.5% and 10% discount rates, equals EGP 100,580,000; 67,040,000 and 50,290,000, respectively. This means that the total economic value of returns on fish production, including lost production due to landfilling and drying activities, range between EGP

470,029,000 and 940,578,000. It is worth mentioning in this respect that these estimations undervalue the fish production from the lake, which could have been higher if optimum conditions in the lake, in terms of water quality and depth, were maintained.

The decline in fish production, as a primary result of pollution and landfilling, has had secondary impacts in the form of lost jobs both of fishermen and of those working in the supporting sector, e.g. marketing and boat maintenance, with consequent impacts on their households' livelihood. The fishermen and associated workers may be seen as vulnerable groups that have high illiteracy rate low skills to be able to seek other jobs. They also have no social security or health insurance. In order to assess the socioeconomic conditions in Lake Maryuit, a wide range of data was collected through a survey conducted in 2007. A preliminary questionnaire form was developed and used in conducting a pilot survey covering a relatively limited number of cases in the area of Lake Maryuit and its surroundings.

According to the socioeconomic survey conducted in 2007, as many as half of the fishermen's children drop-out from the education system as they can not afford schooling costs and/or support their families by working in the informal sector.

Conclusion

It was found, in this respect that the values of some of these services were quite difficult to estimate; for instance adjustments to the local climate of Alexandria city. Moreover, some valuation techniques were not applicable to the case of Lake Maryuit, for instance, travel-cost approach, as it requires that the site to be valued should be unique in that people would be travelling from different places to it so that a demand function for it could be derived, which is again not the case for lake Maryuit. Similarly, the hedonic-pricing method requires the presence of a free functioning market of real estates, and that records of these real estate values before and after pollution in the area (or alternatively in similar areas), that could thus be used as control cases, are available. Yet, none of these conditions were found to exist in the case of Lake Maryuit. It could be suggested, therefore, that this paper, in this context, could be seen as setting the basis for more comprehensive work on estimating the total economic value of the lake.

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ECONOMIC VALUATION OF LAKE MARYUIT FUNCTION AS DETERRENT TO URBAN EXPANSION IN ALEXANDRIA, EGYPT

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Abstract: Lake Maryuit is one of the Northern lakes in Egypt, located to the southwest of Alexandria city. The lake extends for 80 Km along the North western coast of Alexandria and 30 km south and is divided into a number of basins by highways and railroads. The location of the lake, as is, may have acted as a deterrent to expansion of the city of Alexandria in the direction of the latter and thus protected agricultural land from urban encroachment.
This paper attempts to estimate the economic value of the lake being a deterrent to urban expansion in its vicinity. The expansion of built-up area of Alexandria city in general over the period between 1972 and 2002 was monitored using three LANDSAT satellite images of the Alexandria area. This finding is then used to estimate the urban expansion of the city and possible determinants including for instance accessibility, population growth, etc. Urban expansion is then assessed in the lake vicinity assuming that the lake did not exist. The economic value of urban encroachment in this area is then assessed using a production function technique.
It was found that urban expansion in the vicinity of the lake, despite its relative proximity to city centre, has been constrained by the presence of the lake. It could be suggested that the presence of the lake has assisted in saving considerable agricultural area in its vicinity from urban encroachment. Nevertheless, assuming that the did lake did not exist, an estimated area of about 6.44 Km^2, or about 1,465 feddans (1,533 acres) could have been encroached upon by urban expansion. The market value of this area, assuming a price per feddan of EGP 100,000 is estimated at EGP 147 million. This value does not include the value of the lake area itself, but rather its function as a barrier to urban expansion.

1. Introduction

It is typically argued that a major reason for excessive depletion and conversion of wetland resources is often the failure to account adequately for their non-market environmental values in development decisions. Thus by providing a means for measuring and comparing the various benefits of wetlands, economic valuation can be a powerful tool to aid and improve wise use and management of global wetland resources.

1.1. Economic valuation of the environment

Making choices between different goods and services that are traded in markets is usually based on the comparison of their market prices with

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the satisfaction gained from their consumption. However, making choices concerning public goods, such as air and water, which are not traded in the marketplace and have no prices to guide choices, is rather difficult. In such cases, it is important to find ways of assigning a value to these goods and services that can reflect their use and non-use values.

Generally, the total value of environmental goods and services is the sum of four sub-values including the use and non-use values, the former encompasing their direct, indirect and optional values (for more details see Pearce, 1993; Freeman, 1993; EDIWB, 1995).

For the purpose of estimating such economic values of different environmental goods and services, economists have developed a number of valuation techniques. Each of these techniques has its advantages and disadvantages and cannot be employed generally to deal with every possible case (Pearce, 1993). Such economic valuation represents an essential step in incorporating environmental considerations into economic work.

Economic valuation means simply eliciting measures of human preferences for or against changes in environmental conditions. Economic valuation of wetlands, in this respect, means the quantification of the economic value of use of wetland components, functions and attributes.

Four categories of approaches can be employed for economic valuation purposes, namely, direct and indirect observed approaches, and direct and indirect hypothetical approaches. Observed approaches involve the direct or indirect estimation of value from observations of market behavior, with the former including Market Valuation of Physical Effects (MVPE), and the latter including travel cost, hedonic pricing, avoidance expenditures. Hypothetical approaches base their direct or indirect estimation of value, meanwhile, on responses to hypothetical valuation questions.

The MVPE market valuation employed in this paper, values an environmental change, or what would prevent such change from occurring, using market prices, including consumers' surplus (Winpenny, 1991). Nevertheless, it is worth mentioning that where the effect of such change can be sufficiently large to affect market prices, an attempt should be made to predict the new price level. Moreover, the use of actual prices would also be misleading if markets were seriously distorted by monopoly, price controls, protection, etc. Still, it could be suggested that MVPE is the most widely used and intelligible valuation technique, as it appeals to intuition and common sense and is easy to explain and justify (EDIWB, 1995).

1.2. Driving forces of urban expansion

Generally a wide range of factors such as economic and infrastructure development, and industrial structures contribute to urban expansion (Zhao-ling *et al.*, 2007). Similarly, it is argued that urban expansion is governed by geographical and socioeconomic factors, such as population growth, migration patterns and spillovers from densely populated areas (Xiao *et al.*, 2006).

For a specific location in an urban area, there are additional factors underlying its expansion potential including for instance, site characteristics, accessibility to various parts of the urban area, etc. The recognition of these factors and mechanisms in such an urban area can assist in predicting future trends of urban expansion and consequently, contribute to better urban management practices.

The contribution of these socioeconomic factors to the expansion of an urban area can be examined and quantified by analyzing the relationships between changes in the urban area and such factors at different points in time.

1.3. Urban expansion monitoring techniques

Remote sensing and Geographical Information System (GIS) are widely applied to monitor urban expansion and simulating dynamic urban change (Zhao-ling *et al.*, 2007). Remote sensing generally provides an efficient tool to monitor changes in the area of interest over time using time series satellite data (Tachizuka *et al.*, 2002). Accordingly, it is common to utilize remote sensing techniques for monitoring changes in urban areas and providing insights into the extent, trends and nature of these changes.

GIS provide a systematic approach and tools to collect, update, process, analyze and display of land-related data quantitatively.

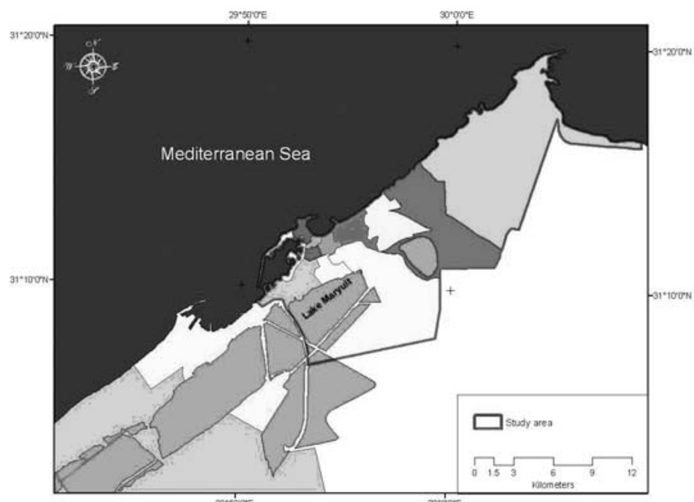
2. Study area

The Alexandria governorate has experienced considerable population increase over the past three decades from 2,317,700 to 3,821,209 inhabitants between 1976 and 2006 (CAPMS 1978 and 2008). This is an increase of about 1,503,509 inhabitants, representing 64.9% of its 1976 population. The spatial distribution of the population is rather uneven between the districts of Alexandria, with inner districts, especially Wassat and Gmorouk districts, reaching their saturation levels and becoming sources of outmigrating population. The more peripheral districts, such as Montazah, Sharrk and Ameryiah districts act more as sink areas for those moving out from the former districts (Fig. 1).

Lake Maryuit is one of the northern Egyptian lakes, located in the north western coast of Egypt. The lake extends for 80 Km along the North western coast of Alexandria and 30 km south and is divided into a number of basins by highways and railroads. In contrast to other lakes in northern Egypt, Lake Maryuit is a closed lake with no connection to the sea. The average depth of the lake ranges between 0.55 m and 1.2 m. The level of water surface is 3 m under the average sea level (El-Sharkawi, 1999).

The main objective of this paper is to estimate the economic value of the lake being a deterrent to urban expansion encroaching on agricultural land located to the south of the lake using the market valuation of physical effects approach. For this purpose, assessment of the magnitude of urban expansion in Alexandria, over the periods 1972-1984 and 1984-2002, is undertaken using remote sensing techniques. A linear regression is used to model urban expansion and study the driving forces behind it. Population and spatial changes from 1972 and 2002 are taken as dependent variables and accessibility to the city centre, the area and population of adjacent development to such expansion as independent variables. Then, the derived regression equation is applied to the vicinity of the Lake to assess the agricultural land area that could have been lost if the Lake was not in its place.

Figure 1. Administrative sections of Alexandria city and study area.



3. Methodology

3.1. Detection of urban expansion

To monitor expansion of the built-up area of Alexandria city during the period of 1972 to 2002, three LANDSAT satellite images for Alexandria were used. The first was a MSS image with a spatial resolution of 57 meter dated 19/09/1972, the second was a TM image with a spatial resolution of 28.50 meter dated 11/09/1984, and the third was an ETM+ image with a spatial resolution of 14.25 meter dated 17/06/2002. Moreover, ancillary data such as topographic map scale 1:50,000 for the city, was also used. The three images had previously been rectified to a common UTM (Universal Transverse Mercator) coordinate system. Using Erdas Imagine 9.1, they were first enhanced through histogram-equalized stretch to increase the volume of visible information.

The three images were acquired through different sensors and have different spatial and spectral resolutions. Therefore it was thought that the post- classification technique would be the most appropriate technique, in which each image is independently classified, in a same manner, with a maximum likelihood algorithm. During the classification process, a large number of training areas (classes) were initially generated in each image. Classes with spectral similarities were aggregated to represent a land cover.

As the main interest is to detect the expansion experienced in the urban area and due to the prevailing patterns of land covers and land uses, it was decided to classify the images into three land cover types including water bodies, cultivated land and wet vegetation[1], and urbanized area including built-up area and vacant urban land.

In order to quantify the reliability of the classified images, an accuracy assessment was performed consisting in comparing 400 ground truth points with the produced classified images. The assessment of classification revealed an overall classification accuracy exceeding 95%[2].

Using ArcGIS 9.2, the classified images were thereafter used to extract vector layers representing the built-up area of Alexandria city over time (Fig. 2). The resulting thematic maps were manipulated in order to analyze changes in the city area over time. For example, to identify the expanded built-up area in each administrative section of the city, the produced vector layers of the built-up area were overlaid (Overlay intersect function) with other vector layers representing the administrative sections of the city. Accordingly, a new vector layer was generated illustrating the extent and size of built-up area of each administrative section in 1972, 1984 and 2002.

During 1972-2002, urban expansion in Alexandria city amounted to 29.76 Km^2. The various administrative sections of the study area did not expand equally in temporal and spatial scales. Spatially, the old inner section of the city such as El Attareen, El Laban, El Manshia and El Gomrok did not

[1] As significant parts of Lake Maryuit are covered by vegetation masses, which have similar spectral behavior of cultivated land, it was decided to agglomerate the two land cover types into one class.

[2] The overall classification accuracy was 95.50% for MSS images of 1972 and TM images of 1984 and 95.25% for ETM+ image of 2002.

experience any expansion during the 1972-2002 period. Other sections, which have a rural fringe, experienced considerable expansion at rates ranging from 2.12% to 49.89% during the 1972-1984 period and from 1% to 28.10% during the subsequent 1984-2002 period. Temporally, changes in sections which experienced expansion of their built up area varied in a similar manner to spatial changes in the two periods. For instance, the built-up area of Sedi Gaber section expanded rapidly (49.89%) during the 1972-1984 period; thereafter, its expansion slowed down (9.75%) in the subsequent 1984-2002 period. The only exception was the case of Montazah section which maintained high rates of expansion in the two periods (Table 1).

Table 1. Changes of built-up area of sections of Alexandria city between 1972 and 2002.

Section	Area km²			Change 1972-1984		Change 1984-2002	
	1972	1984	2002	km²	%	km²	Change %
Alexandria harbour	3.03	3.03	3.03	0.00	0.00	0.00	0.00
Bab Shark	5.18	5.29	5.59	0.11	2.12	0.30	5.65
El Attareen	1.89	1.89	1.89	0.00	0.00	0.00	0.00
El Laban	1.14	1.14	1.14	0.00	0.00	0.00	0.00
El Manshia	0.68	0.68	0.68	0.00	0.00	0.00	0.00
El Raml (I and II)*	12.99	16.20	18.79	3.21	24.68	2.57	15.96
Gomrok	1.62	1.62	1.62	0.00	0.00	0.00	0.00
Karmouz	3.31	3.42	3.45	0.11	3.20	0.03	0.92
Mena El Basal	7.00	7.61	7.81	0.60	8.63	0.21	2.70
Moharam Bek	10.51	13.22	15.42	2.71	25.82	2.20	16.64
Montazah	23.59	29.32	37.55	5.73	24.28	8.22	28.10
Sedi Gaber	5.83	8.74	9.59	2.91	49.89	0.85	9.75
Total	76.77	92.15	106.56	15.38	20.03	14.38	15.64

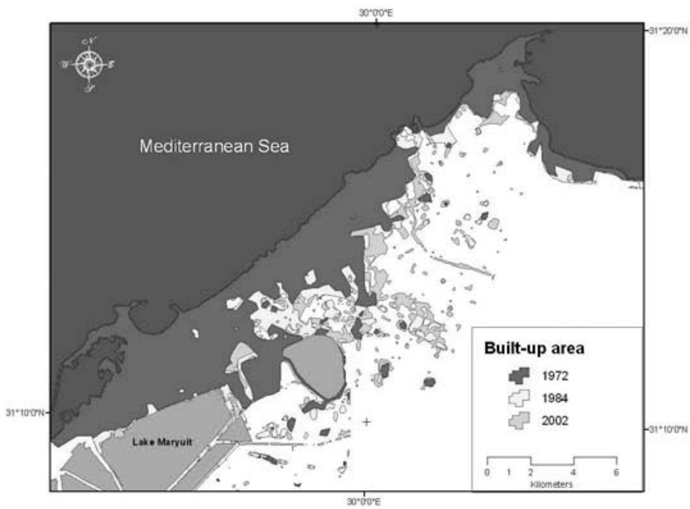
Also, in order to extract the expanding areas during each period 1972-1984 and 1984-2002, both vector layers of the built-up area in the two subsequent periods were overlaid (Overlay erase function). Such a process produced two vector layers representing the changes in built-up area of the city during the periods 1972-1984 and 1984-2002.

Further spatial analysis was carried out to examine the impact of accessibility on study area expansion expressed as distance to city center. Therefore, there was a need to identify the expansion of built-up area in different sections of the study area as a function of the distance from the city center[3]. For this purpose, a multiple buffer zone was created around

[3] It was decided to take the distance from study area as an indicator to the accessibility.

the city center with 1 Km distance interval in a new layer. The created buffer zone layer was first overlaid (Overlay intersect function) on top of each of the two vector layers representing those areas that are added to the built-up area of the city during the 1972-1984 and 1984-2002 periods. This finally produced two vector layers for the expanding areas, in which each parcel of land was characterized by data on its distance from the city center and the administrative section to which it belongs. Secondly, the buffer zone layer, was also overlaid with the vector layer of the lake to produce a new vector layer of various parts of the lake subdivided into zones according to distance to city center.

Figure 2. Urban expansion in Alexandria between 1972,1984 and 2002.



The created vector layers were used to extract quantitative data about changes in built-up area of different sections of the study area during the 1972–1984 and 1984–2002 periods, and the distance between the expanding area and city center as an indicator of accessibility of those expanding areas.

The derived size of the expanding areas in Alexandria city was then regressed against distance from city centre, area of adjacent section and population in adjacent section.

4. *Results*

4.1. *Economic valuation of protected agricultural land*

Table 2 shows the results of the Ordinary Least Squares OLS linear model statistical analysis of urban expansion in Alexandria city. According to this analysis distance to the city centre and area of adjacent section varied as expected and were significant at 5% and 1% significance levels. The population size in adjacent area was, meanwhile, found to be insignificant (Table 2).

The regression equation is:

$$E = 1.69 - 0.0644\ D + 0.108\ A - 0.000008\ P$$

Where:

E: Expanding area by section (m^2)
D: Distance from that section to the city centre
A: Area of the adjacent section
P: Population size of that section

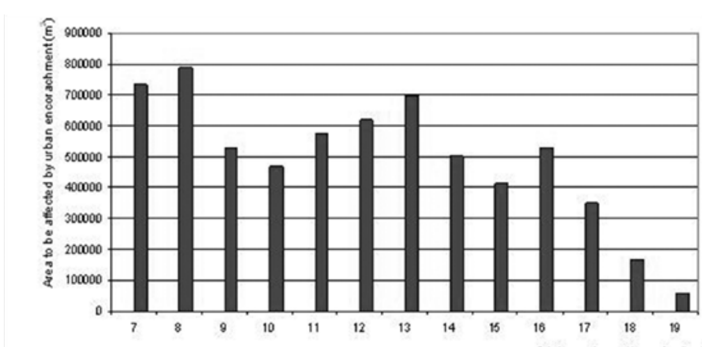
Table 2. Statistical analysis of the OLS linear model of urban expansion in Alexandria city.

R-Sq 68.8%	
R-Sq (adj.) 63.9%	
Variable:	
Intercept	1.6934 (0.7601)★★
Distance to city centre (km)	-0.06436 (0.02714)★★
Area of adjacent section (km^2)	0.10775 (0.03699)★
Population size of adjacent section	-832×10^{-8} (432×10^{-8})

Standard error is reported in parenthesis.
★ Significant at 1% significance level.
★★ Significant at 5% significance level.

The estimated regression equation is then used to project urban expansion in the vicinity of Lake Maryuit, over the same duration, assuming that the Lake did not exist. In this scenario, the total expansion area that would have been encroached on, in the lake vicinity is 7.3 km^2. It could be argued that such an impact is magnified by the fact that all parts of the lake are located within a range of 3 - 19 Km from city centre.

Figure 3. Estimated urban expansion experienced during the 1972-2002 period in Alexandria city at different distances from the city centre.



Using the same regression equation and hypothesizing that the lake was not present in the agricultural land area located behind the lake beyond a distance of 6 km from the city centre (as appearing on the satellite images), the area that would have been encroached by urban expansion equals 6.44 km^2, or about 1465 feddans (1533 acres) (Fig. 3). The market value of this area, assuming a price per feddan of EGP 100,000, is estimated at EGP 147 million. It is worth mentioning that this value does not include the value of the lake area itself, but rather its function as a barrier to urban expansion.

5. Discussion

Lake Maryuit, in its present location may have acted as a deterrent to westward expansion of the city of Alexandria and thus protected agricultural land from urban encroachment. Therefore, the potential for urban expansion in the direction of the lake was assessed. It was found that urban expansion in the vicinity of the lake, despite its relative proximity to city centre, has been constrained by the presence of the lake. It could be suggested that the presence of the lake has assisted in saving considerable agricultural area in its vicinity from urban encroachment. Nevertheless, it is estimated, assuming that the did lake did not exist, an area of about 6.44 km^2, which is about 1465 Feddans (1533 Acres) could have been encroached upon by urban expansion. The market value of this area, assuming a price per Feddan of EGP 100000, is estimated to be about EGP 147 million. It is worth mentioning that this value does not include the value of the lake area itself, but rather its function as a barrier to urban expansion.

This paper is based upon a rough estimate of urban expansion experience in Alexandria, and is considered to be a reasonable means to assess urban expansion pressures in the lake direction. Yet, further indepth study of the economic and socioeconomic factors influencing urban expansion in terms of magnitude, nature and directions is needed to provide a more accurate assessment. Such an analysis would require the inclusion of other factors such as the improvement of infrastructure and city function, the promotion of industrial technology, and the increase of service industry.

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THE PORTUGUESE STUDY SITE

MONDEGO CATCHMENT GOODS AND SERVICES ASSESSMENT UNDER THE MILLENNIUM ECOSYSTEM ASSESSMENT SCOPE

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Abstract: The Millennium Ecosystem Assessment (MA) approach was applied to the Mondego Basin (Portugal), to evaluate the interrelationships between ecosystem services and the socio-economic condition of communities at multiple scales, ranging from a localized part to the whole basin. This document first characterises the main uses and benefits of the Mondego Basin for which ecological and economic values can be estimated either directly or indirectly. It then identifies a subset of the main pressures and impacts that contribute to the development and maintenance of these benefits. This evaluation was conducted to appropriately relate the ecological status and the human wellbeing in the Mondego wetlands. The conditions and trends for the services under study (food production, water resources, recreation and biodiversity), over the period of 1992 to 2006, were analysed across three spatial scales. Overall, it is possible to observe a general decline of food production, and simultaneously higher anthropogenic pressures and impacts, resulting from an increase in the number of local residents and tourists visiting the area. Concurrently, there was a constant improvement of the water quality and biodiversity assets (the latter was included in the assessment, despite not being considered an ecosystem service, since it provides the basis for all considered services and goods). The main goal of this analysis was to integrate the evaluation of ecosystem assets from both an ecological and economic perspective. In addition, the inventory, assessment, and valuation of products obtained from and transferred to the system were carried out.

1. Introduction

1.1. The Millennium Ecosystem Assessment vs Ecosystem goods and services

According to Turner *et al.* (2000), the resilience, maintenance and/or enhancement of a system are linked to the ecological concept of its functional diversity and the social science analogue, functional diversity value. The latter concept combines ecosystem structure, processes and functions with outputs of goods and services, to which monetary, economic, and/or other values can then be assigned. A management strategy based on the sustainable use of ecosystems should have at its core the objective of ecosystem integrity maintenance, i.e., the maintenance of system components, interactions among them ('functioning'), and the resulting behaviour or dynamic of the system. Furthermore, ecosystem services exhibit the two characteristics or properties of economic commodities (Beaumont *et al.*, 2006):

Felicita Scapini, Jean-Marc Boffa, Elisabeth Conrad, Louis F. Cassar and Mariella Nardi (editors), *Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socio-economic and environmental analysis of changes and trends to enhance and sustain stakeholder benefits*, ISBN 978-88-6453-015-4 (online)

i) their consumption increases human utility;
ii) they are scarce as natural resources and funds to preserve them are limited.

Ecosystems are made up of many components, for example, soil, water (lakes, rivers, and ponds), vegetation (prairies, forests), and animals (wildlife). Man-made ecosystems include urban and industrial centres and agricultural systems. Wetlands have been poorly valued, and hence their loss was perceived as a minor cost compared to expected benefits from wetland development projects (Seyam *et al.*, 2001). To manage an ecosystem it is implicit that the interrelationships that exist between various components of the system are understood. For instance, the management of one part of the system (such as the diversion of water for irrigation) will affect other parts of the system (for example the highly nutrient-enriched runoff from surrounding fields). This interdependency is also visible in upstream-downstream effects in basin wetlands. There are two main problems when assessing ecosystem goods and services (Heal & Kristrom, 2005): i) the scale at which certain functions become important is not always the same; and ii) problems may arise when integrating and aggregating all scales of information, where interrelations and feedback loops may operate at scales above the level being assessed. Nevertheless, according to Limburg *et al.* (2002) the definition and quantification of scaling rules that attempt to describe the provision and delivery of ecosystem services still need research.

Assuming these premises, and having as the main target the maximum but sustainable achievement of human wellbeing, the Millennium Ecosystem Assessment (MA) developed a standard framework which intended to characterise and evaluate the ecosystems conditions and trends related to patterns of life of populations and communities. The MA is a United Nations proposal focusing not only on how changes in ecosystem services affect human wellbeing, but also on how ecosystem changes may affect people in future decades. It also considers response options that might be adopted at local, regional, or global scales to improve ecosystem management and thereby contribute to human wellbeing and poverty alleviation. In order to be able to deal with this complex network of interrelations and their changes, as well as consequences at local and global levels, a decision-maker needs to develop a good knowledge of the ecosystem's structure and the extent to which different components can be exploited without risking the loss of the ecosystem's functional integrity.

The importance or value of ecosystems can be roughly divided into three types: ecological, socio-cultural and economic. A service that may hold a certain economic value for people may present a completely different ecological value in terms of ecosystem integrity, making its ecological value discordant with its economical or socio-cultural value (MA, 2005). Every human activity has an impact on the environment, either positive or negative. However, the prices of goods transacted in markets tend not to include environmental costs and benefits, for instance the pollution costs of production. Where the market price fails to take into account such costs and benefits they are termed 'externalities' (Connelly & Smith, 2003). As so, every policy choice, and the benefits and costs associated with it, imply changes in environmental quality or the level of ecosystems services, and the valuation exercise is needed to quantify those variations (Heal & Kristrom, 2005). Moreover, it should be highlighted that ecosystem services and goods concept is inherently anthropocentric. Based on this, according to Beaumont *et al.* (2006), there are two distinct approaches to work with the ecosystem services concept. Among economists, economic valuation methods which focus on the exchange value of ecosystem services (based on consumer preferences and cost-benefit analysis) prevail. On the other hand, ecological valuation methods (with a sustainability perspective), mainly advocated by natural scientists and ecologists, derive ecological prices for ecosystem services through a cost-of-production approach (modelling the interrelations between the biotic and abiotic components of a system). According to Costanza *et al.* (1997), both fields take into account concerns regarding the economy of scale, distribution and efficient allocation of resources.

1.2. The Mondego Basin

A large amount of information is already available on the physical structure and functioning of the Mondego Basin in the literature (Flindt *et al.*, 2007; Marques *et al.*, 1997; 2003; Graça *et al.*, 2002; Feio *et al.*, 2007). Many studies are focused on the biotic integrity of macroinvertebrate communities, as well as water quality, mainly with regards to the implementation scope of the Water Framework Directive (WFD) (EC, 2000). The Mondego Basin has a high overall natural variability of environmental and social conditions. In the inner part of the basin wood industries play a crucial role for local communities. As one moves towards the coastal region, other types of industries predominate, especially those related to paper production, aquaculture, and fisheries. These variations influence the system's management, water uses, and land occupation rates. Nevertheless, knowledge of interactions within and between socio-economic activities taking place in the area and the natural environment, as well as its temporal and spatial variability, is more limited.

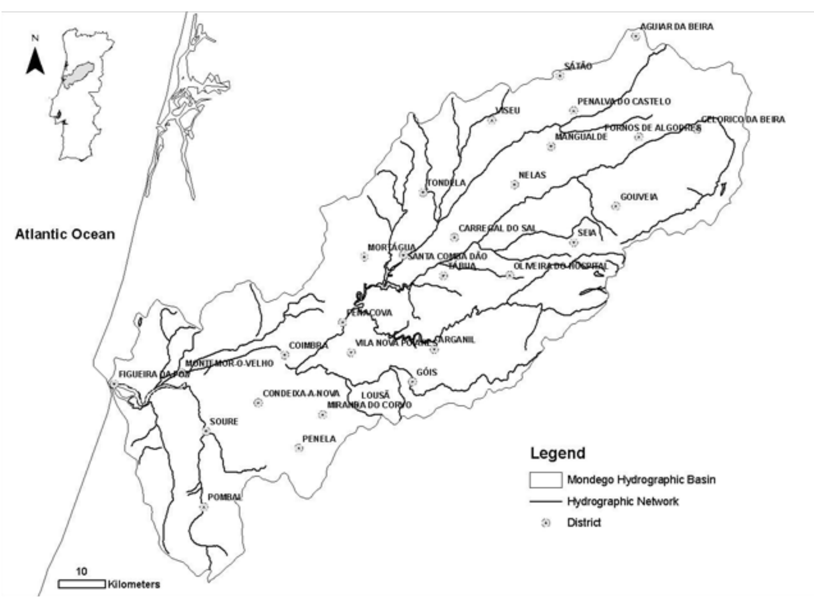
1.3. Study objectives

This work aims to provide an integrated view of both the economic and ecological approaches (as proposed by Beaumont *et al.*, 2006), providing an insight to the economic perspective within the ecosystem components in a balanced approach. The paper explores overlapping interactions among ecosystem services and the main drivers of change, namely land use changes, tourism activities, exotic species introductions, and economic growth trends. As the demand for certain services increases, human actions often rely on the modification of ecosystems, in order to increase their provisioning capacity. This ecosystems anthropogenic transformation often enhances the production of some services at the expense of others (Jackson *et al.*, 2001). Our objective is to make available an overview and simple assessment of the services provided by the Mondego Basin, under the present limited data availability. However, this study is not meant as an exhaustive valuation of all wetland functions or the whole Mondego Basin.

Therefore, the main objectives of this study were to:

i) provide a comprehensive inventory of the ecosystem services and goods (hereafter designated only as ecosystem services) provided by the Mondego system;
ii) interpolate the scale dependence of such assessments, using three different scales: the Mondego Basin, the Lower Mondego, and the Mondego Estuary;
iii) determine the conditions and trends of the main services identified;
iv) estimate the interdependence among services;
v) determine management responses, as well as measures that should be implemented when the condition of ecosystem services is low or shows a tendency to decline.

Figure 1. The Mondego Basin study area.



2. Methodology

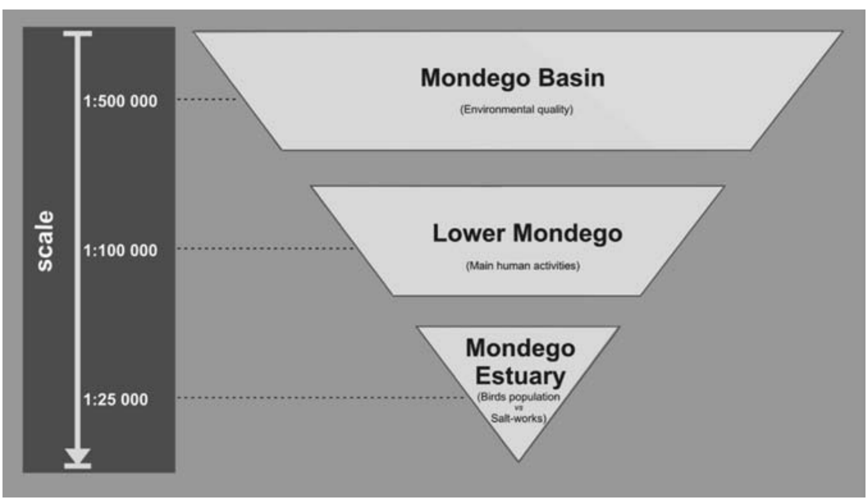
2.1. Study-Site description

The Mondego Basin is located in the centre of Portugal and represents a 6,670 km^2 catchment area, with highly diverse characteristics in terms of hydrology, land-use, and topography. It presents a peculiar and unique functional structure. The basin ranges from mountainous areas to a large alluvial plain discharging into the Atlantic Ocean, with a population currently estimated at 885,561 inhabitants (2006 data). The system can be divided into three main regions (Fig. 1):

i) Upper Mondego: basin area located in the "Serra da Estrela" mountain range, at the river headwaters, along glacial valleys.
ii) Medium Mondego: basin area between the base of "Serra da Estrela" and the city of Coimbra, where the river goes through deep valleys.
iii) Lower Mondego: final part of the river course, consisting of open valleys and plain fields, including the Mondego Estuary ecosystem and a thick dune belt along the coast line.

In each of the three regions, the secondary and tertiary sectors are highly represented in economic activities. But in the Lower Mondego, a strong pressure from the primary sector is also evident with abundant agricultural fields and the Figueira da Foz harbour.

Figure 2. Scales identified in the Mondego catchment.



To summarize, industrial activities related to wood extraction (due to the vast forest area), glass and ornamental factories as well as beverage industries dominate economic activities in the basin. More specifically, in the Lower Mondego region (near the coastal area), paper industry and aquaculture play the major economic role. Fiber and leather industries have a dominant position among economical activities in the Upper Mondego area (PBH Mondego, 2001).

Under the MA scope, three main areas were considered for this study: the Mondego Basin (basin scale), the Lower Mondego region (regional scale), and the Mondego Estuary area (local scale). The objective was to compare trends and patterns among scales and infer about local importance of global basin processes (Fig. 2).

2.2. Method of Analysis

The valuation approach was performed in three steps. Firstly, the condition and main basin uses were characterized considering different spatial scales. Secondly, an inventory of the main services and goods provided by the Mondego Basin was carried out. It is important to note that, biodiversity, despite not being considered an ecosystem service, was included in the assessment, since it is assumed to provide for all considered services and goods, promoting the correct performance of all ecosystem functions. Finally, and based on the inventory results, the ecological valuation perspective was combined with a range of economic valuation methods (economic perspective). Selected economic valuation techniques included mostly direct-use values, specifically the productivity method and market prices surveys. The marginal value for each service was calculated in terms of monetary units per unit area. According to Seyam *et al.* (2001), the use value derived from a certain production or information function is calculated as the product of the marginal value of the function and the area of the wetland that contributes to the function. The assumption is that there is a linear relationship between the area of wetland that contributes to a certain function and the use value delivered by that function.

2.2.1. Data used

In order to obtain an integrated overview of the dynamics and development of the whole basin, two approaches were considered: the catchment ecological valuation and the economic assessment of conditions and trends provided by the Mondego Basin to local communities.

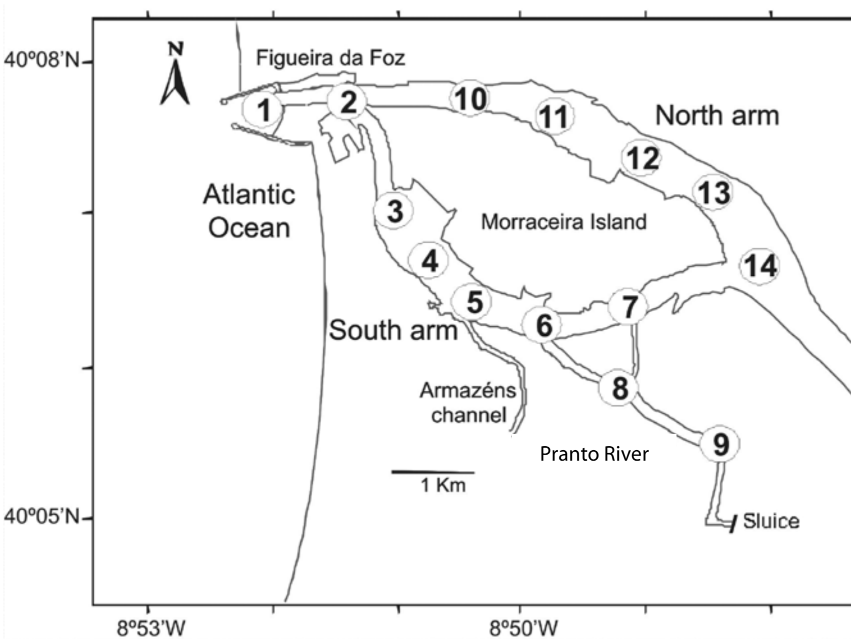
2.2.2. Data requirement for evaluation

2.2.2.1 Ecological approach

The Basin ecological evaluation was assessed based on macroinvertebrate communities present in the river course, giving special preference to data collected for the implementation of WFD (INAG data source).

To estimate biodiversity and water quality in the Mondego Estuary (local scale example), the chosen data set was provided by a monitoring programme for estuarine subtidal soft bottom communities. These data characterised the local system with regard to species composition and abundance, and water and sediment physico-chemical parameters. Samplings were carried out at 14 stations, along the two arms of the estuary, during Spring of 1990, 1992, 1998, 2000, 2002, 2003, 2004 and 2005 (Fig. 3).

Figure 3. Sampling stations used in the Mondego Estuary subtidal survey. Euhaline estuarine: 1, 2, 3, 7 and 10; Polyhaline Sand North Arm: 11 to 14; Polyhaline Sand South Arm: 4, 5 and 6; Polyhaline Muddy: 8 and 9.



For biodiversity classification purposes, in each sampling station, a 1 mm mesh screen was used to sieve samples and collected organisms were identified, counted, and their biomass (g PSLC m^{-2}) was estimated. Three ecological indices (Margalef Index, Shannon-Wiener Index and AMBI) were calculated. The Shannon-Wiener index is a diversity measure that takes into account the proportional abundance of species, the Margalef index is based on the system specific richness and AMBI gives a measure of the species ecological strategies. Table 1 shows the indices' algorithms and Table 2 gives the classification index scores used to assess ecological quality based on benthic macroinvertebrate diversity for Portuguese transitional water bodies (Teixeira *et al.*, 2008). For more details see Marques *et al.* (2007).

Table 1. Indices used in the classification approach: algorithm and description.

Index	Formula description
Shannon-Wiener, H' (Shannon & Wiener, 1963)	$H' = -\sum p_i \log_2 pi$ p_i- proportion of individuals found in the species i
Margalef, d (Margalef, 1968)	$d = \frac{(S-1)}{\log_2 N}$ S- number of species N- total number of individuals
Marine Biotic Index (Borja *et al.*, 2000)	$AMBI = \left\{ \frac{(0 \times \%EG_I) + (1.5 \times \%EG_{II}) + (3 \times \%EG_{III}) + (4.5 \times \%EG_{IV}) + (6 \times \%EG_V)}{100} \right\}$ EG- percentage of the total numerical abundance in the sample for each of the 5 ecological groups (EG_I to EG_V)

Table 2. Classification index scores for Portuguese transitional water bodies (after Teixeira *et al.*, 2008).

	Euhaline	Polyhaline Sand	Polyhaline Muddy
Margalef	5.0	4.0	3.0
Shannon-Wienner	4.1	4.0	3.8
AMBI	0.8	1 – 1.5	2.4

Water quality in the estuary was measured in water samples collected during high tide in the subtidal areas of both arms of the estuary. Samples were taken at 14 sampling stations (Fig. 3), during annual Spring campaigns from 1990 to 2006. Surface and bottom water samples were collected and analysed for dissolved nutrients (nitrate-nitrogen, nitrite-nitrogen and phosphorus) (Strickland & Parsons, 1972; APHA, 1980). Following a request from the European Environmental Agency (EEA), the European Topic Centre on Inland Waters (ETC/IW) prepared a classification methodology for assessing nutrient levels in transition, coastal and marine waters. Table 3 gives concentration intervals for Nitrite+Nitrate (μmol L^{-1}) and for Phosphate (μmol L^{-1}), and quality levels they represent. Weaknesses of this methodology are well known (e.g. it does not take into account the salinity gradient typical of transition systems). Nevertheless, in the absence of better tools, we decided to use it to assess water quality in the Mondego Estuary: Mouth (stations 1, 2 and 10); North Arm (stations 11,12, 13 and 14); Downstream South Arm (stations 3 and 4); Upstream South Arm (stations 5, 6 and 7), and Pranto River (stations 8 and 9) (Fig. 1). Moreover, it was decided to apply the EEA classification to surface and bottom waters at each location separately. It was therefore possible to assess the evolution of water quality, comparing classifications for water collected in identical conditions.

Table 3. European Environmental Agency criteria for assessing nutrient levels in transition, coastal and marine waters (EEA, 1999).

Quality Status	$NO_2^- + NO_3^-$ (μmol L^{-1})	PO_4^- (μmol L^{-1})
Good	<6,5	<0,5
Fair	6,5-9	0,5-0,7
Poor	9-16	0,7-1,1
Bad	>16	>1,1

2.2.2.2 Economic valuation

For the economic and social assessment, the evaluation was performed based on secondary data analysis, i.e., data collection was based on a literature survey of available statistics and existing studies, giving preference to data published by governmental institutes. In a preliminary step, an overview of basin conditions was accomplished, integrating both social and economic factors. Nevertheless, comprehensive examples were supplied both at regional scale and local level (Table 4). At the regional scale, the interaction and overlapping between agricultural activities, water quality supply and biodiversity were considered. At the local level, the interdependence between the four main categories of services considered was integrated. Through indicators used, one can observe the conditions, trends and changes in the services under study.

Table 4. Ecosystem services analysed and data available at the three selected scales.

		Mondego Basin	Lower Mondego	Mondego Estuary
Food Production	Salt			x
	Aquaculture			x
	Agriculture		x*	
	Fisheries			x
Tourism	Tourists	x	x	x
	Establishments	x	x	x
Water	Quality			x
	Availability	x	x	x
	Effluents	x	x	x
	Treated	x	x	x
Biodiversity				x

* for the total Centre Region.

Table 5. Valuation methods and data requirements to assess ecosystem services evaluated in the Mondego Estuary.

Resource/ Activity	Water resources	Food production	Recreation
Valuation Method	Contingent valuation method*	Change in productivity method	Travel cost method
	Water market	Market price method	Market price method
		Contingent valuation method*	Contingent valuation method*
Data requirement	Physical-chemical parameters	Catch/effort	Nº of visitors / tourists
	Survey approach	% Population dependent on it	Nº of establishments
	% of activities	Cost of production (wages and fuel costs)	Area of wetlands
	Tourism data	Prices of products	Water quality
	Recreation activities	Species composition	Aesthetic values
	Effluents	Type of fishing gear / production unit	Main activities
	Water withdraw and usages	Area of wetlands	Any other relevant information
		Water quality	
		Any other relevant information	

* not used in this specific assessment

2.2.3. Valuation Procedure

2.2.3.1. Choosing the appropriate assessment approach

Based on the full range of ecosystem services and goods identified (Table 4), and specifically the Mondego Estuary water usage and corresponding benefits/values (Table 5), it was crucial to identify the appropriate economic assessment approach, taking into account particular features that constitute and determine the system's development.

2.2.3.2. Description of the methodology

Economic valuation includes every countable item in a financial valuation (costs and benefits directly associated with a project) plus any costs and benefits which do not affect financial results but affect or will affect, positively or negatively, the wider economy (e.g. water pollution costs). Two different approaches were considered: the productivity method and the market prices method (for more details regarding the methods see for example Barbier *et al.*, 1997; Lambert, 2003; Tietenberg, 2003).

i) Productivity method

The productivity technique (mostly due to its broad applicability and flexibility in using a variety of data sets) consists in tracing the impact of changes in ecosystem condition through chains of causality, so that it can be related to measures of human wellbeing. In this method, the change in productivity/production of an environmental resource is measured to determine the actual benefits obtained. Such impacts are often reflected in goods or services that contribute directly to human wellbeing (e.g. production of crops or clean water), and as such are often relatively easily extracted and valued.

ii) Market price method
The most commonly used valuation approach is using market transactions as an indicator for value. Given that goods and services are exchanged in the market place, the value people place on the commodity is reflected in its price. Prices are therefore used to determine the value of an ecosystem feature. Market price methods rely on observing changes in prices for goods and services that are traded in a market, based on a change in environmental quality.

3. Results

3.1. Mondego Basin socio-economic characterization

An economic, social and ecological profile of the Mondego Catchment was carried out based on institutional data obtained from Instituto Nacional de Estatística (INE), Instituto Nacional da Agua (INAG), Ministry of Agriculture, etc., for the period of 1992 to 2006. Table 6 provides an overview of the main characteristics, proportions, and land use distribution in the three considered areas, in 2006.

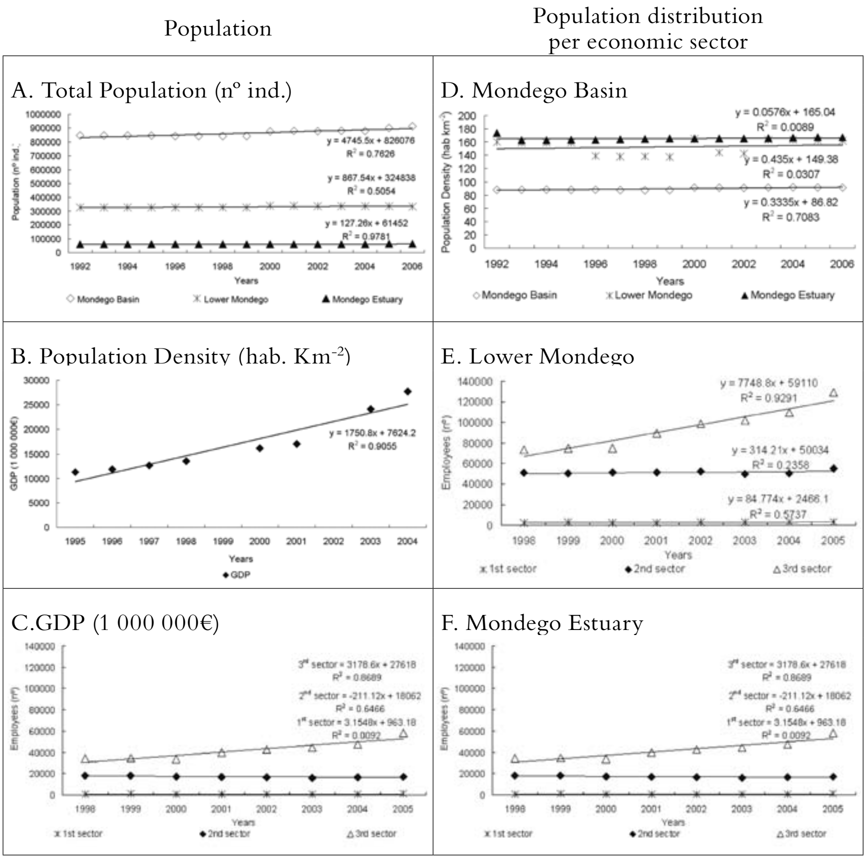
Table 6. Main characteristics of the Mondego Basin, Lower Mondego and Mondego Estuary study sites, using 2006 data.

	Area (Km^2)	Population (nº of ind.)	Small basins included	Land Use (ha)					
				RAN	REN	Urban	Industrial	Urban parks	Tourism
Portugal	92,391	10,599 095	–	x	x	481,082	75,151	37,837	18,707
Mondego Basin	6,645	885,561	9	27,983	466,482	77,560	9,965	3,154	1,209
Lower Mondego	250	334,161	3	x	x	23,078	3,098	1,404	724
Mondego Estuary	7.2	63,372	1	x	22 738	2,537	1,171	165	380

Sources: INE – Instituto Nacional de Estatística; INAG – Instituto da Água; RAN= Reserva Agrícola Nacional; REN= Reserva Ecológica Nacional; x – data not available.

Furthermore, population distribution among economic sectors (primary, secondary and tertiary) was also considered, in order to account for the importance of local resources for human wellbeing and quality of life. In the primary sector we included those activities that imply the direct use of natural resources, such as agriculture or fisheries. Extractive and transforming industries are included in the secondary sector. Finally, we included the services provided by society to local populations (e.g. banks, transports, etc.) in the tertiary sector (Fig. 4D to F).

Figure 4. Population data and socio-economic characteristics of the study area (from 1992 to 2006), in the three scales under study (Mondego Basin, Lower Mondego and Mondego Estuary): A. Population data (total number of individuals); B. Population density (hab. Km^{-2}); C. Gross Domestic Product (from 1995 to 2004). Population distribution per economic sector (from 1998 to 2005): D. Mondego Basin; E. Lower Mondego and F. Mondego Estuary.



From a general point of view, the total number of individuals depending on the Mondego catchment has been increasing. This pattern is also reflected in their distribution throughout the basin and an increment in population density. Along with these trends, the region GDP (from 1995 to 2004) presented a strong increase, with the 2004 value doubling that of 1995. This value represents 19.2% of the Portuguese GDP, with an employment base of 163,395 individuals (2004 data). Considering the Basin as a whole, one observes an increment in the number of employees from the three economic sectors. Nevertheless, on a finer scale, the secondary sector has declined in the Lower Mondego region and in the Mondego Estuary area. In the estuary there was as well a decrease of the primary sector, reflecting the abandonment of resource extraction activities, combined with a significant increase in service provision, mainly tourism and recreational activities.

3.2. Inventory of ecosystem services and goods

A wide range of goods and services are provided by ecosystems, and specifically by the Mondego Catchment area, resulting in significant ecological, social, and economic benefits. This approach provides a comprehensive and transferable framework for a site-specific assessment enabling the evaluation of costs and benefits of exploitative activities, and facilitating management and conservation processes. For this particular case study, the main ecosystem services and goods were assessed (Table 7).

3.3. Ecosystem services assessment

In spite of the intrinsic importance and function of each of these services and goods, only three of them were subject to a more detailed and exhaustive evaluation: food production, water quality, and recreation, as well as of their relationship to biodiversity assets. To undertake this evaluation only the Mondego Estuary system was taken into account (see Table 7).

3.3.1. Food production

To estimate food production, agriculture (Fig. 5), fisheries (Fig. 6), aquaculture and salt production (Fig. 7) were considered. Unfortunately, agriculture data was only available for the Centre Region of Portugal, which encompasses not only the Mondego Basin but also other surrounding locations. Nevertheless it was assumed as indicative of the area trends and conditions. The remaining items (fisheries, aquaculture, and salt production) were analysed only at the scale of the Mondego Estuary.

The agricultural productivity function was considered as a trend measuring the system's capacity to support and maintain these anthropogenic activities. There was a significant overall decline for the 7 main crops on the region (potatoes, rice, maize, rye, beans, apple, and peach) concerning area, production and productivity (together they decreased from 946,298 tons in 1992 to 383,165 tons in 2006).

Data on fish catch and prices for the Mondego Estuary, considering the Figueira da Foz harbour, were used to assess the fisheries production value. A gradual decline of total fish catches (from 16,358 ton in 1992 to

Table 7. Inventory of ecosystem services and goods in the Mondego Estuary.

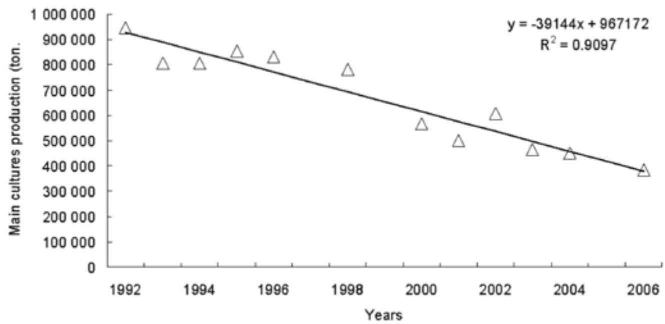
	Category	Service/Good	Description/Function
Goods	Production services	Food production	Extraction of products for human consumption (aquaculture, agriculture, fisheries)
		Raw materials	Extraction of products for other purposes than human consumption (minerals)
		Pharmaceutics	Extraction of products for medicinal or pharmaceutics purposes
		Ornamental resources	Extraction of products for, for example, decorative purposes
		Renewable energy	Extraction of benefits from natural resources (e.g. electricity extraction)
Services	Cultural services	Eco-tourism	Use of ecosystems for leisure (e.g. museums, parks)
		Recreation	Use of ecosystems for entertainment and psychological health through the viewing of species in their environment (e.g. bird watching)
		Cognitive values	Cognitive development, including education and research
		Cultural heritage	Value associated with natural system components (e.g. religion, cultural and spiritual traditions)
		Non-use values	Value which we derive from systems and species, without using them
	Regulating services	Gas & climate control	Balance and maintenance of the chemical composition of atmosphere and water by species
		Disturbance regulation	Dampening of environmental disturbances by biogenic structures (e.g. storm, flood or drought protection and mitigation; soil erosion and retention)
		Carbon sequestration	
		Bioremediation	Removal of pollutants through storage, dilution, transformation, or burial (e.g. waste assimilation)
	Supporting services	Nutrient cycling	Storage, cycling and maintenance of availability of nutrients by organisms
		Water quality/availability	System capacity to provide water for human usage (both water usage *in situ* or water removal)
		Soil health	Soil fertility, formation and habitat measure
		Nurseries	System capacity to provide habitat and suitable conditions for species or juveniles to develop
		Habitat provision	Habitat provided by and for species and that contribute to a higher genetic diversity
		Pollination	System ability to promote genetic variability
		Resilience/Resistance	Extent to which ecosystems can absorb recurrent natural and anthropogenic perturbations and continue to regenerate

11,008 ton in 2006) and an increase in fish prices were observed. This trend is in accordance with worldwide fisheries trends (MA, 2005). The continuous erosion of this activity is reflected in the reduced number of fishing boats from 1994 to 2006 (Fig. 6C).

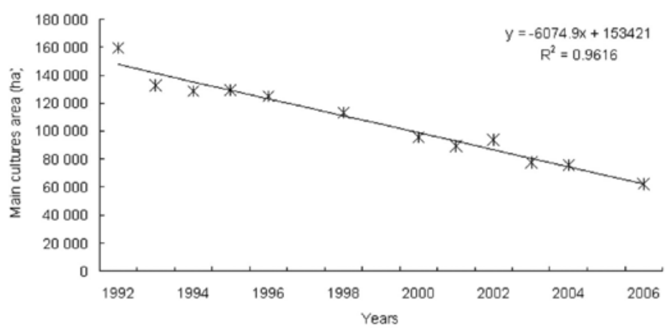
Figure 5. Estimated food production in the Centre Region, from 1992 to 2006: A. Agriculture production (ton.); B. Agriculture production prices (1000 €); and C. Agriculture productivity (ton. ha^{-1}).

Agriculture

A. Agricultural production (ton.)



B. Agricultural area (ha)



C. Agriculture productivity (ton.ha-1)

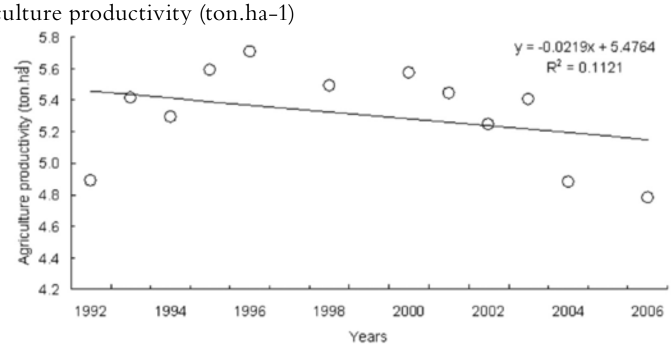
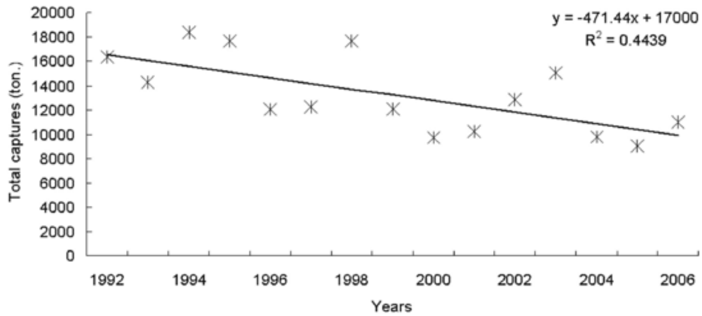


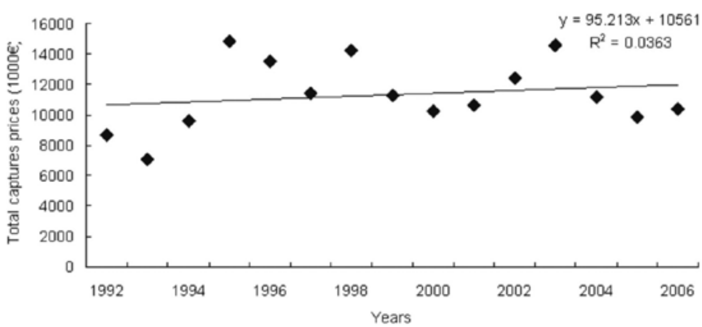
Figure 6. Estimated fisheries production for the Mondego Estuary from 1992 to 2006.

Fisheries

A. Fisheries (ton.)



B. Fisheries catch prices (1000€)



C. Fisheries boats from 1994 to 2006 (nº)

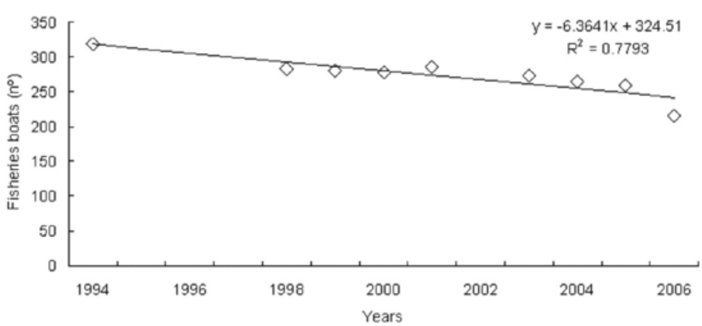
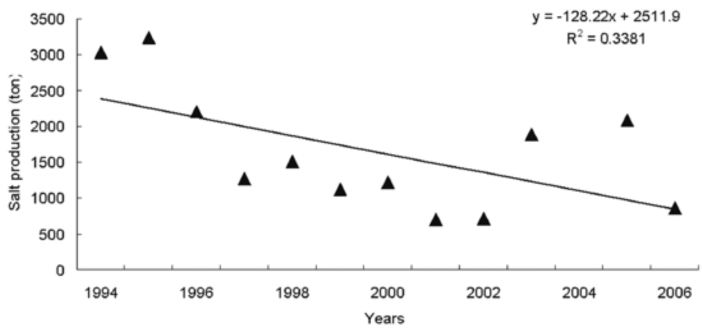


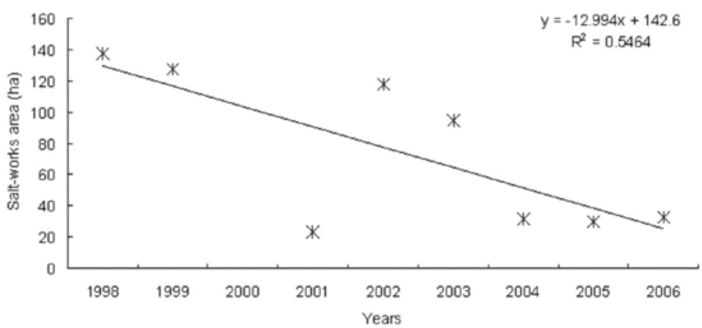
Figure 7. Estimated salt production in the Mondego Estuary.

Salt

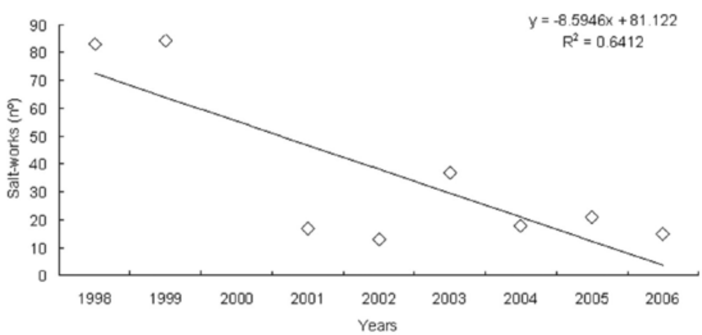
A. Salt production from 1994 to 2006 (ton.)



B. Salt production area from 1998 to 2006 (ha)



C. Number of salt production enterprises from 1998 to 2006 (nº)



Salt production is another active enterprise in the Mondego Estuary. However, high costs resulting from traditional extraction, together with competition from other producing areas in Portugal and abroad have led to its progressive decline (Fig. 7C) and the closure of production units. Since the 1980s, some of the inactive salt production units have been converted to fish farming, mainly of a high intensity type, where local species like *Sparus aurata* and sea bass (*Dicentrarchus labrax*) are grown. Despite the fact that the area devoted to fish farming has been increasing in the estuary, the same has not been happening to production. In fact, total production in 2003 was 200 tons/year, while ten years before each of the companies involved in this activity produced approximately 120 tons/year. The decline in farmed fish production appears to be mainly related to water quality, since presently it is only possible to cultivate 1kg of fish per m^3, compared to the 2-3 kg of fish per m^3 obtained in the past. Nutrient enrichment and the subsequent eutrophication of the system, leading to a fall in water-dissolved oxygen, might be one of the possible factors affecting the production potential.

3.3.2. Recreation

The touristic activity (number of tourists and number of establishments) of Figueira da Foz was used as indicator of pressure and impact upon the system (Fig. 8).

In the Mondego catchment area, the touristic activity is socially and economically significant. Figure 8A shows a progressive increase in tourist numbers coming to the Mondego Basin, although the number of facilities provided to tourists has been decreasing in the Lower Mondego and in the Mondego Estuary. It is also important to consider seasonal impacts, as the touristic activity reaches a peak during the summer period (July to September), namely at the scale of the Mondego Estuary. For example, considering the 2006 data, was possible to observe that during summer season there was an increment of 20.4% on the Mondego Basin as a whole, 38.3% on the Lower Mondego region, and 48% on the Mondego Estuary location. Comparing these trends with the population distribution by economic sector (Fig. 4F), it is clear that local populations have replaced land activities (e.g. agriculture or fisheries) by the provision of services, namely touristic services.

3.3.3. Water resources

Water volume use and effluents production were used as indicators of water resource management (Fig. 9). Due to the lack of data regarding the entire Basin, water quality was assessed only for the Mondego Estuary area (Table 8). The two water resource variables showed an increase in the three domains considered. Not surprisingly, these variables followed the behaviour of the population data (Fig. 4A and B). As the

Figure 8. Touristic activities in the Mondego study area, considering the three studied scales (Basin, Lower Mondego, and Mondego Estuary), from 1992 to 2006.

Tourism

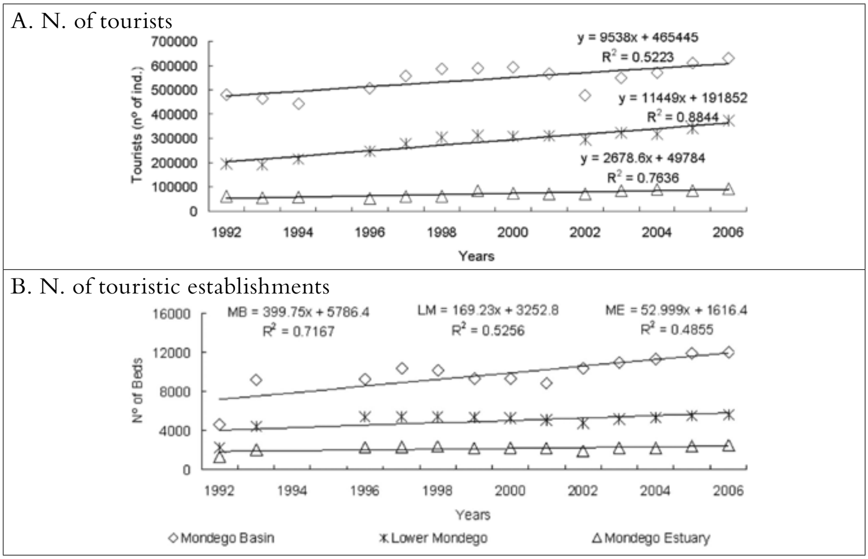
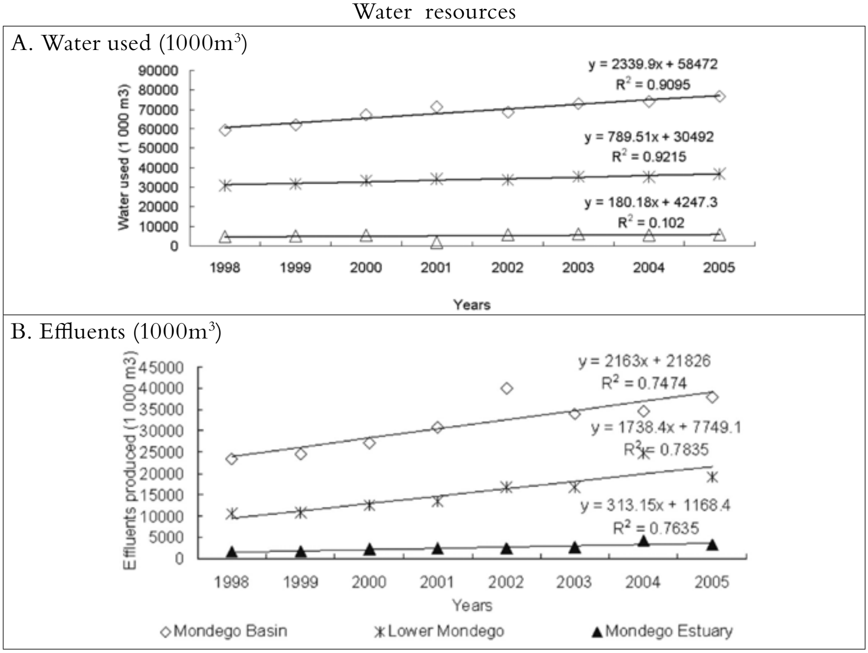


Figure 9. Water resource statistics in the Mondego study area, comparing the three studied scales (Basin, Lower and Mondego Estuary), from 1998 to 2005.

Water resources



population increases there is a consequent increment of activities, leading to higher water use and effluent production (Fig. 9).

Table 8 gives the results obtained from applying the EEA classification criteria with respect to the Nitrite+Nitrate and Phosphate parameters in the Mondego Estuary area. It was possible to observe that a progressive decline in EEA classification scores has been taking place, with a concomitant degradation of water status during the time period considered. Additionally, surface waters have consistently presented higher levels of NO_3+NO_2 and worse scores than bottom waters, clearly suggesting that the main sources of these nutrients lie upstream of the study area.

Table 8. Results from the application of the EEA classification criteria (EEA, 1999) with respect to the Nitrate+Nitrite and Phosphate parameters, to the five zones considered in the Mondego Estuary: M. Mouth (stations 1, 2 and 10); NA. North Arm (stations 11, 12, 13 and 14); DSA. Downstream South Arm (stations 3 and 4); USA. Upstream South Arm (stations 5, 6 and 7), and P. Pranto River (stations 8 and 9), during spring months (April to June) from 1990 to 2006. 2005 (Red: Bad; Yellow: Poor; Green: Fair, Blue: Good).

NO3+NO2												PO4											
SURFACE WATER						BOTTOM WATER						SURFACE WATER						BOTTOM WATER					
	M	NA	DSA	USA	P		M	NA	DSA	USA	P		M	NA	DSA	USA	P		M	NA	DSA	USA	P
1990						1990	2,3	5,3	5,9	5,3	4,3	1990						1990	0,96	0,59	0,92	0,90	1,62
1991						1991						1991						1991					
1992						1992	5,9	15,1	16,0	10,4	11,9	1992						1992	7,21	12,47	7,76	5,54	21,07
1993						1993						1993						1993					
1994						1994						1994						1994					
1995						1995						1995						1995					
1996						1996						1996						1996					
1997						1997						1997						1997					
1998						1998	15,9	31,1	16,6	22,0	23,6	1998						1998	0,55	0,57	0,24	0,34	1,13
1999						1999						1999						1999					
2000						2000	1,5	23,1	18,4	17,7	14,7	2000						2000	1,02	2,25	2,08	2,22	2,05
2001						2001						2001						2001					
2002						2002	12,7	13,8	8,9	9,3	6,5	2002						2002	3,20	3,70	3,71	3,64	3,19
2003	10,2	18,2	5,7	17,6	27,5	2003	4,5	8,2	4,4	11,3	16,9	2003	0,96	1,39	0,71	1,63	2,06	2003	0,79	1,03	0,67	1,32	2,25
2004	5,8	11,6	3,8	13,7	15,8	2004	1,8	7,1	2,9	14,6	11,2	2004	0,68	0,96	0,64	1,81	2,61	2004	0,39	1,11	0,51	1,51	2,35
2005	5,9	5,9	10,2	8,1	13,4	2005	6,6	5,7	10,5	7,3	15,0	2005	0,55	0,72	1,32	0,88	3,02	2005	0,49	0,71	1,11	0,80	3,05
2006	17,3	12,1	21,1	20,4	18,4	2006	12,8	13,7	19,8	10,5	20,0	2006	1,18	0,87	1,54	1,18	2,65	2006	0,58	0,78	1,41	0,78	2,72

3.3.4. Biodiversity

Due to lack of data regarding the entire system and region, only the Mondego Estuary was accounted for in the biodiversity assessment. The Ecological Quality Status (EQS) based on benthic macroinvertebrate diversity (for more details see Marques *et al.* 2007) was assessed in the following four estuarine areas (Table 9): Euhaline estuarine, Polyhaline Sand North Arm, Polyhaline Sand South Arm and Polyhaline Muddy.

The North arm presented a strong biodiversity decline in 1992 followed by some recovery. This situation may have been caused by engineering works undertaken in this area to regularise the river banks and narrow the channel. From 1998 onwards, the estuarine mouth and North arm showed significant improvements, ranging from moderate to good EQS. The South arm also presented a significant decline in biodiversity until 1998, which was probably a consequence of the eutrophication process observed in this subsystem. From 1998, following the implementation of several experimental mitigation measures (Marques *et al.*, 2005), the system's biodiversity began showing signs of improvement. As a whole, a gradual enhancement of the system´s ecological condition has taken place.

Table 9. Ecological Quality Status (EQS) of the macrofaunal communities in the Mondego Estuary, from 1990 to 2005, according with the P-BAT multimetric index (Marques *et al.* 2007) developed in the scope of the WFD implementation (B: Bad; P: Poor; M: Moderate, G: Good; B: Excellent).

Zones	1990	1992	1998	2000	2002	2003	2004	2005
Euhaline estuarine	M	M	G	G	G	M	G	G
Polyhaline Sand North Arm	G	M	G	M	G	M	G	G
Polyhaline Sand South Aram	G	G	P	G	M	M	M	G
Polyhaline Muddy	M	G	M	G	G	G	G	G

3.3.5. Benefit-Cost Analysis (BCA)

The Benefit-Cost Analysis (BCA) is a methodology that compares the present value of all social benefits with the present value of costs in using those resources. The costs consist of both direct costs of implementing conservation measures and opportunity costs of foregone uses (Pagiola *et al.*, 2004). It can give valuable insights into the economic efficiency of management and regulatory actions. If the net value (benefits minus costs) of an action is greater than zero, then that project is considered to be economically efficient and should be supported (Tietenberg, 2003). The more benefits exceed costs the better society is in economic terms as a result of the activity (Lipton *et al.*, 1995). This technique is therefore human-centred and individualistic, and is only concerned with measuring how people value things, not how they should value them. An overall estimation of the ecological and social importance of the areas under study was performed considering investments and benefits obtained at the three scales considered in the system. The investments that local communities were willing to make to protect and mitigate pollution or other pressures (as water treatment systems or fire protection were considered as costs; Fig. 10A–C). We considered profits obtained from protected areas as benefits (Fig. 10D–F). Finally, a rough BCA was performed, considering estimated benefits versus investments in those areas (Fig. 11A–C).

Since the BCA is used to evaluate environmental policy actions it is imperative that all costs and benefits are considered. It is important to highlight that the only objective of the BCA carried in this case was to provide a preliminary estimation of costs and revenues managed by and made available to local communities. This implies that benefits that cannot be directly and accurately valued are not included in this analysis, which might explain the low values of the Benefit/Cost Ratio (BCR). In fact, the BCR was generally less than one for all sites and components analysed. This is in accordance with other studies (e.g. Esteban & Dickie, 2004) where non-use values are not included in the assessment. In our case, estimated BCR values were higher than one only twice (Total B/C ratio and Water B/C ratio), at the Mondego Estuary scale, both in 2004.

Figure 10. Benefit-Cost Analysis of the study area, comparing the three studied scales (Basin, Lower and Mondego Estuary).

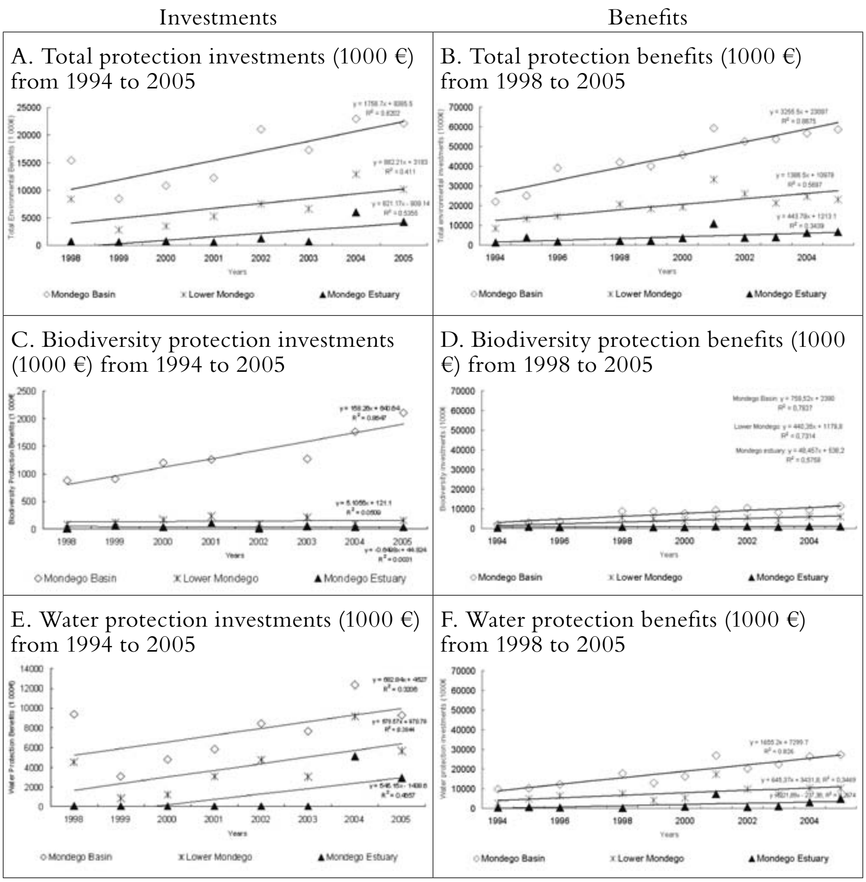


Table 10 summarises the trends regarding the present condition and future directions of services considered and of ongoing management actions, if no measures are meanwhile undertaken to improve the system or at least mitigate the impact of human activities.

Figure 11. Benefit-Cost Analysis of the study area, from 1998 to 2005 considering total, water and biodiversity investments and revenues.

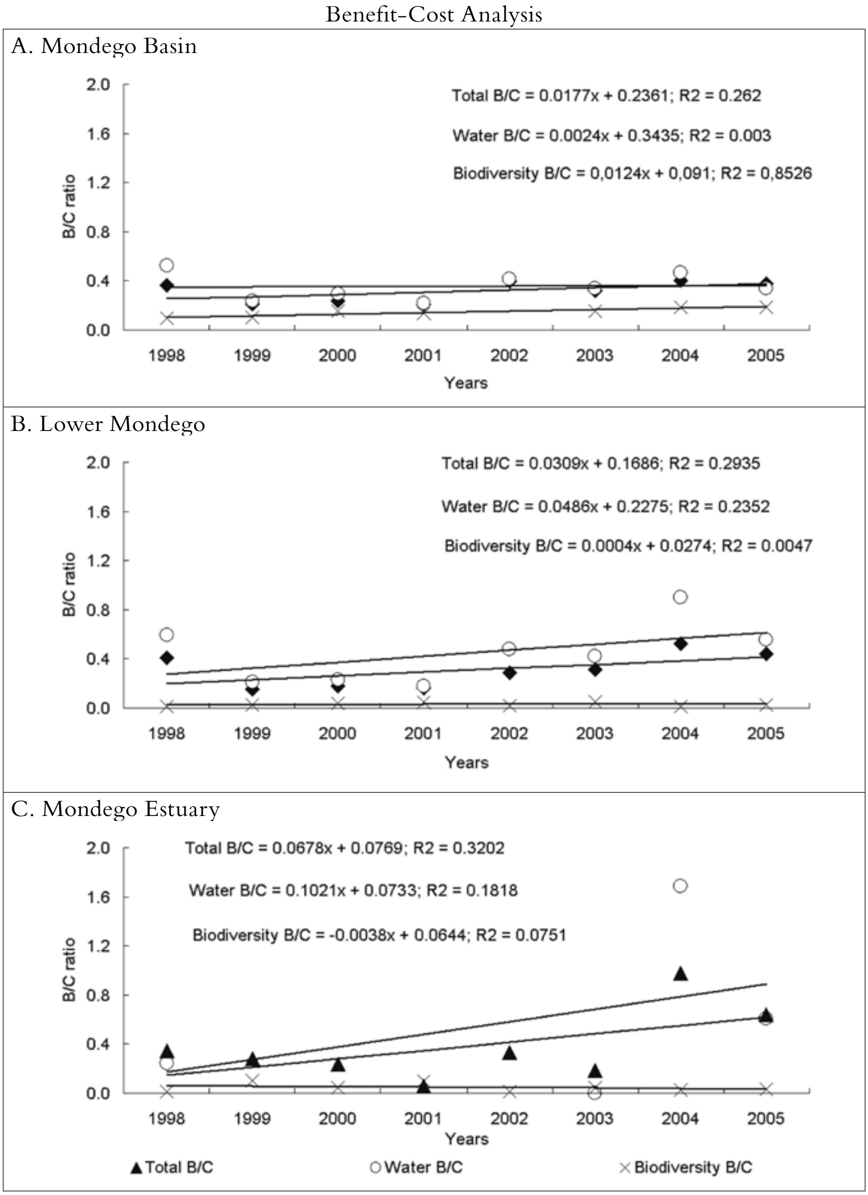


Table 10. Overall trends of goods and services considered at the three scales studied (Mondego Basin, Lower Mondego and Mondego Estuary), in the period 1992 to 2006.

				Mondego Basin	Lower Mondego	Mondego Estuary
Population data		Population		↑	↑	↑
		Population density		↑	↑	↑
		GDP			↑*	
		Economic sectors	1st	↑	↑	↓
			2nd	↑	↓	↓
			3rd	↑	↑	↑
Recreation		Establishments		↑	↓	↑
		Tourists		↑	↑	↑
Water		Treated water		↑	↓	↑
		Water uses		↑	↑	↑
		Effluents		↑	↑	↑
		Water quality		–	–	↑
Food Production	Fisheries	Fish catches		–	–	↓
		Prices		–	–	↑
		Aquaculture		–	–	↓
	Salt	Salt production		–	–	↑
		Salt production area		–	–	↓
		Salt production units		–	–	↓
	Agriculture	Used agriculture area			↓*	
		General cultures			↓*	
		Productivity			↓*	
Biodiversity				–	–	↑
Environmental investments		Total		↑	↑	↑
		Water protection		↑	↑	↑
		Biodiversity protection		↑	↑	↓
Environmental benefits		Total		↑	↑	↑
		Water protection		↑	↑	↑
		Biodiversity protection		↑	↑	↓
B/C ratio		Total		↑	↑	↑
		Water protection		↑	↑	↑
		Biodiversity protection		↑	↑	↓

* for the total Centre Region.

4. Discussion

4.1. Conditions and Trends

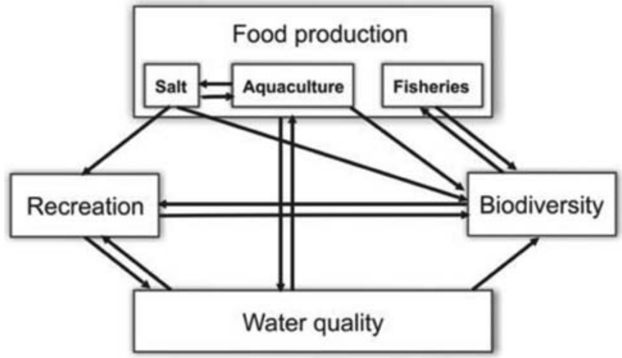
Overall, human activities cause a sequence of environmental damages and stresses, which may alter the ecosystems' natural processes. The most important problems in aquatic environments are related to nutrient input (eutrophication), erosion, sediment load (increase of water turbidity), sewage drain, water quality alteration, microbiological pollution, changes in the biological communities structure, introduction of exotic species, pollution in general, habitat destruction and loss of diversity (Marcos & Pérez-Ruzafa, 2003). A dynamic society requires monitoring and adjusting these ecosystem services blend as society's priorities change (Bromley, 1997) to insure that the highest valued combination of services is produced. Since some services are not priced (e.g. fish habitat and recreation), this raises a challenge to water managers (Loomis *et al.*, 2000).

In the Mondego River Basin, population pressure drives the observed changes in water uses. Shipping, fishing, agriculture and recreation were the most important uses reported. Nevertheless, water industrial use and water extraction for domestic usage as well as irrigation appear also to play an important role in each of the three scales analysed in the system. Land use and water resources are obviously linked. The impact and pressure of land use practices and intensity on both water quantity and quality can be substantial. Currently, the water quality service seems to require highest attention as it influences the performance of all other services to a large extent. It appears that agricultural activities are responsible for eutrophication symptoms observable in the estuary. On the other hand, it is important to keep in mind that this activity is economically essential in the Low Mondego River Valley area. All measures that might be undertaken to solve this environmental problem must take into account the socioeconomic reality.

4.2. Interrelations among Ecosystem Services

Social, cultural and economical problems overlap on top of environmental challenges. Activities are rarely isolated or take place through linear cause-effect relations. Instead they interact, meet and compete for area, summing up effects, and producing a complex network of inter-relations, which makes the analysis of the situation even more difficult (Fig. 12). A typical example of interactions between different activities can be seen in the Mondego Estuary. Agriculture and aquaculture activities produce waste, increasing water nutrient concentration and obviously lead not only to degradation of water quality, but also influences agriculture itself, aquaculture production, and affects the aquatic communities' diversity. Presently, following the implementation of a number of experimental mitigation measures in 1998 (Marques *et al.*, 2005), diversity of the subtidal benthic macroinvertebrate community appears to have improved. Impoverished benthic communities, which serve as food for many fish species, might eventually cause a decrease in fish production. In general, due to this intrinsic and complex network of inter-relations and inter-dependencies, we may say that any measure undertaken to improve an ecosystem service in isolation will directly or indirectly have repercussions on the others.

Figure 12. Inter-relations between the different services in the Mondego Estuary.



Regarding the food production service, namely the salt extraction activity, it is reasonable to consider that a decrease in the area occupied by salt production will mean not only an obvious drop in local salt production, but will also be detrimental to many bird species (and consequently biodiversity). This system is an important stopover and refuge area for migrating birds along the north-western coast of Portugal and is particularly important for waders, especially for species such as the Pied Avocet (*Recurvirostra avosetta*) and Greater Flamingo (*Phoenicopterus rubber*). During the breeding season the site is regionally important for species such as Black-winged Stilt (*Himantopus himantopus*) and Little Tern (*Sterna albifrons*). Portuguese salt pans are usually regarded as mainly providing supplementary feeding over high-water, on the assumption that this habitat is less suitable than mudflats for most waders (Rufino *et al.*, 1984; Múrias, *et al.*, 1997; 2002; Luís, 1999; Lopes *et al.*, 2001). In the Mondego Estuary, for example, up to 42% of the total number of waders can be found feeding in the salt pans at low tide, irrespective of the season, against some 70% at high tide (Múrias *et al.*, 2002). Moreover, this system was designated as a Ramsar site (Ramsar site 1617), and consequently its eventual loss may be detrimental to many species.

4.3. Biodiversity vs economic activities

According to Díaz *et al.* (2006), in the broad sense, biodiversity is the number, abundance, composition, spatial distribution, and interactions of genotypes, populations, species, functional types and traits, and landscape units in a given system. This asset in some cases can be considered an ecosystem service, while in others a driver/ necessary condition for ecosystems to function (Jaarsveld *et al.*, 2005). While the provision of all ecosystem services requires, to some extent, the presence of living organisms, in some cases it is not the variety of living organisms that matters, but the fact that only a few particular organisms, essential for a service provision, are present (MA, 2003). The MA considers biodiversity to be not only an ecosystem service in its own right but also the basis for other important services, including nature-based tourism, rural diets and traditional medicines (MA, 2003). Nevertheless, in our case, biodiversity assets were not considered as ecosystem services *per se*, but as a system property allowing the provision and delivery of several services and goods, and with no economic value or price assigned. Biodiversity influences ecosystem services, which contribute to making human life both possible and worth living. As well, biodiversity provides direct conditions for numerous organisms that are important for human material and cultural life, having well-established or putative effects on a number of ecosystem services mediated by ecosystem processes. Also, by affecting ecosystem processes (e.g. plant biomass production, nutrient and water cycling, soil formation and retention) biodiversity indirectly supports the production of food, fiber, potable water, shelter, and medicine. Moreover, changes in biodiversity affect ecosystem services supply and resilience.

Links between biodiversity and ecosystem services have been gaining increasing attention in recent scientific literature (Díaz *et al.*, 2006). Nevertheless its direct connection to services and goods provision is still unclear. More information regarding these interactions is essential to a full understanding of how biodiversity decline may affect society and economy. In economy, biodiversity can be considered as an example *per excellence* of the existence of bequest value. Although not directly used, it has a tremendous value to society, in terms of recreational activities, endangered species knowledge and protection, and as base for a number of system processes and functions that allow the maintenance of ecosystem integrity, and the natural flow of energy and materials.

Despite documented trends, the market economy fails to regulate the pollution flow to the environment and its known negative consequences. In reality, pollution costs are still not experienced by the polluter (externality). Thus, pollution social costs (i.e., the lost income due to the considerable loss of bird nidification spots or migratory routes across the Mondego Estuary, as a consequence of salt-pan habitat loss in this case) may be greater than the private cost (i.e. no private expenses associated with aquaculture water contamination). Others in society pay the economic price of these environmental impacts that they may not have caused. In order to contribute to bridging this information vacuum and precisely measure impact, a survey would need to be conducted in the area to evaluate the value given by people to the system's natural features.

4.4. Exotic species introduction

As mentioned before, biodiversity is characterised by the living organisms' variability and the diversity of ecological processes of which they are part. When a species is lost or a new one is introduced in a particular location, the ecosystem services associated with this species may change. In the study area, the trade-off between biodiversity and food provision may be given as example. Ecological services provided by biodiversity have economic, aesthetic, scientific and recreational value and are more easily discussed and monetarily quantified than their intrinsic value (Krantzberg & Boer, 2006).

In the Mondego catchment area, several exotic plant and animal species threaten the wetlands natural integrity. A well-known and reported example was the introduction of the Louisiana Red swamp crayfish in the Lower Mondego valley, which consists of approximately 15,000 ha of agricultural land, of which 60% are rice fields.

In 1974, *Procambarus clarkii* was introduced in the Guadalquivir rice fields (Spain) aiming at filling the gap left by the extinction of the indigenous *Austropotamobius pallipes* due to a fungal infection (Habsburgo-Lorena, 1978). With this introduction a double production of rice and crayfish was expected. However, six years after the introduction, crayfish populations had spread over all rice fields of Seville, causing serious damages to rice crops (Velez, 1980). The first record of *P. ckarkii* in Portugal dates back to 1979 in the Caia River, and in 1990 the population spread to the Lower Mondego River area (Adão & Marques, 1993; Anastácio *et al.*, 1995). Crayfish impacts on rice yields may be direct or indirect. Direct effects include consumption of seeds and plants, clipping plants and disturbance of normal rooting process. Due to its burrowing behaviour the crayfish indirectly hampers the establishment of rice fields, affecting young plants and rice development (Anastácio & Marques, 1996). According to Correia *et al.* (2005), densities of 3 crayfish m^{-2} prevented rice from growing and densities of 1 crayfish m^{-2} had a quantifiable negative impact on rice seedling survival (65.6% on seedling reduction; 41.6% on grain production; and 62.1% on rice shoots). As in other areas of the world, the development of dense populations of *P. clarkii* in the Lower Mondego River area caused severe rice yield losses, namely in 1990 and 1991. Since then, mitigation measures and models have been constructed to mitigate the impacts of this species on agricultural crops.

4.5. Assessment of scales

The scale effect in this study is particularly highlighted while integrating the biodiversity results (local scale) with Lower Mondego agriculture production (regional scale). In 1993 the South arm presented strong eutrophication symptoms, leading to a severe reduction on local biodiversity. It appears that agricultural activities (Lower Mondego regional scale), mostly due to the release of nutrient enriched waters from fields, were co-responsible for the eutrophication symptoms observed in the Estuary. In face of this problem, two major mitigation measures were undertaken in 1997/98: i) the agriculture fields' runoff was diverted into the North arm, and ii) the communication between the two estuarine arms was improved (Marques *et al.*, 2003). As consequence, the local estuarine biodiversity started to improve. On the other hand, when considering the trade-off between food production and ecosystem assets, such as biodiversity or ecosystem integrity, is important to keep in mind that food production is economically crucial in the Low Mondego River Valley area. All the measures that might be undertaken to solve any environmental problem must take into account the socioeconomic reality. It can be assumed that the highly structured and man-modified environment provides suitable conditions for the achievement of a balanced interaction between services and assets, even at different scales. This study allowed to show the importance of scales assessments when quantifying areas of concern for ecosystem services provision and its relation to human well-being (Jaarsvel *et al.*, 2005; Barbier *et al.*, 2008).

4.6. Economic analysis Overview

Since the BCA is used to evaluate environmental policy actions it is imperative that all costs and benefits are considered. It is important to highlight that the only objective of the BCA carried in this case was to provide a preliminary estimation of the costs and revenues managed by and made available to local communities. This implies that benefits that could not be directly and accurately valued were not included in this analysis, which might explain the low values of Benefit/Cost Ratio (BCR). In fact, the BCR was generally less than one for all sites and components analysed. This is in accordance with other studies (e.g. Esteban & Dickie, 2004) where non-use values were not included in the assessment. Nevertheless, it must be reminded that economic valuation cannot place a value on species survival or on the ecosystem functional and ecological role, except from the human perspective (MA, 2005). In our case, we estimated BCR values higher than one only twice (Total B/C ratio and Water B/C ratio), at the Mondego Estuary scale, both in 2004. Even so, it should be noted that in some cases (e.g. the preliminary BCA analysis performed on the Mondego Estuary) the economic value is negative despite having a highly positive ecological value, reflected on the conservation and protection of endangered and unique species (being or not under the protection of European environmental legislation, such as NATURA 2000). Moreover, it must be highlighted that even when benefit revenues are not the primary objective of wetland exploitation and conversion, activities such as agriculture, aquaculture, and urban and industrial facilities expansion are normally considered important for economic development and social growth.

5. General Conclusions

It is important to take in consideration that the present work was not an exhaustive valuation study. The full value of the Mondego catchment cannot be calculated without taking into account all the direct and indirect use values, and without estimating the real wetlands value rather than focusing solely on market prices which may underestimate their real value. Our preliminary values may provide a starting point for a more exhaustive and detailed Mondego wetlands's valuation. Nevertheless, regarding the Mondego River Basin, seven main conclusions may be drawn:

1. Population growth have been pushing ecosystems' structure and functions toward a 'service society';
2. A progressive loss of natural and agricultural lands to development and service provision has been taking place;
3. Demands on ecosystems for recreational activities and aquaculture production have been increasing;
4. The introduction of exotic species are potentially able to cause substantial undesirable environmental effects (e.g. threats to biodiversity) or production values;
5. There is a clear need to evaluate the crucial link between land uses and water quality and quantity in order to achieve sound resource management;
6. Broader scales tended to mask local patterns (scale-dependency effect on ecosystem service evaluation);
7. It will be necessary to develop accurate cost-benefit analysis, taking also into consideration the ecosystems' indirect use values (through Net Present Value estimation).

Moreover, water management plays a crucial role in the provision and delivery of all considered services and goods. It is a vital parameter to obtain economic efficiency, environmental protection, and sustainability (Turner *et al.*, 2004). According to Turner & Dubourg (1993), there are three key issues regarding water management:

1. Water is generally non-substitutable;
2. Water faces rising overall demand and intensification of use;
3. Water has limits to use, that should be well defined to obtain a sustainable use of this resource.

Along with water management and protection, an accurate biodiversity asset evaluation is required in order to better understand what ecosystem services and goods essential for the wellbeing of human populations can be supplied. Indeed, both resources are fundamental to an ecologically sustainable social and economic growth and development.

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ABSTRACTS

APERÇU SUR LE COTÉ SOCIAL L'EAU DANS LE NORD-OUEST MAROCAIN: L'EXEMPLE DES BASSINS OUED LAOU ET TAHADDART

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Les caractéristiques physiques, la nature et l'importance du potentiel hydraulique, combinées aux autres facteurs déterminant dans l'un et l'autre bassin, font que le côté social dans ces deux bassins se caractérise par une grande diversité et richesse de cas et de modèles montrant les façons dont les populations se comporte et agissent envers l'élément eau. En effet, l'approche de ce thème permet de dévoiler certaines représentations et attitudes sociales, spatiales, environnementales… inscrites dans la mémoire collective à travers le temps et l'espace. Le savoir traditionnel, se rapportant à l'eau, dans le territoire étudié a été acquis, et continue de l'être, au fil du temps. Il englobe tous les aspects de cet élément: biophysiques, économiques, sociaux, culturels et spirituels. Ce savoir est transmis oralement ou écrit au moyen de dictons, proverbes, contes, écrits ... ainsi que par des actions et des observations.

La communication tente d'aborder la question sociale de l'eau à partir de plusieurs axes:

- L'importance du patrimoine hydraulique, dont on va traiter le côté matériel (types de points d'eau, architecture des ouvrages hydrauliques…), les traditions, la toponymie hydrique…;
- Le savoir traditionnel et gestion de l'eau: types de partage traditionnel de l'eau d'irrigation entre les ayants droits, sachant que plusieurs mesures d'adaptations ont été adoptés dans plusieurs terroirs;
- Le comportement de la population vis-à-vis de l'eau et la question du genre dans l'aire de l'étude. Comment les personnes âgées, qui sont les principaux détenteurs du savoir, et qui ont un sens aigu de l'observation des tendances et des changements subtils de l'écosystème, réagissent face aux mutations hydrauliques ?;
- L'accès à l'eau potable dans l'aire de l'étude. Cet axe permettra de faire le point sur les différentes instances et responsables de l'eau (mobilisation, distribution, assainissement…) sans oublier le rôle de la société civile dans le domaine. Le degré d'équipements de base du logement dans les deux bassins est un indicateur d'un grand intérêt à ce niveau;
- Problèmes hydriques: l'accent est mise sur la gestion du quotidien, les conflits d'usage de cette ressource naturelle entre l'amont et l'aval dans chaque bassin, entre les ayants droits et les services officiels ..., la concurrence entre les secteurs de consommation, les maladies hydriques et mesures de soin…;

En conclusion, la communication essaie de tracer des lignes de recherches sur certains questions/problématiques dans le rapport Homme-Eau-Espace dans certains pays de la Méditerranée, et qui nécessitent des approfondissements.

Felicita Scapini, Jean-Marc Boffa, Elisabeth Conrad, Louis F. Cassar and Mariella Nardi (editors), *Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socio-economic and environmental analysis of changes and trends to enhance and sustain stakeholder benefits*, ISBN 978-88-6453-015-4 (online)

DIVERSITY OF TERRESTRIAL ISOPODS AT THE NAHLI PARK (NORTH-EAST OF TUNISIA)

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In Tunisia, most studies on the biodiversity of woodlice were restricted to records of individual species, their geographical distribution and their ecological preference. In fact, only few investigations have been carried out relating to the structure of terrestrial isopod communities. In this present work, we have assessed the diversity of terrestrial isopods according to habitat and altitude at the Nahli Park. We selected 3 habitats for sampling: (i) a dense maquis of *Pistacia lentiscus, Rosmarinus officinalis, Erica multiflora, Globularia alypum, Callycotome villosa* with some trees of *Pinus halepensis*, (ii) a degraded maquis of *Erica multiflora, Pistacia lentiscus,* and *Juncus* sp. with some *Pinus halepinsis,* and (iii) a forest of *Eucalyptus* sp., *Pinus halepensis, Erica multiflora, Pistacia lentiscus* and *Juncus* sp. Sampling was carried out in May 2006, January 2007 and November 2007. In each site, specimens were collected in an area of 7.5 m^2, divided into 30 (0.5×0.5 m) quadrats which were randomly distributed. At the Nahli Park, 7 terrestrial isopods species, belonging to 3 families, Platyarthridae, Armadillidiidae, and Porcellionidae, were found. The sampled species belong to 5 biogeographical categories. Furthermore, they are not evenly distributed in the studied habitats; they varied in the number of species as well as in number of specimens. The community similarity estimated by the Bray-Curtis index shows that habitats are clustered according to vegetal associations.

THE QUALITY OF SUPERFICIAL WATER RESOURCES IN THE MEJERDA LOW PLAIN (TUNISIA)

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In order to evaluate superficial water quality in the Mejerda low plain, 120 water samples were collected from 8 stations along the Mejerda River, 1 station along the Chaffrou River and 1 station along the Tlil River. All these stations are located downstream of potential polluters' effluents. One draw-off was effected monthly in every station, during the period from March 2007 to February 2008. The results of the physical, microbiological and chemical analysis of water revealed the absence of heavy metals, pathogenic micro-organisms and reduced nitrogenous components (ammonium NH4 and organic nitrogen). The high values of the COD and BOD parameters showed the existence of organic pollution downstream, the effluents of agro-alimentary industries and sewage purification stations. Moreover, chemical pollution resulted from the tanneries' effluents (high values of salinity and chlorides) in the unique Mejerda tributary, the Chaffrou River. Water quality evaluation was based on the superficial water grid multi-uses. According to this grid, we noted a deteriora-

tion of water's quality. In the upstream area of the Mejerda river, the water has a passable quality belonging to class 2, and can thus be allowed in drinking-water supplies after rigorous treatment. From the bridge El Battane to the river outlet, water's quality becomes mediocre (class 3) and is only suitable for irrigation.

LOCOMOTOR ACTIVITY RHYTHM OF *TALITRUS SALTATOR* FROM TWO GEOMORPHOLOGICALLY DIFFERENT BEACHES: KALAAT LANDALOUS AND OUED MEDJERDA (TUNISIA)

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The supra-littoral Amphipod *Talitrus saltator* represents an excellent bio-indicator of beaches' and coastal dunes' stability. The locomotor rhythm of this species was recorded in July and September from two beaches presenting a different balneal activity: Kalaat Landalous and Oued Medjerda, in order to study the effect of the summer season on the locomotor behaviour. Two experiments were undertaken simultaneously for the two areas. In each experiment, the individuals were registered during two different photoperiodic regimens, as 7 days simulating natural photoperiod and 7 days continuous darkness. The recording concerns adult individuals (N = 15) which were maintained isolated at constant temperature (18 ± 0.5°C). The mortality percentage of Kalaat Landalous beach population was equal to 0% as well as before and after summer. On the other hand, the Medjerda river population was characterized by an increasing mortality percentage; it is about 20% and 33% at July and September, respectively. The analysis of the wave forms showed that whatever the photoperiodic regimens or the season of recording, 3 major profiles were identified: unimodal, bimodal and multi-modal. However, it is the percentage of each profile which differs. In addition, the periodogram analysis showed that the periods of the locomotor rhythm under LD conditions are close to 24h and are longer in free running conditions.

BIODIVERSITÉ, FONCTIONNEMENT ET ÉTAT DE LA QUALITÉ ECOLOGIQUE DES STRUCTURES BENTHIQUES DE L'ESTUAIRE DE TAHADDART

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L'étude de la macrofaune benthique de l'estuaire de Tahaddart, s'inscrit dans le cadre du projet WADI. Elle se propose d'apporter des éléments de réponse aux

objectifs attendus par le workpackage 1 (description qualitative du système), le workpackage 2 (description quantitative du système) et le workpackage 3 (évaluation des impacts sur les différents compartiments). Les recherches menées sur ce compartiment biologique concernent la zone intertidale estuarienne essentiellement. Elles sont basées sur une approche spatiale (31 stations échantillonnées en juin 2006), d'une part, et temporelle (17 stations prélevées entre juin 2006 et juin 2007), d'autre part. La faune benthique de l'estuaire de Tahaddart compte 67 espèces réparties sur 10 groupes zoologiques et dominés par les Mollusques, Crustacés et Polychètes. Elle s'apparente globalement à celles des lagunes et estuaires nord-atlantiques marocains. L'originalité est, toutefois, son organisation en trois communautés bien distinctes (similarités ne dépassant guère 30%) sans continuum biologique caractéristique des écosystèmes côtiers semi-fermés, notamment les estuaires. Les trois communautés identifiées, se succédant de l'aval vers l'amont, correspondent à la communauté à *Eurydice pulchra – Bathyporeia nana* installée sur un fond sableux, la communauté à *Upogebia pusilla – Carcinus maenas* sur fond vaseux avec présence de *Zostera noltii* et la communauté à *Hediste divesicolor – Scrobicularia plana – Cyathura carinata* des fonds vaseux non végétalisés. La communauté à *Upogebia pusilla – Carcinus maenas* s'est avérée la plus diversifiée et la mieux structurée. L'habitat sédimentaire, les herbiers de *Zostera noltii* et la bioturbation seraient les éléments clés du fonctionnement actuel et de la structuration des communautés benthiques de l'estuaire de Tahaddart. L'état de la qualité écologique de l'écosystème benthique a été réalisé à l'aide de l'AMBI et du M-AMBI. Les résultats obtenus plaideraient en faveur d'un bon état écologique. Ceci a été confirmé par les résultats obtenus, aux mêmes stations biologiques, par l'étude géochimique des sédiments et par les mesures de potentiel Redox. L'intégration de tous les résultats se rapportant à l'écosystème benthique de l'estuaire témoignerait d'une légère accumulation de matière organique et d'un recyclage complet des nutriments dans l'estuaire de Tahaddart. Celui-ci est donc peu perturbé et les connaissances acquises sur le compartiment benthique dans le cadre du projet WADI serviront, en toute connaissance de cause, d'état de référence dans tout programme de suivi ultérieur.

LES MACROINVERTEBRÉS AQUATIQUES DU RÉSEAU HYDROGRAPHIQUE LAOU ET DU PARC NATIONAL DE TALASSEMTANE (RIF, MAROC): BIODIVERSITÉ, DEGRÉ DE VULNÉRABILITÉ ET ÉTAT DE CONSERVATION

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Les écosystèmes aquatiques continentaux sont parmi les écosystèmes les plus sensibles aux altérations humaines et aux changements climatiques notamment ceux situés dans les régions côtières. Le bassin versant Laou, le plus important

cours d'eau du Rif occidental méditerranéen, est un site revêtant une originalité incontestable. Il trace son chemin sur 70 Km, vers la mer à travers d'impressionnantes gorges tout en étant dominé par des falaises majestueuses. La géomorphologie et le climat de la région ont favorisé la mise en place d'une faune et flore singulière, en terme de diversité, d'endémismes et de rareté. Tout ces particularismes en terme de formations géologiques, paysagères comme par ses composantes faune et flore, ont fait qu'une grande partie de ce bassin versant est incluse dans l'aire protégée la plus originale du Rif occidental: le parc national de Talassemtane "PNTLS", lequel fait également partie de la première Réserve de Biosphère Intercontinentale de la Méditerranée Occidentale "RBIMO". Dans le but de compléter et d'actualiser l'information sur la diversité des macroinvertébrés aquatiques du bassin versant Laou et du parc national de Talassemtane, une série de prospections hydrobiologiques ont été menées dans les différents habitats types jalonnant les deux sites. L'analyse du degré de vulnérabilité des espèces recensées a permis l'identification des espèces hautement menacées. En outre, l'état actuel de conservation et les principaux impacts auxquels sont soumis ces écosystèmes aquatiques sont également déterminés.

ASSESSING EROSIONAL IMPACTS AT COLLELUNGO, PARCO REGIONALE DELLA MAREMMA

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Coastal dune fields represent a dynamic geomorphological environment, dependent both on processes occurring within their immediate area, as also on processes occurring much further afield within the watershed, for their survival. In the Collelungo area of the Parco Regionale della Maremma, coastal dunes not only provide a habitat for the endemic *Limonium etruscum* as well as a suite of other species, but the adjoining beach also constitutes an important socio-economic resource. Time-series plots of dune transects were constructed at 4 selected stations along the Collelungo area, based on readings taken in 2003, 2005, 2006, 2007 and 2008. The aim was to evaluate changes in the extent and spatial morphology of the dune system at Collelungo over time, thus enabling relative measurement of change, identification of trends and prediction and assessment of impacts. Qualitative evaluation of vegetation cover was also undertaken. Results indicate different trends in different parts of the beach, with erosion being evident in areas closer to the mouth of the Ombrone River, and accretion occurring in the direction of longshore drift. There is also evidence of salt-water incursion into the freshwater aquifer in the area, and challenges can be expected to be magnified in the light of climate change, particularly given the immense socio-economic difficulties involved in modifying activities in the large watershed area of the Ombrone.

ASSESSING IMPACTS IN MEDITERRANEAN WATERSHEDS: WADI LESSONS

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Watershed issues in the Mediterranean can be considered in two ways: (i) as site-specific factors dependent on the unique geomorphology, ecology and social context of each watershed, or (ii) as pan-Mediterranean issues that transcend individual sites. In the case of the latter, several such factors were identified through research conducted within the ambit of the WADI project. These include the critical links which often exist between biological resources and watershed dynamics, land use conflicts within the watershed, the range of demands and pressures placed upon watersheds, economic and social dependence on the watershed for activities and services, as well as the political difficulties involved in managing watersheds due to the fact that these often span local, regional and national jurisdictions and are the subject of fragmented responsibilities. The resources and services rendered by watersheds can be conceptualised as four priority compartments, namely biodiversity, land, ecosystem services and water. These are nested within a framework of biophysical and anthropogenically-induced pressures. Management needs to act outside this system boundary to address watersheds holistically. Trade-offs will be inevitable in managing watersheds, and negative impacts cannot be avoided. However, there is also strong potential for developing management systems based on subsidiarity which render socio-economic benefits for locals.

RE-ASSESSING ENVIRONMENTAL CHALLENGES IN OUED LAOU, NORTHERN MOROCCO

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In 1998, an assessment of environmental challenges in the Rif mountains of northern Morocco was carried out by Moore, Fox, Harrouni and El Alami. The authors identified population growth as a driving force of environmental pressures in the region, with the latter falling into three main categories, specifically (i) non-sustainable use of natural forests, (ii) changes in the agricultural system, and (iii) *Cannabis* cultivation. Through research conducted within the ambit of the WADI project, the environmental situation in Oued

Laou was reviewed, with the aim of evaluating changes and trends since the 1998 assessment, and in order to identify key management issues. Clearance of natural forests appears to persist as a problem, also leading to secondary impacts of gullying, soil erosion and sedimentation of water bodies. Agriculture also appears to be expanding into more marginal areas, as does the cultivation of *Cannabis*, both also contributing to accelerated soil erosion. In addition, a new and substantial pressure was identified, namely urbanization, which poses a major threat to the landscape character of the Oued Laou area. The study provides several pointers for management, including the need for addressing problems at a broad landscape scale and in a holistic manner, including not only conservation aspects but also socio-economic components. It is suggested that appropriate planning concepts, such as that of biosphere reserves, may be well suited to the Oued Laou area.

DIVERSITE ET DISTRIBUTION DE QUELQUES ARTHROPODES LITTORAUX DE QUATRE PLAGES DU N-E DE LA TUNISIE

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La diversité des peuplements d'arthropodes littoraux ainsi que la densité et la distribution spatiale des talitridés semi-terrestres ont été étudiées pendant la même saison (Mars 2008) au niveau de quatre plages voisines de la basse vallée de la Majerda. Ces plages, diffèrent par quelques structures morphologiques notamment la présence de ports et par le degré de fréquentation. En effet, les deux plages de la région de Kalaat Landalous, dont l'une située au niveau du port, sont étroites, distantes de quelques centaines de mètres et dépourvues de dunes bordières mais limitées par une sebkha occasionnellement couverte par les eaux des pluies. Les deux autres plages, celles de Sidi Ali El Mekki et du port de Ghar El Melh, sont bordées par quelques petites dunes bordières séparant la plage de la lagune. Les résultats ont montré que la plage du port de Kalaat Landalous abrite l'effectif le plus élevé en arthropodes probablement dû à la faible fréquentation de cette plage. Pour la région de Ghar El Melh, la plage de Sidi Ali El Mekki renferme plus d'insectes que celle du port, tandis que la plage du port abrite plus de talitres. La sex ratio des talitres de ces deux plages est en faveur des femelles. Deux espèces de talitres, *Talitrus saltator* et *Talorchestia brito* sont présentes au niveau des 2 plages de Kalaat Landalous avec un effectif plus réduit dans la station plage du port. Dans les 2 stations, Talorchestia brito est plus abondante que Talitrus saltator. La distribution spatiale des talitres diffère d'une plage à l'autre en fonction de la richesse en sable, de la présence ou non des dunes bordières, de la morphologie, de la nature et du degré de fréquentation de la plage. Les talitres occupent les endroits les plus humides et les moins érodés.

ÉTUDE DE LA QUALITÉ DE L'EAU DE DEUX BASSINS VERSANTS NORD MAROCAINS: LAOU & TAHADDART

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Ce travail porte sur l'étude de la qualité biologique de l'eau par le biais des macroinvertébrés benthiques de deux bassins versant rifains (Nord du Maroc) Laou & Tahaddart, en appliquant comme indice biotique l'IBMWP adopté par la péninsule ibérique. Afin d'évaluer la fiabilité de cette indice biotique, nous avons réalisé en parallèle une étude sur la qualité physico-chimique et microbiologique. Les résultats obtenus montrent que les cours d'eau du bassin versant Laou sont en général de bonne qualité biologique (classe I & II) et physico-chimique (classe I & II). Ce sont surtout les stations situées en milieux naturels, à l'abri de tout impact humain. La baisse de la qualité des eaux dans les stations situées en aval des petites et des grandes agglomérations ne serait que la conséquence d'une perturbation du milieu. Celle-ci est due à la contamination des eaux par des rejets agricoles et urbains. De plus, la majorité des stations du bassin versant Tahaddart présentent également une qualité biologique et physico-chimique de classe I ou II. Toutefois, à partir de l'automne 2007, la qualité physico-chimique et biologique de 73% des stations du bassin versant Tahaddart a connue une dégradation très importante due d'une part à la sécheresse et à la dérivation des eaux et d'autre part au pâturage.

DISTRIBUTION DES AMPHIBIENS DU BASSIN VERSANT D'OUED LAOU (MAROC): IMPLICATIONS EN TERMES DE CONSERVATION

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Le bassin versant d'Oued Laou se trouve dans la région Nord-Ouest du Maroc, sur le littoral méditerranéen et occupe une superficie d'environ 930 Km^2. Il se situe entre deux cadres géographiques contrastés, le littoral et la montagne et se caractérise par la présence de climats allant du semi-aride au perhumide. Cette région présente un grand intérêt biogéographique, paysager et de biodiversité et possède une diversité exceptionnelle aussi bien en flore que faune. Neuf espèces d'amphibiens ont été détectées dans le bassin versant d'Oued Laou, ce qui représente 70% de l'ensemble des espèces présentes au Maroc. Il s'agit d'un des groupes d'animaux les moins étudiés au Maroc, et qui ne bénéficie d'aucun type de protection légale dans ce pays. L'importante diversité en amphibiens observée dans le bassin versant d'Oued Laou est le résultat de la grande diversité d'habitats qui caractérise cette région. Les zones les plus riches sont Jbel Kelti, Bou Hachem et le sud ouest du bassin versant (9 es-

pèces). Ces zones sont incluses dans le Parc National de Talassemtane et le sibe de Bou Hachem. Les espèces les plus rares sont *Pleurodeles waltl* et *Pseudepidelea viridis*. Les plus abondantes sont *Bufo mauritanicus* et *Pelophylax saharicus*. Les espèces les plus menacées sont *P. waltl*, *Salamandra algira* et *Alytes maurus*. Les principales menaces qui pèsent sur les amphibiens d'Oued Laou sont la déforestation et la pollution de l'eau. Les mesures de protection à prendre sont l'élaboration de textes législatifs incluant les amphibiens au Maroc et la prise en considération des amphibiens et de leurs habitats dans la zonation des aires protégées du bassin versant de Oued Laou.

DIVERSITY AS A TOOL TO FACE ENVIRONMENTAL VARIATION. TWO CASE-STUDIES ON THE MOROCCAN SANDY SHORES

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The shores of Northern Morocco are subject to different kinds of pressure, the on-going development plans for this Region on the one hand, and the natural environmental conditions on the other. The behaviour of species inhabiting sandy shores is known to be related to environmental changes. In this research we studied sandhopper behaviour displayed at a wadi mouth, which is a transitional environment, to unravel the links between environmental variation and behavioural adaptation. The set of environmental conditions was represented by the two WADI study sites in Northern Morocco, one on the Mediterranean shore (Oued Laou) and the other on the Atlantic one (Asilah). Each site included a wadi mouth and different environmental conditions characterising the two banks. Behavioural tests on the local amphipod populations were carried out at the two sites on both wadi banks before and after summer, identified as the critical season. The results obtained from these experiments highlighted a high diversity, in terms of sandhopper species, seasonal patterns of abundance, and behavioural strategies. Such diversity, at different nested levels, is displayed at local scale and may represent a buffer for ecosystem resilience to the on-going changes, most of them connected to the human uses of the sandy beach resource.

DIVERSITY OF THE TERRESTRIAL ISOPODS IN THE TAHADDART CATCHMENT AREA (NORTH-WEST OF MOROCCO)

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In North Africa, only few studies on the diversity of terrestrial isopods communities have been performed. Till the 20th century, some lists of woodlice species were established in different countries of this region and about 90 species were

mentioned. More recent investigations were focused on the systematic, the geographical distribution of some common genera, *Porcellio, Porcellionides* and *Armadillidium*. Within the framework of MEDCORE and WADI projects, the terrestrial isopod diversity in some regions of Tunisia and Morocco has been investigated. In this presentation, we focused on the woodlice diversity at the Tahaddart area according to plant associations. Sampling was carried out in May 2008 in 12 natural habitats: 4 sites with forest vegetation, 3 sites with maquis vegetation, 4 sites with meadow vegetation and 1 site, near the river mouth with halophilous plants. In each habitat, specimens were hand collected by the three authors during a period of one hour and preserved in 70° alcohol and then identified. In the Tahaddart area, 2454 specimens belonging to 19 species and 7 families (Tylidae, Philosciidae, Halophilosciidae, Armadillidiidae, Armadillidae, Platyarthridae and Porcellionidae) were collected. These species, variously distributed in the different habitats, allowed us to compare the abundance, the diversity and the distribution pattern of these isopods between the 12 habitats. Diversity is quite high in the different studied habitats; the highest value was observed in open areas. The latter are also the most balanced habitats. The community similarity estimated by the Bray-Curtis index shows that habitats are clustered according to plant association.

NUMERICAL IMPORTANCE OF WATERBIRD POPULATIONS WINTERING IN WADI SITE (TUNISIA)

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Information on of the individuals number in a population represents some of the most basic data needed to conserve populations. Over the past decades, many waterbird populations have undergone rapid changes in number as well as in distribution in response to the creation of refuges, man-made wetlands and climate change. These continuing changes need to update population estimates on a regular basis. Consequently, 25, 375, surveys of wintering waterbirds in wetlands belonging to WADI site were carried out. During 2006-2007 and 2007-2008 winter periods, a total of 25,375 individuals and 44 species were detected belonging to 8 orders and 16 families which were mainly occurring in flocks. Charadriiformes are the most abundant taxonomical group with 14,097 individuals (55.55 % of the total) as well as the most diverse with 23 species (52.27% of the total). The most abundant species accounted for more than 92.01 % of the total abundance were *Phoenicopterus ruber* (33.89%), *Calidris alpina* (24.71%), *Vanellus vanellus* (12.24%), *Calidris minuta* (9.88%), *Tadorna tadorna* (5.91%), *Larus ridibundus* (3.09%), *Tringa totanus* (1.24%) and *Anas clypeata* (1.04%). Furthermore, only sebkhat Ariana site satisfied three selection criteria of the Ramsar Convention (Ramsar 2005: criteria 2, 5 and 6) confirming its international importance in the conservation of waterbirds populations. Indeed, the carrying capacity of this site is higher than 2,000 individuals with the presence of one threatened species (*Oxyura leucocephala*) and two species wich constitute more than 1% of the original population (*Tadorna*

tadorna and *Phoenicopterus ruber*). However, the continuing changes on the WADI wetlands structure cause a general perturbation of the considered winterquarter and its avifauna. Thus, it's essential to use appropriate management strategies to enhance the value of this area for the waterbird species, which were very sensitive to habitat productivity changes.

A PRELIMINARY SPATIAL ANALYSIS OF THE POPULATION OF *LIMONIUM ETRUSCUM* ARRIGONI ET RIZZOTTO AT PARCO DELL'UCCELLINA, TUSCANY, ITALY

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A population of *Limonium etruscum* Arrigoni et Rizzotto was subject to a preliminary spatial analysis in its type locality at the Parco dell'Uccellina on the coastal fringe between Marina d'Alberese and Collelungo. Occurrence of this plant was investigated along a number of permanent belt transects extending inland from the shoreline up to a perpendicular distance of 150m. Field data was initially collected as presence/absence of the species within a $1m^2$ square quadrat at replicate points along each metre-interval of a transect and subsequently amalgamated into cumulative occurrence counts for each five-metre interval. Individual plants were recorded within a range of 51m to 138m from the shoreline with peak abundance being attained in the 100m-120m interval and decreasing very sharply further inland. The abundance of *L. etruscum* as highly correlated with salinity of the substratum ($r=0.86$; $n=19$). The spatial distribution of plants on scales of $100m^2$ was described through calculation of a T-Square Index and resource usage of individual plants estimated using Voronoï tessellations. Values of the T-Square Index suggested uniform to overdispersed distributions of individuals, whilst analysis of Voronoï tessellations did not indicate any correlation between dimensions of individual plants and the area of substratum utilized.

SPATIAL DISTRIBUTION AND INTERANNUAL VARIATION OF MACROPHYTIC VEGETATION COLONISING THE SAND DUNE SYSTEM AT CALA FRANCESE, COLLELUNGO IN THE MAREMMA NATIONAL PARK, ITALY

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The macrophytic vegetation of the sand dune systems colonising the sand dune system at Cala Francese was censused in July 2006 and April 2007 in order to determine patterns of spatial distribution and interannual change in the communities

sampled. Vegetation cover was investigated along a number of permanent belt transects extending inland from the shoreline up to a perpendicular distance of 150m. Field data was initially collected as presence/absence of macrophytes within a $1m^2$ square quadrat at replicate points along each metre-interval of a transect and subsequently amalgamated into cumulative occurrence counts for each metre interval. Exploratory analysis using NMDS suggested the presence of three distinct clusters of spatial points, corresponding to distinct vegetational zones in the field. Separation along Component I indicated a cluster of points corresponding to nearshore sampling units correlated with the occurrence of *Ammophila arenaria, Euphorbia paralias* and, particularly, *Xanthium italicum*. A second cluster corresponding to sampling units situated behind the crests of the dune was also indicated by separation along Component I and was strongly correlated with the occurrence of *Limonium etruscum, Juncus acutus* and *Inula crithmoides*. A third cluster, indicated by separation of the second cluster along Component II, was correlated with the occurrence of *Pinus* sp., *Juniperus oxycedrus* and *Erica arborea*. The three clusters were detected during both years of this study and their superimposition suggests very little interannual change in community structure and composition. Data from another study in this volume (Chelazzi et al.) suggests a strong correlation between salinity of the substratum with the occurrence of the cluster comprising *Limonium etruscum*, *Juncus acutus* and *Inula crithmoides* whilst differences in species composition between the *Ammophila arenaria/Euphorbia paralias/Xanthium italicum* zone and the *Pinus* sp./*Juniperus oxycedrus/Erica arborea* zone are attributable to stability of the substrate.

PATRIMOINE DE L'EAU, PATRIMOINE DES HOMMES ET DE LA CULTURE MEDITERRANÉENNE ET MONDIALE

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Dans la partie de la recherche pluridisciplinaire WADI (Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socio-economic and environmental analysis of changes and trends to enhance and sustain stakeholders benefits), un intérêt non secondaire affronté par les géographes était orienté vers une approche culturelle de l'eau (Cultural Geography, Water uses heritage, Hydraulic Archaeology), c'est-à-dire l'étude des biens matériels et immatériels des différents usages ou pratiques de l'eau, dignes d'être repérés et classés, étudiés et sauvegardés, soit l'archéologie hydraulique, nouveau filon de la culture, digne d'être rangé parmi le patrimoine culturel de l'humanité de l'UNESCO (Maury, 2008). Ici la recherche a porté non seulement sur quelques sites WADI (El Hondo, Elche; Valle de Rio Mondego Coimbra), mais aussi, sur de nombreux cas et situations dans des pays méditerranéens (du Maroc et du Portugal à la Turquie et l'Iran, des pays MENA et au-delà) et du monde (Europe, Canada, Amérique du Sud, Chine, etc.), hors cadre de recherche WADI et sur de nombreuses années, selon un filon de recherche nouveau, en cours de définition (Maury, colloque Napoli, 2005), qui nécessite une méthodologie pluridisciplinaire (interdisciplinaire?) d'étude et d'inventaire, et une action forte sur le terrain, au-delà de réalisations ponctuelles remarquables ci et là, une sensibilisation accrue pour le repérage et la valorisation des biens matériels et surtout immatériels.

L'exemple de El Hondo et surtout l'action ponctuelle de la sauvegarde d'un patrimoine en péril de la "Sociedad de Riegos El Progreso" démontre la possibilité d'action suivie et concertée entre experts et responsables locaux, société civile et medias (Paper Martín-Cantarino, Maury, 6th WADI International Meeting, Coimbra, 2007). Signalons que l'Espagne offre déjà, entre Catalunya, Levante, Murcia et l'Andalucia, une bonne dizaine de museos de l'agua, et quelques dizaines en Europe: France, Belgique, Allemagne, Grande-Bretagne, Autriche, Suisse, etc.), aussi en Iran, Amérique (New York) – un nouveau à Coimbra au Portugal, et probablement d'autres initiatives du genre dans les zones d'étude du programme WADI. Quant à la Vale do Mondego (Portugal), des efforts concrets locaux devraient être approfondis (Penacova), comme d'ailleurs dans le monde entier, où une multitude d'actions locales (publiques ou privées ou associatives) devraient être articulées en un parcours culturel et social, auquel doivent être associés des acteurs multiples (experts, décideurs, mais aussi de précieux témoins) mettant en jeu intérêts économiques et dynamiques sociales locales, comme la transmission du savoir-faire, de la culture matérielle.

Soit un parcours allant de la ruine (du bien) ou de l'oubli (de pratiques) jusqu'à la juste et digne valorisation d'un ensemble reconnu de biens matériels et immatériels liés aux usages de l'eau, comme mémoire active de la culture de l'eau, dans le cadre du développement soutenable.

LE TERROIR RAMLI DE GHAR EL MELH (TUNISIA): PEUT-IL RESISTER ENCORE LONGTEMPS ?

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Les résultats obtenus grâce aux observations géomorphologiques et à l'enquête socio-économique, surtout à travers les questions relatives aux tendances, à la perception de la population de son environnement et à son attachement au terroir ainsi qu'aux différents risques naturels actuels ou annoncés pour les prochaines décennies, ne sont pas toujours rassurantes quant à l'avenir du terroir Ramli. Ce terroir a déjà subi différentes mutations et montre des signes de dégradation souvent suite à des interventions humaines imprévoyantes qui n'ont cessé de se multiplier au cours des dernières décennies Plusieurs parcelles ont disparu, d'autres sont abandonnées et des formes de dérèglement commencent à se multiplier menaçant de conduire vers des situations de rupture dans des composants naturels ou humains essentiels pour l'équilibre du système. Outre les différents problèmes et difficultés rencontrés par les propriétaires (rendements, coût de l'exploitation, main d'œuvre, pénurie en matériaux nécessaires au renouvellement et à l'entretien du sol, …), les menaces viennent des caractéristiques sociodémographiques

de la population directement impliquée ainsi que du développement, au moins dans certains secteurs du terroir, d'une nouvelle perception de l'espace qui tend à privilégier la vocation touristique du site au détriment de l'activité agricole. Le site est également guetté par différents risques naturels pour lesquels les fellahs ne sont pas toujours préparés. Outre les transformations, par érosion ou par progradation, du cordon littoral qui s'interpose entre le complexe lagunaire et la mer, il est d'une grande vulnérabilité à l'éventuelle élévation marine annoncée pour les prochaines décennies. Des éléments de solution peuvent être déjà recherchés chez les intervenants dans le terroir, surtout les vieux d'entre eux et qui sont à la fois propriétaires et natifs de la région. L'enquête révèle qu'ils ont été jusque là capables d'adapter leurs techniques aux modifications survenues au niveau de la dynamique du milieu. L'enquête révèle aussi que le savoir faire peut exister aussi chez les moins âgés. Mais la population encore vraiment attaché au sol, bien expérimentée et ayant une bonne perception de son environnement est de plus en plus rare. Quelques recommandations seront avancées en vue de permettre à ce terroir d'échapper à la déprise totale et de conserver son originalité et son attrait.

LE TERROIR RAMLI DE GHAR EL MELH (TUNISIA): LA POPULATION IMPLIQUÉE, LE TRAVAIL, LA PLACE DE L'ACTIVITÉ AGRICOLE DANS L'ÉCONOMIE FAMILIALE ET LES CONTRAINTES

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Dans le cadre des activités du Projet Wadi, une enquête socio-économique a été réalisée auprès des exploitants du terroir Ramli de Ghar El Melh. Le questionnaire, déjà présenté à l'occasion de réunions précédentes, est constitué de 148 questions organisées autour de 5 rubriques. L'enquête a touché 80 parcelles réparties sur les différentes parties du terroir. Dans cet exposé, nous avançons les résultats de la partie consacrée aux questions relatives aux aspects socio-démographiques et professionnels des interviewés et aux caractéristiques des parcelles exploitées ainsi qu'aux techniques et méthodes de travail du sol, à la place du terroir dans l'économie locale et aux contraintes évoquées par la population impliquée. Cette enquête révèle que la population travaillant dans ce terroir est exclusivement masculine, âgée et d'un niveau d'éducation souvent limité. Il s'agit toutefois d'une population qui continue assez majoritairement à maîtriser les techniques de la culture Ramli. Celle-ci échappe encore à la mécanisation, mais elle est déjà grande consommatrice des fertilisants chimiques et dépendante sur plus d'un plan (semences, marché, main d'œuvre, …). On découvre aussi que le travail du sol ne constitue pas la seule occupation. Ceci est expliqué par des raisons de rentabilité mais il est dû à la nature du site. L'exploitation des parcelles Ramli s'intègre dans un système agriculturepêche typique. Ce système est ancien et a longtemps permis des formes de régulation de l'économie familiale traditionnelle locale. Aujourd'hui, il connaît des difficultés d'ordres variés ; ce qui appelle à plus de vigilance si on veut que ce terroir puisse continuer à exister tout en conservant son originalité et sa valeur patrimoniale.

BEYOND WADI PROJECT – THE ISSUE OF COMMUNICATION

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The dissemination of the results obtained in the framework of projects funded by the European Commission has become more and more an issue because 1) the results obtained through public money must be accessible to the public also beyond the scientific community; 2) most relevant results from EC-funded projects remained ineffective. Therefore WADI has dedicated a specific work package, the WP5, to "dissemination" throughout the project, addressed to several levels of audience. The instruments developed have been adapted to the audience: to whom – what – how to communicate.

In the proposal we had identified the following target audience:

1) stakeholders;
2) researchers and interested students;
3) public;

Each audience contains different target groups, e.g., policy makers, managers, local people, men and women, school children, university students, etc…, to be identified in the contexts of the study sites. The contents of the dissemination should be selected among the project results looking for those relevant for the target group. A multidisciplinary project like WADI has produced results that can be of interest to various audience. Now the task is to develop and tune communication instruments to each target audience. This has been an issue throughout the implementation of WADI and the flow of information in some cases has been difficult.

A brain storming is needed within the partnership to evaluate communication efficiency and plan further dissemination actions of WADI.

ECOLOGICAL FUNCTIONING OF TRANSITIONAL WATER BODIES: FROM CONCEPTUAL AND MECHANISTIC MODELS TO MANAGEMENT

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The fact that about three billion people (half of the current global population) concentrates in only 200 km of coastal zone, makes it easy to understand why this zone is also the one showing the fastest and most intense degradation trends among all earth's landscapes. Transitional water bodies (TWB), i.e., estuaries, semi-enclosed bays, lagoons, salt marshes, and coastal lakes, are under extreme stress owing to this high population density and their growing demand of various water uses. Within WADI project (Water Demand Integration; INCO-CT2005-015226), we have conducted extensive field ecological assessment in two important North African Mediterranean TWB: (1) a brackish water coastal lake, Lake Maryut, Alexandria, Egypt, and (2) a marine coastal lagoon, Ghar el Melh Lagoon, in Ghar el Melh, Tunisia. The study encompassed environmental and ecological assessment in all relevant compartments of the two ecosystems, i.e., the sediment, the water column and the biota, and used physiological, structural, and environmental descriptors. Special emphasis was placed on the macrophytic vegetation. The assessment allowed identifying the state of the ecosystems as they clearly fit well known ecosystem conceptual models. Both environments were found to be spatially highly inhomogeneous showing a mosaic distribution of sub-environments eventually fitting different models that might be representing transitions between ecosystem states. Lake Maryut (its main basin) was found to be a hypertrophic shallow lake with a total exclusion of submerged vegetation and, therefore with the autotrophic compartment situated in the water column. The severe anoxic status and high lead concentration on the water, makes imperative attentive consideration by the local authorities about the safety of the various ecosystem services Lake Maryut is currently providing to the population. Suggestions for bioremediation plans have been initiated. This year, CEAB-CSIC established collaboration with the project ALAMIM (Alexandria Lake Mariout Integrated Management; MED/2005/110-648) in order to couple their hydrological information with our ecological data base aiming to end up with an integrated mechanistic model (PCLAKE) as a final tool for prediction of scenarios and defining management strategies.

Ghar el Melh Lagoon presented an interesting patchy composition of environments clearly governed by (a) the influence of the proximity to the opening to the sea, (b) the depth distribution over the lake, and (c) the wind forcing. These factors determined three main environments: (1) a shallow one with sparse seagrass coverage and clear waters close to the opening (NE), (2) a shallow environment dominated by opportunistic benthic macroalgae with clear waters and suitable for eel farming (NW and W), and (3) a deep environment with a high wind forcing and sediment re-suspension leading to turbid waters and extremely poor benthic vegetation coverage. In the overall, the health of the lagoon was considered to be good.

Although analytical works on samples of both TWB studied will be still in progress for 2 or 3 months after this meeting, the general pictures obtained together with the available literature, provided a largely sufficient pack of evidence indicating that it is time to favour investments in monitoring, bioremediation, and social awareness strategies, and to minimize those in scientific research.

SEASONAL PATTERN OF *CYMODOCEA NODOSA* BIOMASS AND RHIZOME GROWTH IN THE LAGOON OF GHAR EL MELH (TUNISIA)

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The annual growth and biomass cycle of *Cymodocea nodosa* (Ucria) Ascherson in the Ghar El Melh lagoon (north-east Mediterranean coast of Tunisia) during November 2006-November 2007 is described. Two sampling stations were selected, the first close to the communication channel with the sea and the second inside the lagoon. The vitality of the *Cymodocea nodosa* meadows in the two stations was compared according to shoot density, plant biomass and rhizome growth. The rhizome production was estimated by marking rhizome terminals. All data showed a clear seasonality. In general, maximum biomass and rhizome growth was reached in summer. The station under marine influence showed the highest value of shoot density (until 1083 shoot/m^2 in summer) and biomass (until 570 g/m^2 in summer); on the other hand, the rhizome growth was significantly higher in the second station (until 0.5 mm/day in summer).

APPORT DE LA GÉOPHYSIQUE POUR LE CONTRÔLE DE L'INTRUSION MARINE DANS L'AQUIFÈRE CÔTIER D'OUED LAOU (NORD DU MAROC)

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Le contrôle de l'intrusion d'eau salée marine dans les aquifères côtiers est essentiel pour une prévision à un stade précoce de la détérioration des eaux souterraines. Cette salinisation peut mettre en danger la qualité de l'eau des puits et des forages. Ce contrôle implique la conception de réseaux de suivi et de stratégies d'échantillonnage en utilisant à la fois des méthodes directe et indirecte. Les méthodes directes se résument dans la mesure des eaux souterraines en prélevant directement les points d'eau (piézomètres ou puits), alors que les méthodes indirectes se basent essentiellement sur des campagnes géophysiques tel que la méthode électrique et électromagnétique. Dans le présent travail, une étude comparative des résultats obtenus à partir des méthodes géophysiques appliquées dans l'aquifère côtier d'Oued Laou (nord-est du Maroc) est présentée. Chaque méthode présente son propre utilité, ainsi que leurs complémentarités, pour détecter un début de l'intrusion d'eau salée qui affecte les zones côtières de l'aquifère d'Oued Laou.

IMPORTANCE DE LA BASSE VALLÉE DE LA MEDJERDA POUR L'AVIFAUNE EN TUNISIE

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La basse vallée de la Medjerda représente un ensemble complexe d'écosystèmes caractérisé essentiellement par la variété de ses ressources hydriques: des cours d'eau permanents et temporaires, des lagunes, des sebkas, des lacs collinaires, des barrages, etc. La région compte deux sites RAMSAR notamment la lagune de Ghar El Melh et l'embouchure de l'oued Medjerda et un site ZICO, celui de Garet Mabtouh considéré comme une zone importante pour la conservation des oiseaux selon les critères de BirdLife International. Cette importante diversité des habitats de la basse vallée de Medjerda se traduit par une richesse de sa faune avienne où plus de 80 espèces d'oiseaux ont été recensées, soit environ le quart de l'avifaune tunisienne. Ces espèces sont réparties en plusieurs groupes: les oiseaux d'eau, les passereaux, les rapaces et les oiseaux marins. Par ailleurs, le site abrite plusieurs espèces d'intérêt international et régional:

trois espèces globalement menacées, l'Erismature à tête blanche *Oxyura leucocephala*, le Busard pâle *Circus macrourus* et le Goéland d'Audouin *Larus audouinii*,

quatre parmi les 15 espèces protégées à l'échelle de la région méditerranéenne selon la convention de BONN; il s'agit du Flamant rose *Phoenicopterus ruber*, le Grand cormoran *Phalacrocorax carbo*, la Sterne Caugek *Sterna sandvicensis* et la Sterne naine *Sterna albifrons*.

Outre son importance pour l'avifaune sédentaire, la basse vallée de la Medjerda et plus précisément Jbel Ennadhour constitue l'un des sites les plus importants pour les oiseaux migrateurs en Tunisie. En effet, on peut y observer 12 espèces de rapaces et plus de 30 espèces de passereaux.

SCIENTIFIC RESEARCH INVESTIGATIONS ON *POSIDONIA OCEANICA* MEADOWS: AN EXPERIENCE OF ENVIRONMENTAL EDUCATION IN TUNISIA

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In the framework of MEDCORE and WADI projects on the ecology and management of Mediterranean coastal areas and water conservation, we decided to include the local dissemination of scientific investigations in Tunisia. This activity is destined to schoolchildren between 10 to 15 years old. Ours goal is to show the importance of the seagrass *Posidonia oceanica* as a high ecological and economical ecosystem and its importance as a bioindicator of water quality. Twenty workshops were organized between November 2007 and June 2008 for 1200 participants coming from several inshore cities of Tunisia (Governorate of Bizerte, Tunis, Ben Arous, Ariana, Nabeul, Monastir, Gabès and Medenine). A test was performed before and after the presentation on *Posidonia oceanica* ecosytems to evaluate schoolchildren's knowledge. Six hundred tests were usable showing the increase of schoolchildren knowledge on *Posidonia oceanica* meadows after the workshop. Participants seem to be concerned by environmental problems and motivated to change their environmental behavior.

PINNA NOBILIS LINNAEUS, 1758 POPULATION IN THE GHAR EL MELH LAGOON (TUNISIA): BIOLOGICAL CHARACTERISTICS

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The Ghar El Melh lagoon is one of the most important wetlands in Tunisia, and was declared a Ramsar site in 2007. In the framework of the WADI project a survey of the fauna in this lagoon indicated the presence of a young population of *Pinna nobilis* inhabiting in *Cymodocea nodosa* meadows mixed with *Ruppia* sp and *Nanozostera noltii* at -1 m depth. A study was conducted in the lagoon and 30 dead fan shells were sampled for the biometric study in the laboratory. The density of the population of *Pinna nobilis* was about 5,42 ind./100m^2. Seventy-six percent of pinnids have a total height between 20 and 30cm corresponding to an age of 2-3 years. Maximal age of the fan shell in Ghar El Melh is estimated at 4 years, and related to the widening of El Boughaz (lagoon-sea connection) and the improvement of water quality. Shells of *Pinna nobilis* oriented the opening of their valves preferentially in the direction of the marine current entering in the lagoon. Fauna associated to *Pinna nobilis* has been identified and 13 species have been counted. A relationship between the size of *Pinna nobilis* individuals and the number of sea urchin partners was noted.