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MEDITERRANEAN COASTAL LAGOONS: SUSTAINABLE MANAGEMENT AND INTERACTIONS AMONG AQUACULTURE, CAPTURE FISHERIES AND THE ENVIRONMENT

GENERAL FISHERIES COMMISSION FOR THE MEDITERRANEAN

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MEDITERRANEAN COASTAL LAGOONS: SUSTAINABLE MANAGEMENT AND INTERACTIONS AMONG AQUACULTURE, CAPTURE FISHERIES AND THE ENVIRONMENT

by

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PREPARATION OF THIS DOCUMENT

This publication has been prepared within the project "LaMed – Strengthening cooperation on fisheries and aquaculture management in the Mediterranean and the Black Sea" implemented by the General Fisheries Commission for the Mediterranean (GFCM) in 2011–2012 and funded by the Directorate General for Fisheries and Aquaculture of the Italian Ministry of Agricultural, Food and Forestry Policies (MiPAAF). The LaMed project was divided into two components:

- Component 1. Fisheries laws and regulations in the Mediterranean and the Black Sea
- Component 2. Mediterranean coastal lagoons management: interactions between aquaculture and capture fisheries

In particular, component 2 was designed and developed within the overall context of integrated coastal zone management (ICZM) and ecosystem approach from an aquaculture perspective. The main objective of this component was to explore issues related to the sustainable use of coastal lagoons in the Mediterranean area, taking into consideration the ecological features and intrinsic fragility of lagoon ecosystems and the variety of management strategies applied in different countries and at different times. The goal was to gather elements for the development of a sustainable management strategy, also through the preparation of guidelines to be translated in a Mediterranean action plan for coastal lagoons management, within the framework of the GFCM objectives and mandate. This document represents the main outcome of the project and offers a comprehensive – although not exhaustive – review aimed at providing background information and technical support to administrators, managers and decision-makers.

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ABSTRACT

The Mediterranean region hosts around 400 coastal lagoons, covering a surface of over 641 000 ha differing in both their typology and use. Fisheries and various forms of aquaculture have been traditionally carried out in Mediterranean coastal lagoons since ancient times and are part of the cultural heritage of the region. Traditional lagoon management linked to extensive aquaculture and fish harvesting has certainly contributed, over time, to preserve these peculiar ecosystems, although much of the coastal lagoon areas have progressively disappeared due to land reclamation and other uses. Recently, coastal lagoons have become a relevant environmental concern: land claiming, pollution and the lack of management, among other factors, have strongly modified both the structure and functioning of these sensitive coastal ecosystems. In particular, the management of traditional aquaculture and capture fisheries activities has been identified as the main instrument to maintain lagoons' ecological features and to prevent the degradation of their sensitive habitats, both from an environmental and socioeconomic point of view. To guarantee the sustainability of aquaculture and capture fisheries in lagoons, proper management plans should be established so as to ensure the preservation of both biodiversity and local knowledge. This should also be considered as a fundamental pillar for any programme aiming at the preservation and restoration of lagoons' environment.

This volume is divided into three main sections. The first part of the document (Part 1) gives an overview of the general context, with particular reference to the LaMed project carried out within the activities of the GFCM Committee on Aquaculture (CAQ) and to the main conclusions of an ad hoc expert meeting held in 2011, and presents a review of Mediterranean coastal lagoons summarizing the information obtained from literature and from country reports compiled within the project activities. In the second part (Part 2), eleven country reports collected from Albania, Algeria, Egypt, France, Greece, Italy, Montenegro, Morocco, Spain, Tunisia and Turkey are fully presented and offer an updated review of the state of Mediterranean coastal lagoons and of interactions among aquaculture, capture fisheries and the environment. Finally, five case studies are presented in the third part of the document (Part 3). These works have been selected by some of the experts of the LaMed project and provide insights on: 1) the lagoon of Venice, the most exhaustively studied coastal lagoon in the whole Mediterranean; 2) the Doñana area, an interesting example of productive wetlands dedicated to sustainable aquaculture in Spain; 3) the state of the European eel resource and its exploitation and elements for the preparation of a common management plan in the GFCM area; 4) the status of advice and management of European eel towards a stock-wide assessment and; 5) the indicators on the sustainability of Mediterranean coastal lagoons.

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ABBREVIATIONS AND ACRONYMS

ADD	Aquaculture Development Directorate (Albania)
AEWA	African Eurasian Waterbird Agreement
ANPE	National Agency of Environment Protection
APAL	Agency for the Protection and Management of the Littoral
CAQ	Committee on Aquaculture
CCRF	Code of conduct for responsible fisheries
CR	Country report
CRDA	Commissariat for agriculture development
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
EAA	Ecosystem approach to aquaculture
EAF	Ecosystem approach to fisheries
EAM	Environment and aquaculture in the Mediterranean
EC	European Commission
EFF	European Fisheries Fund
EIFAAC	European Inland Fisheries and Aquaculture Advisory Commission
EMP	Eel management plan
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FEAP	Federation of European Aquaculture Producers
FMO	Fishery management organization
GAFRD	General Authority for Fisheries Resources Development
GDP	Gross domestic product
GFCM	General Fisheries Commission for the Mediterranean
GIS	Geographic information system
IACF	Interaction between aquaculture and capture fisheries
IBA	Important bird areas
ICZM	Integrated coastal zone management
ICES	International Council for the Exploration of the Sea
Ifremer	Institut français de recherche pour l'exploitation de la mer
INRA	Institut national de la recherche agronomique
INRH	Institut national de recherche halieutique
INSTM	Institut des sciences et technologies de la mer
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IUU	Illegal, unreported and unregulated (fishing)
MARA	Ministry of Agriculture and Rural Affairs
MADR	Ministère de l’agriculture et du développement rural (Algeria)
MAP	Action Plan for the Mediterranean
MiPAAF	Italian Ministry for Agricultural,Food and Forestry Policies
MPA	Marine protected area
MRRH	Ministère de la pêche et des ressources halieutiques (Algeria)
NDF	Non-detriment finding
NGO	Non-governmental organization
ONDPA	Office national développement et protection aquacole, Spa (Algeria)
PCI	Principles, criteria, indicators
PDO	Protected designation of origin
RAC/SPA	Regional Activiy Centre for Specially Protected Areas
SCI	Sites of community interest
SGIPEE	Study Group on International Post-evaluation on Eels
SIPAM	Information System for the Promotion of Aquaculture in the Mediterranean
SPA	Special protection areas for birds
SPAMI	Specially protected areas of Mediterranean importance
SPZ	Special protection zone
SSB	Spawning stock biomass

SZC	Special zones of conservation
TLA	Traffic-light approach
Unesco	United Nations Educational, Scientific and Cultural Organization
WCED	United Nations World Commission on Environment and Development
WFD	Water Framework Directive
WGSC	Working Group on Site Selection and Carrying Capacity
WGSA	Working Group on Sustainability in Aquaculture
WWF	World Wild Fund for Nature

PART 1

MEDITERRANEAN COASTAL LAGOONS: A SYNTHESIS REPORT

1. GENERAL CONTEXT

1.1 Coastal lagoons within the framework of the GFCM

Within the GFCM framework, lagoon management and interactions between aquaculture and capture fisheries have been raising considerable interest over the past years. Already back in 1960 and 1973, two reports on brackish water aquaculture in the Mediterranean region were published (De Angelis, 1960; GFCM, 1973) and in 1983, a FAO/GFCM Expert Consultation on the Management of Coastal Lagoon Fisheries was held in Rome, Italy, to compile experiences on coastal lagoon fisheries management (Kapetsky and Lasserre, 1984). This compilation had been recommended in connection with the GFCM Symposium on the Management of Living Resources in the Mediterranean Area (Palma de Mallorca, Spain, 1980), held in conjunction with the fifteenth session of the GFCM. A FAO Fisheries Technical Paper, *Management of coastal lagoon fisheries and aquaculture in Italy* was then prepared by Ardizzone *et al.* (1988).

Later on, during the GFCM Consultation on the application of Article 9 of the FAO Code of Conduct for Responsible Fisheries (CCRF) in the Mediterranean region (Rome, July 1999), interactions and potential conflicts between resource users in the Mediterranean were highlighted. On this occasion, the role played by coastal lagoons as important elements for Mediterranean aquaculture in its extensive practices was recognized.

It became clear that within a sustainable use of natural aquatic resources, ecosystem interactions between aquaculture and capture fisheries had to be taken into consideration more thoroughly. In fact several commitments to a wider approach to fisheries and aquaculture management have been made in recent years, such as the implementation of the CCRF, the integrated coastal zone management (ICZM) approach and the ecosystem approach to fisheries (EAF) and to aquaculture (EAA) (FAO, 1995; 2004; 2005; FAO Fisheries Department, 2003; Cury and Christensen, 2005; Rice and Connolly, 2007; Soto *et al.*, 2008). Broad principles and approaches for effective and responsible fisheries and aquaculture management are contained in the CCRF, many of which relate to ICZM. The ICZM approach aims at establishing sustainable economic and social activities in coastal areas while protecting the coastal environment, by bringing together all the stakeholders involved in the development, management and use of coastal zones and factoring in their interests and responsibilities.

A preliminary commented inventory of the relationships between aquaculture and capture fisheries in the Mediterranean region was presented and discussed during the AdriaMed[1] technical consultation on "Interactions between aquaculture and capture fisheries", held in Rome (Italy), in November 2003 (Cataudella *et al.*, 2005). The discussion held stressed that interactions between aquaculture and capture fisheries had to be considered within their ecological, economic, social and governance dimensions in order to be correctly understood. It was also highlighted that a correct assessment of such interactions and the establishment of local and regional targets for conservation and management represented the basic steps towards the implementation of the ICZM approach and of the EAF/EAA.

Coastal lagoon areas are considered as some of the main environments where a sound knowledge of the interactions between aquaculture and capture fisheries is essential to assist the decision-making process towards the sustainable management of natural resources. Furthermore, the historical participation of the main actors of both capture fisheries and aquaculture in this process represents a key element for the physical conservation and the best utilization of natural resources in lagoon areas.

As a follow-up to the technical consultation, a review of selected issues related to the ecological dimension of interactions between aquaculture and capture fisheries was prepared (Cataudella

[1] AdriaMed project: Scientific cooperation to support responsible fisheries in the Adriatic Sea (FAO regional project GCP/RER/010/ITA).

et al., 2005) and a pilot study on interactions between capture fisheries and aquaculture was carried out in the Lezha lagoon complex, one of the most important coastal wetlands of Albania (Tancioni *et al.*, 2007), in order to provide an example of practical EAF/EAA application.

In 2005, an expert meeting on the "Re-establishment of the Network on Environment and Aquaculture in the Mediterranean (EAM)" (FAO, 2006) highlighted some crucial issues that should be addressed when dealing with interactions between aquaculture and capture fisheries, such as a better integration of aquaculture within coastal zone management and the need for an improved public image of aquaculture.

During the sixth session of the GFCM CAQ held in 2008 in Tirana (Albania), delegates acknowledged that the environmental degradation was underway in many coastal lagoons, most likely due to shortcomings in current management approaches. They also recognized that it was essential to revitalize the work carried out to date on lagoon management. On this occasion, and during the thirty-fourth session of the GFCM (Tunisia, 2009), the CAQ was asked to reconsider coastal lagoons and their management as a priority issue within its activities.

1.2 The LaMed-2 project

1.2.1 Objectives

In light of the clear gaps and needs in coastal lagoon regional management highlighted within the framework of FAO and GFCM over the years, the GFCM Secretariat drafted and submitted, in 2010, a project proposal on lagoons to be presented to the Directorate General for Fisheries and Aquaculture of the MiPAAF, which expressed particular interest is this topic and decided to fund the initiative within the component 2 of the LaMed Project (hereafter "LaMed-2").

The main objective of LaMed-2 was to:

> Explore the main issues in dealing with interactions between aquaculture and capture fisheries in Mediterranean coastal lagoons in its sustainability dimensions (environmental, economic, social and governance).

To fulfill this aim, an inventory of Mediterranean coastal lagoons was compiled to gather existing information on sites, their environmental features as well as human activities carried out within lagoons and in surrounding areas, with particular reference to aquaculture and capture fisheries. The scientific and technical outputs of the project were intended to be integrated into the GFCM decision-making process through the CAQ. The GFCM countries, as the main beneficiaries of the project, would thus have been provided with suitable background information for a better management of their coastal lagoons.

1.2.2 Project strategy and implementation

With the aim of exploring the main issues related to the interactions between aquaculture and capture fisheries in Mediterranean coastal lagoons, the LaMed-2 strategy consisted in assisting GFCM countries[2] in the process of analyzing the status of aquaculture and capture fisheries activities in coastal lagoons within ICZM and from an integrated ecosystem perspective.

The project was implemented at the Mediterranean level under the overall responsibility of the GFCM Secretariat. For activities to be carried out at the national level, cooperation was established between GFCM and the competent administrative and research institutions/departments for aquaculture development and the main responsibilities for project implementation were addressed (Fig. 1).

[2] Albania, Algeria, Bulgaria, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Japan, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Romania, Slovenia, Spain, Syrian Arab Republic, Tunisia, Turkey and the EU.

The participation in project activities or the provision of assistance from other ministries in charge of coastal lagoon management was coordinated in cooperation with the national GFCM/CAQ focal points. The project strategy also contemplated the participation of officers, local experts, research institutions and, whenever possible, local stakeholders and non-governmental organizations (NGOs) in the different activities. The project development also took advantage from activities carried out by the CAQ subsidiary bodies, with which strong links were established. An extensive recourse was made to the human resources and expertise available in CAQ working groups, namely the Working Group on Site Selection and Carrying Capacity (WGSC), the Working Group on Sustainability in Aquaculture (WGSA) and the Information System for the Promotion of Aquaculture in the Mediterranean (SIPAM). This optimized use of resources ensured a high level of countries participation in the implementation and follow-up of the project.

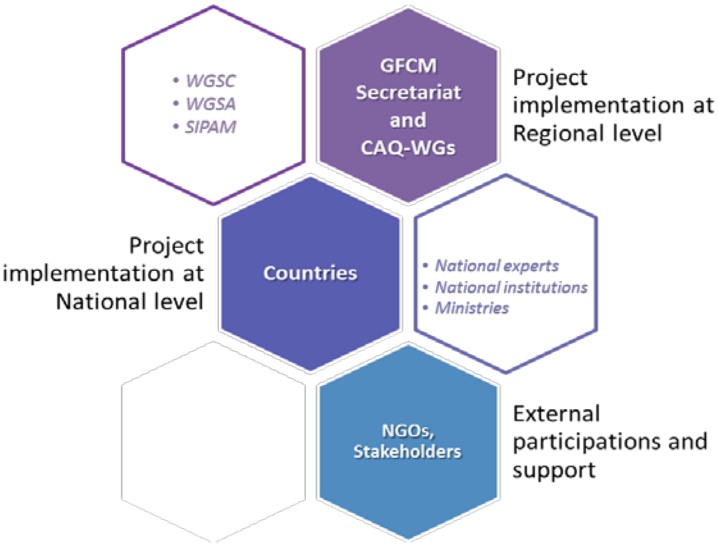


Figure 1. LaMed-2 strategy plan and cooperation mechanisms

The project started with the establishment of a network of experts in Mediterranean coastal lagoons – the LaMed-2 Expert Network – who worked together to carry out the project activities, starting from an inventory of lagoons in Mediterranean countries. Designated national experts prepared: i) **Profiles** for each coastal lagoon (or system of coastal lagoons in a specific geographic area) in their country, providing generalities and relevant information and ii) **Fact sheets** on selected lagoons providing typical examples of different lagoon typologies existing in their country (e.g. differences in ecology, management, ownership) or representing the major lagoons systems. Finally, the information gathered through profiles and fact sheets was collated into a final country report[3] placing particular emphasis on interactions among aquaculture, capture fisheries and the environment. During this process, the expert network convened a meeting on "Mediterranean coastal lagoons management: interactions between aquaculture and capture fisheries" (Cagliari, Italy, 28–30 June 2011) to further discuss major issues related to lagoon environment (Fig. 2). Progress was made towards the analysis and understanding of interactions among aquaculture, capture fisheries and the environment by integrating several studies and data on fisheries in coastal lagoons. The following paragraph outlines the main topics discussed and the main outcomes of the meeting.

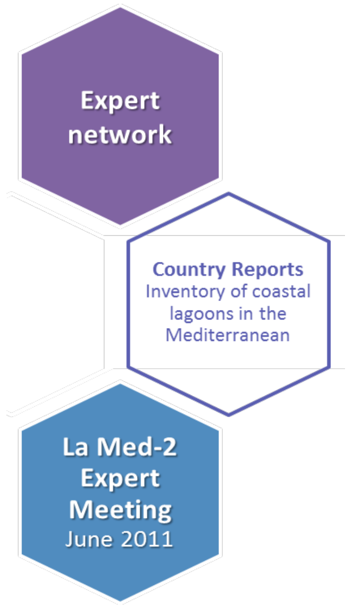


Figure 2. LaMed-2 activities and expert network

[3] Country reports from Albania, Algeria, Egypt, France, Greece, Italy, Montenegro, Morocco, Spain, Tunisia and Turkey are included in PART 2 of the present publication.

The CAQ meeting on "Mediterranean coastal lagoons management: interactions between aquaculture and capture fisheries" (LaMed-2). A step towards a GFCM management plan on coastal lagoons

On the occasion of the meeting on "Mediterranean coastal lagoons management: interactions between aquaculture and capture fisheries", the LaMed-2 expert network had a chance to present and review the status of coastal lagoons in each country (GFCM, 2011[4]) and to discuss the importance of preserving fisheries activities *sensu lato* in lagoon systems, also in light of their significant contribution to the regional/global fish supply.

Participants of the CAQ meeting on "Mediterranean coastal lagoons management: interactions between aquaculture and capture fisheries" (La Med-2) (Cagliari, Italy, June 2011)

The process of reviewing the status of coastal lagoons in the Mediterranean basin clearly highlighted that an environmental degradation had occurred over time in many lagoons and had entailed negative impacts on fish resources, which subsequently led to a consistent decrease of aquaculture/capture fisheries production.

In fact, although demanding different types of management and representing different forms of exploitation, extensive aquaculture and artisanal capture fisheries are strongly linked due to the common use of living resources within the lagoon ecosystems. The sustainability of both largely depends on the stability of the lagoons' ecological conditions and on the state of target fish populations. In this view, it was recognized that the fundamental role of "traditional" fishers' knowledge on lagoons had been contributing, since ancient times, to maintain favourable conditions to preserve the ephemeral lagoon environment.

The experts agreed that the existing detrimental conditions, which characterized the majority of Mediterranean lagoons, were determined by a lack or insufficiency of lagoon management plans and unclear legal regulatory frameworks. These inadequacies had led to environmental and socioeconomic issues, including negative effects on lagoons' fishing communities, and could cause the loss of their traditional knowledge and biodiversity.

Lagoon management is therefore recognized as the main instrument to keep preserving the ecological features of lagoons and prevent the degradation of their sensitive habitats, both from an environmental and socioeconomic point of view. In particular, experts underlined that, in order to guarantee the sustainability of aquaculture and capture fisheries in lagoons, an adequate management plan should be in place.

In light of the above aims, any coastal lagoon management plan in the GFCM area should:

1. Be in line with the CCRF and in particular with the provisions referring to aquatic ecosystems, fish habitats, multiple uses of coastal zones, ICZM, the participation of

[4] http://151.1.154.86/GfcmWebSite/CAQ/LaMed-2/2011/Report_LaMed2_Cagliari2011.pdf

fishers, environmental and other interested organizations, the role of artisanal fisheries and aquaculture including culture-based fisheries, in accordance with international laws;

2. Factor in the principles of the main international conventions and declarations regarding the protection and conservation of coastal lagoon areas and, more generally, of sensitive habitats and biodiversity, giving emphasis to the role played by local communities in coastal areas;
3. Consider traditional aquaculture and artisanal capture fisheries as a management priority, since they contribute in particular to the conservation of the ecological and economic services provided by the ecosystem and of lagoon biodiversity. In particular, the preservation of fishers' traditional knowledge should be considered as an element of common interest for Mediterranean countries to be shared and capitalized.

The experts recognized that, in order to efficiently reflect these principles into sustainable management plans for aquaculture and capture fisheries in Mediterranean coastal lagoons, there was a need to foster the development of a common regional strategy and to implement it in a cooperative approach. It was recognized that this common regional strategy should focus on preventing coastal lagoons from any further degradation and take into account solutions to restore the environment.

In this view, the meeting concluded that a Mediterranean management plan for coastal lagoons could be potentially developed to identify suitable management strategies based on a multifunctional, disciplinary and stakeholder approach, with the aims of: i) preserving wetlands and nursery areas for selected biological communities; ii) protecting traditional management practices such as artisanal capture fisheries and extensive aquaculture; and iii) avoiding any intensification of such activities.

A management plan for lagoons could be considered as an important tool for the protection of fisheries and aquaculture activities and an active component in conservation policies taking into account integrated coastal management and the ecosystem approach.

1.2.3 Project outputs

In conclusion, the activities implemented within the LaMed-2 project allowed scientists to review the state of Mediterranean coastal lagoons and to identify the main issues related to environment and to the human activities carried out in these areas. The lack of adequate management of lagoons and related fisheries activities was identified as a limiting factor reducing the capacity to control ecological and socioeconomic damages caused to lagoons. This review enabled to draw an up-to-date picture of the state of coastal lagoons in the region and to identify key concepts to be included in sustainable management plans for lagoons towards their environmental protection and the conservation of their human, cultural and traditional heritage.

The information gathered through the project also contributed to build and update the background information. This process facilitated the development of guidelines and recommendations on the interactions between capture fisheries and aquaculture through a systemic approach taking into account ecological, economic, governance and legal factors. Given the peculiar nature of these ecosystems, where aquaculture, capture fisheries and the environment interact together, various elements have been identified to elaborate a regional management plan, starting from a set of guidelines for the sustainable management of lagoons. It emerged from the CAQ LaMed-2 expert meeting that discussing and developing proposals for a future management plan and guidelines for coastal lagoons had to be considered as a priority in the agenda of Mediterranean countries, and that the GFCM – thanks to its capacity to involve all countries and possible stakeholders at the regional level – was the most appropriate forum to pursue the process initiated within LaMed-2.

2. SUSTAINABLE MANAGEMENT IN MEDITERRANEAN COASTAL LAGOONS: INTERACTIONS AMONG CAPTURE FISHERIES, AQUACULTURE AND THE ENVIRONMENT

Stefano Cataudella, Donatella Crosetti, Eleonora Ciccotti, Fabio Massa

Wetlands and coastal lagoons are valuable and sensitive environments and their important role has been widely recognized at the international level, in particular within the framework of the Convention on Wetlands (Ramsar, Iran, 1971) – the so-called "Ramsar Convention" – and the Convention on Biological Diversity (CBD) signed at the United Nations Conference on Environment and Development (UNCED) (Rio de Janeiro, Brazil, 1992).

Lagoons are an integral part of the coastal landscape. They are the typical zones between the continent and the sea where the existence of ecological gradients, due to the transition from the continental to the marine domain creates the peculiar ecological conditions that characterize these ecosystems. Due to the sedimentological, hydrological and biological gradients, coastal lagoons form complex mosaics of different habitats where one can observe a significant environmental heterogeneity, not only from one lagoon to another but also within the same lagoon (e.g. connectivity of food webs, interfaces with the lagoon's watershed and the adjacent sea, etc.). The composite structure and functions of these highly resilient and productive ecosystems, together with their efficient trophic transfer, offer unique opportunitiesto to create enabling environments on which human activities can be based.

In particular, the rich fish assemblages found in lagoons have always represented a source of income and livelihood for human settlements throughout the Mediterranean basin. Since ancient times, coastal lagoons have offered important spatial potentialities for coastal communities to develop fishing exploitation patterns and traditional lagoon management models, which have been applied in both time and space in the Mediterranean and in other parts of the world. Lagoons are therefore historically important since they form an integral part of the cultural heritage of coastal communities throughout the GFCM area.

Aerial view of the Thau lagoon (France), photo ©H. Farrugio, 2011

Recently, coastal lagoons have raised considerable environmental concerns: land claiming, pollution and the lack of management, among other factors, have strongly modified both the structure and the functioning of these sensitive coastal ecosystems. The lack of an adequate management of these areas has been recognized as the main cause leading to an ecological degradation of the lagoons and of their sensitive habitats. This is also seriously affecting traditional aquaculture and capture fisheries activities, which have been historically contributing to the conservation of lagoons environment and to the well-being of coastal communities and are at risk of disappearing.

This chapter presents a review of relevant and up-to-date information on Mediterranean coastal lagoons, gathered in country reports (see paragraph 1.3 and Part 3) and exiting literature.

Selected examples have been extracted from the country reports and are illustrated within each section. Particular reference is made to the northern Adriatic *valli* complex[5] (Italy), which represents an interesting historical reference model where sound management strategies have enabled to ensure over time the sustainability of fishing and hunting in these coastal areas (Ardizzone *et al.*, 1988). The vocation of the *valli* for fisheries clearly comes out in their ancient Latin name of "*piscatoriae aquae*" (waters for fisheries) (Del Rosso, 1905).

2.1 Historical and geographical characteristics of coastal lagoons

Coastal lagoons, as they can be seen today, are the result of centuries of interactions between natural dynamics and human management, as witnessed by the presence of coastal populations who used to live in coastal lagoons several thousand years ago.

2.1.1 Etymology and definition of lagoons

In the social and historical context of the Mediterranean region, coastal lagoons have always been well recognized and distinguished from other transitional water bodies such as low lands, salt marshes or wetlands. It is not a coincidence that the word "lagoon" – attested in the English language since the early seventeenth century (Oxford English Dictionary, 1971) and used worldwide to indicate a marine waterbody separated from the open sea where seawater mixes with continental freshwater – originates from the Italian word "*laguna*" (from the Latin "*lacuna*", derivating from the word "*lacus*" = lake), which originally referred to the waters surrounding the city of Venice.

In general, there are many typologies to which lagoons can be ascribed, and the distinction among them is essentially based on their geological origin and on the presence of tidal influence (Brambati, 1988; Carrada and Fresi, 1988; Ciccotti *et al.*, 2012). Typically, lagoons are ecologically defined as "shallow water bodies separated from the ocean by a barrier, connected at least intermittently to the ocean by one or more restricted inlets, and usually oriented shore parallel" (Kjerfve, 1994). However, there is a somehow improper use of the terms "lagoon", "coastal lake" and "pond" throughout the Mediterranean area. This confusion partly stems from the use of terms which describe local points of interest (e.g. "lagoon", "coastal lake", "pond", "*esteros*", "*étang*", "*marsh*", "*marais*", "*stagno*", etc.) rather than the real nature of the different environments – even in similar areas within the same country. Moreover, the term "lagoon" can have a different meaning from a biological or a geological point of view, depending on the geomorphological characteristics. According to the classification proposed by Brambati (1988), the key parameter to characterize lagoons from other coastal waters such as ponds is the presence of tidal range, which only occurs in lagoons and not in coastal ponds.

Recently, the issue of classifying Mediterranean lagoons in typologies has become topical in relation to the criteria introduced by the Water Framework Directive 60/2000/EC (WFD), which provides for the protection and sustainable management of inland water ecosystems, including transitional, coastal and ground waters. The Directive has introduced a new terminology for aquatic systems. In particular, transitional waters are defined as "surface water bodies in the vicinity of the mouth of a river, saline because of their proximity to coastal waters but essentially influenced by freshwater flows". According to this Directive and to its subsequent interpretations (de Wit *et al.*, 2011), Mediterranean lagoons fall within the category of coastal lagoons (in contrast, most Atlantic lagoons are considered as coastal waters, due to the predominant and determinant effects of marine tides). As transitional waters, Mediterranean lagoons can be further classified according to the influence of tide (microtidal lagoons, tidal

[5] The *valle* is a portion of a lagoon, extremely variable in dimensions, enclosed by embankments communicating directly or indirectly with the sea (Ardizzone *et al.*, 1988) in Northen Italy. Valliculture is one of the most ancient aquaculture practices in the history of humanity that was born thanks to the wit and power of observation of coastal fishers who started building barriers to trap fish (mostly eels and mullets) in the *valli* during their seasonal migrations (Ravagnan, 1992).

range > 50 cm; non-tidal lagoons, tidal range < 50 cm) and to their size, which categorizes lagoons with a surface area greater or smaller than 3 km^2 (Basset *et al.*, 2006).

2.1.2 Lagoons lifespan

Mediterranean coastal lagoons are relatively young ecosystems. Most of them have been formed during transgressional periods of sea level rise in the Holocene, 5 000–1 000 years ago. Regardless of the mechanisms that have given rise to the different coastal lagoons (de Wit *et al.*, 2011), all share the characteristic of changing shape and dimensions in time and space, due to natural processes, and of being ephemeral ecosystems. Barnes (1980) mentions that the typical lifetime of a coastal lagoon is around 1 000 years, but several lagoons can have a longer existence. The Venice lagoon in the Adriatic Sea formed 5 000 years ago, while some lagoons have been existing since Roman times and others have formed during the medieval period (de Wit, 2011). Nevertheless, the lifespan of coastal lagoons is related to human efforts to manipulate their morphology through earthworks, dredging and other structural interventions. Coastal lagoons in their present shape are therefore the result of strong interactions between coastal dynamics and human intervention (see paragraph 2.5).

2.1.3 Surface coverage, size range and ownership

At present, the Mediterranean hosts around 400 coastal lagoons covering a surface of over 640 000 ha. The figures provided in Table 1 have been extracted from the country reports (Part 2) and compared or integrated with data from literature. Discrepancies between sources relating to the number of lagoons arise from the fact that saline lakes and other coastal swamp areas may be included or not in the count. Likewise, differences in their area extent are due to the fact that, depending on the source of information, the coastal lagoon surface may refer to the water surface only or also include the land surrounding the lagoon.

Table I: Number and surface of coastal lagoons in the Mediterranean
(*Country reports,**Hecker and Tomàs Vives, 1995; Kerambrum, 1986; www.ramsar.org; http://medwet.org)

Country	Number of lagoons	Surface (ha)	
		total	Min–max
Albania*	12	25 398	250–9 352
Algeria*	1	825	
Bosnia and Herzegovina **	0	0	
Croatia **	0	0	
Cyprus **	1	1 107	
Egypt*	5	199 000	6 000–78 000
France (Med. coast)*	20	52 164	86–15 000
Greece*	76	34 511	2–68 000
Israel **	0	0	
Italy*	198	167 575	2–57 000
Lebanon **	0	0	
Lybia**	4	3 390	50–3 100
Malta **	1	11	
Monaco **	0	0	
Montenegro*	2	1 642	150–1 492
Morocco (Med. coast)*	1	11 500	
Slovenia **	1	650	
Spain (Med. coast)*	14	58 695	3.7–21 000
Syrian Arab Republic **	0	0	
Tunisia*	6	50 000	150–23 000
Turkey*	58	34 250	4–6 400
Total	400	640 718	

In general, Mediterranean coastal lagoons greatly vary in size, ranging from 2 ha (e.g., the Chalikiopoulou lagoon, Greece) to 78 000 ha (Manzala lake, Egypt).

In some areas, lagoons are very extensive and they are sometimes completely or partially subdivided into smaller confined areas. For instance, the Venice lagoon, which has a total estimated surface of over 57 000 ha, hosts around 36 smaller *valli* ranging between 10 and 1 700 ha (Marino *et al.*, 2009; Italy country report). In other countries, lagoons are small and scattered along the coast.

As concerns property, in many countries coastal lagoons are publicly owned, although confined areas of these lagoons may often be private. When utilized for extensive fish culture, lagoons are often managed by local regional authorities or leased to local fishers groups, cooperatives or private companies, which may or may not have exclusive fishing rights and lagoon management obligations. Many Venetian *valli* in Italy have private owners; in France, more than 10 percent of lagoons have been bought by the Conservatoire du littoral, an institution dedicated to the protection of coastal zones (France country report). In Albania, Greece and Tunisia, all coastal lagoons are public domain; in Albania, 10-year licenses for fishing rights are given to fisher's cooperatives or to private fishers. In Tunisia, there is a system of licenses to private companies and private fishers. In Egypt, four lagoons belong to the public domain and one is owned by a public company (Tunisia and Egypt country reports).

2.1.4 Historical loss of coastal lagoon surface

The surface covered by coastal lagoons is the remnant of a much larger extent of wetlands in the whole Mediterranean region and indeed, much of the original area covered by coastal lagoons has disappeared today. Different consumptive uses of lagoon areas and of the surrounding land for agriculture, industry, and urban development have contributed to the contraction of the overall coastal lagoon surface. In several countries, reclamation interventions have deeply changed the coverage and the fate of the lagoons.

The first land and water management interventions date back to 5 000 BC, in Mesopotamia and in Ancient Egypt. As a matter of fact, the Romans achieved a lot of land reclamations in the Pontine Marshes and in Tuscany (west coast of Italy). To give an idea of the extent of the loss of lagoon surface, it is enough to consider that in Italy wetlands covered over 3 million ha in pre-Roman times, decreased to 1.3 million ha in 1865 and cover at present 160 000 ha (Rossi Doria and Bevilacqua, 1984; Italy country report). It was in the late nineteenth and early twentieth centuries, when many European countries initiated programmes of landscape sanitation to drain lowland marshes, that Mediterranean wetlands suffered the most radical contraction (Webb, 2009).

In Spain, the process of draining wetlands started in the mid-nineteenth century and accelerated after 1918 with the introduction of a law to reclaim wetlands for agriculture and break the malaria cycle in the western Mediterranean. It is estimated that around 60 percent of Spanish wetlands have disappeared in the last 40 years (Spain country report). In Maremma (Italy), coastal wetlands have practically disappeared after the land reclamation carried out in 1828–1830; in the Pontine Marshes after the *bonifica* (reclamation) in the 1930s, only the four coastal lagoons (locally called lakes) of Caprolace, Monaci, Fogliano and Sabaudia survived. The Comacchio reclamation programmes reduced the extension of the *valli* by about 80 percent (from 73 000 ha to 13 000 ha now). The Venice lagoon also was greatly reduced, firstly in the eighteenth century with the deviation of some rivers to avoid sand stack, then between 1800 and 1900 for agriculture reclamation, and still in the period 1924–1960 as increasing urbanization and industrial development in Porto Marghera constrained even more the lagoon surface (Italy country report). In Albania, more than 50 percent of the coastal wetlands have been lost due to the development of drainage projects and marshland reclamation schemes after the 1950s (Albania country report). In Greece, the wetland surface of the Amvrakikos Gulfhas decreased from 65 percent in 1945 to 41 percent in 1999, due to the extension of artificial and cultivated areas (Greece country report). In Egypt finally, the deltaic lagoons of Edku, Burullus and Manzala have lost about 60–75 percent of their original surface in the last sixty years due to siltation, spread of aquatic weeds and conversion of land (El Mezayn, 2010; Egypt country report).

The demographic increase, the need for larger areas for agriculture, but also the urgency to address malaria that affected populations in many rural areas, led to massive land reclamation, which was also facilitated by the introduction of mechanization.

Many coastal lagoons have survived through time and through reclamation programmes only because fish production represented an income of social and economic interest. Several Mediterranean coastal lagoons would not have lasted without continuous management by local communities aimed at enhancing fish production or hunting, thus enabling not only the physical conservation of these environments but also the safeguarding of their biodiversity value. In fact, human activities that mimic natural processes and dynamics allow not only ecological communities but also economic activities to survive (see paragraph 2.5).

Molentargius lagoon (Sardinia, Italy), photo ©A. Fenza, 2011

2.2 Ecological issues and features of lagoons

An exhaustive and formal ecological assessment of Mediterranean coastal lagoons, of their structure and functioning, is beyond the purpose of this review. Several research and scientist networks have worked and keep working on the ecological aspects of lagoons. A few highlights that may be useful to discuss future prospects for Mediterranean coastal lagoon management are presented here, while paragraph 2.3 is dedicated to the complex biodiversity that sustains fisheries activities in lagoons.

According to Barnes (1980), coastal lagoon science is relatively young, but nowadays only tropical lagoons can be considered as poorly studied (Esteves *et al.*, 2008). For the Mediterranean region, there is a vast quantity of information available on basic ecology, living resources, environmental issues or management, although Perez-Ruzafa *et al.* (2010) point out that research towards understanding coastal lagoon ecological processes in the Mediterranean region has been discontinued over time.

The need to monitor many coastal ecosystems has stemmed from the necessity to document environmental quality, to follow restoration, to detect management interventions or to address specific requirements. Many research frameworks exist in most Mediterranean countries; projects have been launched and are still ongoing to tackle the multiple aspects of coastal lagoon science in Europe, North Africa and in the western Mediterranean Sea (Thompson and Flower, 2009). Apart from past contributions within the framework of the FAO-GFCM (see paragraph 1.1), the extensive review of literature and an analysis of the information gathered in this document show that the volume of data obtained from monitoring frameworks and scientific knowledge on different aspects of lagoon ecology that derives from it are extremely high; many Mediterranean coastal lagoons have been studied over the last 30 years, although the amount of information and the level of scientific knowledge differ among the different countries and lagoons.

Notwithstanding their differences in size, location, climate and management regimes, Mediterranean coastal lagoons share many features such as shallowness, connections with the sea through channels and inlets, coastal barriers and strong physical and ecological gradients (Unesco, 1981); as anywhere else in the world, they feature a high productivity and a large variety of habitat interfaces within a complex ecological stability. If these general characteristics are largely recognized, the question is "What are the factors that determine the structure and functioning of ecosystems with such characteristics?" (Carrada and Fresi, 1988). Distinct criteria such as salinity, substrate type, formation, isolation, size, morphology, etc. (Barnes, 1980; Guelorget and Perthuisot, 1983) have been summoned in order to describe the functioning of coastal lagoon ecosystems. Salinity has been usually considered as the essential parameter to explain observed gradients in density, biomass, species richness or diversity (Por, 1972; 1980). In the early 1980s, Guelorget and Perthuisot (1983) proposed that zonation patterns and species distribution in the lagoons be determined by confinement, i.e. the degree of separation from the marine domain. Later, Perez-Ruzafa and Marcos (1992, 1993) suggested that the colonization rate by marine species was the main factor shaping the lagoon assemblage structure in a confinement gradient, and that the species composition in each lagoon resulted from competition between marine and lagoon species (Perez-Ruzafa *et al.*, 2007). Mariani (2001) confirmed that fish community in lagoons appeared to be consistent with current salinity trends. In any case, the majority of biological assemblage characteristics, including community structure and productivity still relate to the geomorphologic characteristics of lagoons (Perez-Ruzafa *et al.*, 2007) and are conditioned by environmental stress (Gamito *et al.*, 2005).

> Some lagoons have been extensively studied and monitored in their main ecological components. In the Orbetello lagoon (central Italy), several studies have been carried out between the late 1990s and 2000 due to the need to document environmental conditions and to monitor the outcomes of human interventions in the lagoon (Innamorati, 1998; Innamorati and Melillo, 2004; Italy country report). The lagoon of Venice, the second largest lagoon of the Mediterranean after the deltaic lagoons of Egypt, is the most studied lagoon: intensive monitoring programmes are constantly carried out and ongoing in order to provide information regarding the protection, control, surveillance and monitoring of the lagoon system with a view to preserving the city of Venice (Italy country report). The Venice lagoon has been subject to the most important land and water management interventions in time. In this large lagoon, there is a wide array of land and water uses, which have strongly influenced the lagoon ecosystem.

Coastal lagoons in the Bay of Cadiz (Spain), photo ©J.C. Macias, 2011

2.3 A complex biodiversity

Mediterranean coastal lagoons are unanimously described as areas exposed to natural disturbance, depending on morphodynamics and climatic factors such as freshwater flooding and summer drought. This brings about fluctuations in salinity, which are due to seasonal variations in precipitations and evaporation, and marked seasonal temperature fluctuations, which are more or less significant depending on the lagoon size and latitude. These oscillations may create extreme conditions for many taxa, and the resulting biodiversity is characterized by a low number of highly specialized species. On the other hand, the composite mosaic constituted by the surrounding lagoon landscape, barrier islands, coastal spits and contiguous wetlands provide ecotones which create extremely diversified habitats supporting a rich biodiversity.

2.3.1 Seagrasses and seaweeds

A key factor in sustaining lagoon biodiversity is the presence of seagrass meadows that proliferate in productive lagoons with an efficient trophic transfer; seagrass meadows are in fact at the basis of the ecosystem functioning and create the potential for specific habitats. In the Mediterranean region, there are three species of euryhaline seagrasses: *Zostera noltii*, *Z. marina* and *Cymodocea nodosa*. These seagrass species not only provide the physical habitat for a rich fauna but also play a fundamental role in biogeochemical processes contributing to lagoons water quality. With low nutrient levels and clear water conditions, such as those typical of a pristine oligotrophic state, *Zostera* spp. and the aquatic plants of the *Ruppia* genus are the dominant macrophytes taxa of the lagoon. By contrast, the massive presence of opportunistic seaweeds such as *Gracilaria*, *Ulva* and *Cladophora* spp. along with cyanobacteria indicate a degraded eutrophic state of the lagoon environment (Viaroli *et al.*, 2008).

When seaweeds constitute an important biomass, they can be exploited with conspicuous yields and incomes, as it occurred in the Nador lagoon, in Morocco (Morocco country report) and in the north Adriatic lagoons, where green algae and *Gracilaria* are used for the production of paper and manure for agriculture as well as in the chemical and pharmaceutical industries (Italy country report).

2.3.2 Benthos

Lagoon benthos includes a wide variety of mobile or sessile aquatic organisms living in or on the substrate and represents a cornerstone for the cycle of nutrients in the lagoon environment. With regard to photosynthetic organisms, besides seagrasses and seaweeds as mentioned above, a large number of microscopic primary producers (microalgae or phytoplankton) can grow attached to solid substrates, on rocks, on the sediment or on macrovegetation. Zoobenthos consists of macroinvertebrates that live on the bottom of water bodies and on some macrophytes. In addition to molluscs (filter feeders) and crustaceans, which are very important for lagoon fisheries (see paragraph 2.4.1), lagoon zoobenthos includes flatworms, annelids and larvae of insect species that can tolerate salinity variations. The surface area, water salinity and outlet width and length of lagoons can actually be considered as key parameters limiting and defining the environmental niche space of benthic macroinvertebrates in lagoon ecosystems (Garrido *et al.*, 2011).

2.3.3 Fish communities

Coastal lagoons are nursery areas, feeding grounds and pathways for the diadromous[6] migration of many fish species (Koutrakis *et al.*, 2005; Franco *et al.*, 2006a). Regardless of morphological and environmental variability related to the size of the lagoons, the gradients and the trophic state of the waterbody, the basic structure of fish communities in the Mediterranean does not differ considerably from one lagoon to another; it shows a substantial stability characterized by a relatively low diversity in species but a high abundance of specimen per taxon. The structure of fish assemblages can be attributed to the dominance of those groups that better tolerate the fluctuations of abiotic and biotic factors as well as to the nature of food webs that are established in the lagoon systems.

When considering fish species in relation to their ecological guilds (Elliott and Dewailly, 1995), different groups are represented in the Mediterranean: from resident species that spend their entire life cycle within the lagoon, to marine seasonal species that reproduce at sea but migrate to lagoons for trophic reasons and marine precocious juveniles migrants that use lagoons as nursery areas. Adventitious marine species that occasionally enter lagoons are generally present near the tidal channels, while freshwater species usually remain close to river inputs. Species richness and composition of fish communities can be explained by the rate of water exchange between the sea and the lagoon (Perez-Ruzafa *et al.*, 2007), which supports the idea that fish species richness in coastal lagoons is mostly determined by colonization rates from the adjacent coastal zone (Mariani, 2001; Perez-Ruzafa *et al.*, 2004; 2006). Franco *et al.* (2008) has confirmed that, in Mediterranean coastal lagoons, fish assemblages were dominated on average by marine species with a majority of marine migrants (juveniles and adults) rather than marine stragglers.

Fish harvest from the Tortolí lagoon (Sardinia, Italy), photo ©F. Massa, 2011

[6] Migration of fish between the sea and freshwater.

Species such as *Anguilla anguilla, Atherina boyeri, Dicentrarchus labrax, Liza ramada, Mugil cephalus* and *Sparus auratus,* have been reported to be present in all Mediterranean lagoons; other species of Mugilidae and Sparidae have been found very frequently in more than 70 percent of the lagoons, while about a hundred species have been characterized as occasional or specific to few lagoons since they were present in less than 15 percent of the lagoons (Perez-Ruzafa *et al.,* 2007).

Concerning the European eel (*A. anguilla*), it is worth noting that it is the only catadromous species of the Mediterranean which migrates over long distances between the ocean – where eels spawn – and brackish and freshwaters – where growing takes place. The complex biology and life cycle of eel makes it exposed to several threats of anthropogenic nature, including overfishing, pollution, coastal habitat loss and climate change. These are supposedly the main causative agents of the stock-wide decline that this species has been facing in Mediterranean lagoons and in European inland and coastal waters. A comprehensive review on European eel is presented in case study 3 (see paragraph 3.3) and specific issues related the management of eel stocks are illustrated in case study 4 (see paragraph 3.4).

Besides the above-mentioned species, a number of adventitious coastal marine species can be found in Mediterranean coastal lagoons. They occasionally enter in lagoons whenever they find favourable conditions (e.g. reduction of freshwater inputs that can entail a rise in salinity or a lessening of saline gradient) and remain for long or short periods. Sardines, croakers, seabreams, red mullets, flounders, soles, groupers can be occasionally or permanently present within the lagoon fish assemblage and become a conspicuous share of the lagoon yields. In recent years, also lessepsian species such as the marbled spinefoot (*Siganus rivulatus*) and the dusky rabbitfish (*S. fuscescens*) have entered in the Mediterranean basin via the Suez Canal and have been commonly reported as dwellers of eastern Mediterranean lagoons.

In coastal lagoons with low salinity, freshwater species such as tilapias (*Oreochromis niloticus* and *Sarotherodon galilaeus*) and cyprinids (*Cyprinus carpio* and *Carassius carassius*) can also be present (Egypt and Spain country reports). The big-scale sand smelt (*Atherina boyeri*) is the only commercial euryhaline finfish that reproduces in coastal lagoons. *A. boyeri* has been subject to several systematic revisions and genetic studies, which indicate the existence of three species belonging to the genus *Atherina*: *boyeri, lagunae* (Milana *et al.,* 2012) and *mochon* present in the Manzala lake, Egypt (Egypt country report).

The presence and persistence of adventitious marine species can be the symptom of a change in the lagoon conditions, as indicated by the occurrence of anchovy (*Engraulis encrasicolus*) in the Nador lagoon, in Morocco (Malouli Idrissi and Zahri, 2002; Malouli Idrissi *et al*, 2003; Morocco country report) and in the lagoon complex of the Valli di Comacchio, in northern Italy (Italy country report) where anchovies are caught together with sprat (*Sprattus sprattus*).

2.3.4 Birds

The number of aquatic bird species observed in Mediterranean lagoons adds up to several hundreds, given that the Mediterranean region is an important refuge of migrating birds from southern and northern latitudes. The richness and population abundance of avian species indicates that the aquatic bird fauna is extremely important in terms of ecological relevance and conservation in all the lagoons of the Mediterranean. Birds are in fact critical components of the lagoon ecological processes (e.g. food webs) and, at the same time, coastal lagoons are essential for all wetland birds as they provide habitats and feeding grounds. Lagoon ecosystems can sustain both herbivorous (e.g. waterfowl of the *Anseriformes* order, ducks, geese, swans, etc.) and carnivorous species that feed on small benthic invertebrates and on fish (e.g. cormorants).

Water birds are probably the most extensively monitored species among the living components of coastal lagoons (Aymerich and Cedran, 2011) and several international legal instruments have been promoted to protect them, starting with the Ramsar Convention (1971), which is the first intergovernmental treaty providing a framework for national action and international cooperation for the conservation and wise use of wetlands and birds.

Common stilt (*Himantopus himantopus*) specimen in the Cabras lagoon (Sardinia, Italy), photo ©A. Santangeli, 2008

Recently, the increasing number of ichthyophagous birds inhabiting coastal lagoons has created a remarkable impact on lagoon fishing production; conflicts between fishers and bird conservationists are still ongoing (see paragraph 2.6.5).

2.4 Exploitation of living resources in coastal lagoons

Local communities have always exploited the complex and diverse environment of lagoons to harvest fish, crustaceans and molluscs, among others. Nonetheless, many coastal lagoons have recently experienced a general decrease in fishing yields, mainly due to environmental degradation, overfishing and the lack of suitable lagoon management plans. Large water projects aimed at claiming land for agriculture, industry, harbouring, etc., have failed to consider the intrinsic value of coastal lagoon biodiversity and their related services and products.

2.4.1 Species of commercial interest

The main commercial species produced in Mediterranean coastal lagoons are the following:

- fish species: grey mullets (with 5 species: flathead grey mullet, *Mugil cephalus,* and thick lipped grey mullet*, Chelon labrosus, Liza ramada, L. saliens* and *L. aurata*), gilthead seabream (*Sparus aurata*), European seabass (*Dicentrarchus labrax)* and spotted seabass (*Dicentrarchus punctatus)*, eel (*Anguilla anguilla*), big-scale sand smelt (*Atherina boyeri*);
- shellfish species: Mediterranean mussel (*Mytilus galloprovincialis*), caramote prawn (*Penaeus kerathurus*), red swamp crayfish *(Procambarus clarki),* clams (grooved carpet shell, *Ruditapes decussatus;* Japanese carpet shell, *R. philippinarum*) and oysters (European flat oyster, *Ostrea edulis*, and Pacific cupped oyster, *Crassostrea gigas*).

Among fish species, grey mullets (Mugilidae family) are highly represented in Mediterranean coastal lagoons with five species, often making up the majority of the production of the lagoons. To give a few examples, in the Koycegiz lagoon (Turkey), grey mullets represent 78.4 percent of the production (Deniz, CR), in all the Greek coastal lagoons 56 percent (Reizopoulou, CR) and in the Lesina lagoon (Italy) 35 percent (2003 figures, Maccaroni *et al.*, 2005). The presence of a species or another depends on the morphological characteristics and ecology of the single species in relation to the environmental conditions present in the lagoon. For instance, adult *C. labrosus* prefers hard substrates and marine salinities whereas *M. cephalus* and *L. ramada* can live at low salinities, even in freshwater. Among grey mullets, the flathead grey mullet, *M. cephalus*, is greatly appreciated for its salted and dried egg roe, sold as a delicacy.

As a predator at the top of the food web in coastal lagoons, the European seabass, *D. labrax*, only represents a small percentage of the total coastal lagoons production, and restocking actions reflect this balance. Indeed, the percentage of European seabass fry in restocking actions never exceeds 5–6 percent (Ardizzone *et al.,* 1988). The spotted seabass (*Dicentrarchus punctatus)* is also captured in the Bardawil lagoon (Egypt, Bardawil, FS), though it represents a minor production compared with the European seabass.

The gilthead seabream is a very rustic species, but among all lagoons species it is certainly more sensitive to low temperatures. To cope with this problem, in the northern Adriatic *valli* and in northern Turkey, seabreams are wintered in *ad hoc* culture facilities, where water temperature is kept above the lethal temperature for the species.

A comprehensive review on eel is presented in this publication by Farrugio (case study 3), and specific issues related the management of eel stocks are analyzed by Ciccotti (case study 4).

The big-scale sand smelt (*Atherina boyeri*) is the only euryhaline finfish species that reproduces in coastal lagoons. *A. boyeri* has been subject to several systematic revisions, and genetic studies indicate in fact the existence of three different species. The new name of *A. lagunae* has been recently proposed for the lagoon form (Milana *et al.,* 2012).

The marbled spinefoot *(Siganus rivulatus)* and dusky spinefoot (*S. luridus*), also commonly called “rabbitfish”, are lessepsian species which have migrated to the Mediterranean via the Suez Canal and are present in Egyptian lagoons.

Other fish products are important resources of income for coastal lagoon fishers. This is the case of the greatly appreciated salted and dried egg roe obtained from the flathead grey mullet (*Mugil cephalus*) and commonly known as *bottarga* (Italian)*,* or *boutargue* and *poutargue* (French)*, botarga* (Spanish) (from the Arab *boutharkha* = dried fish eggs): this delicacy of the Mediterranean gastronomic tradition is sold in fact at high prices (up to 200 €/kg). In Greece, in the Missolonghi-Aitoliko lagoon complex, the egg roe is one of the few seafood products that can boast of the “protected designation of origin” (PDO) label.

Mullet salted egg roe (Koycegiz lagoon, Turkey), photo ©H. Deniz, 2011

In the Tsoukalio-Rodia lagoon in Greece, egg roe production has grown from 173 kg in 1975 to 2 692 kg in 2000. In the Koyceciz lagoon in Turkey, around 3 tonnes of mullet dry roe are produced yearly. Also, in Egyptian lagoons mullet egg roe (locally called "*batarekh*") is produced, the one from the Bardawil lagoon (60 tonnes per year) being considered of the highest quality due to the high salinity of the lagoon; *batarekh* is also produced in large quantities in winter from cultures of thinlip mullet (*Liza ramada*) and sold at the local markets (Egypt country report). The Orbetello lagoon (Italy) has an annual production of egg roe ranging from 0.5 to 1 tonne (Lenzi, *pers. comm.*) and, as processing by-product, ripe females from which ovaries are removed to be salted and dried are filleted, hot smoked, and packed as high priced products.

Among other taxa, shellfish (oysters, mussels and clams) are very common in lagoon environment, representing important exploited resources that have been harvested for human consumption since ancient times throughout the Mediterranean region.

Oyster culture has been introduced by Sergius Orata in the Lucrino lake (Naples, Italy) around 100 B.C. and its production represents one of the first aquaculture trials in Mediterranean coastal lagoons. Oysters used to be a delicatessen in the ancient Roman world (Giacopini *et al.*, 1994) and their culture under the Roman Empire lasted over five centuries. There is some evidence that the ancient Romans also practised shellfish farming in the lagoon of Diana, in Corsica (France country report).

It is interesting to note that in Mediterranean coastal lagoons, the autochthonous European flat oyster (*Ostrea edulis*), harvested since Roman times, has been recently replaced by the indigenous Pacific cupped oyster (*Crassostrea gigas*). The Pacific cupped oyster was introduced in Europe and in the Mediterranean after the drastic decline of *O. edulis* production in the early 1960s, due to the impact of two parasitic epizooites (*Bonamia ostreae* and *Marteilia refringens*) (Lapègue *et al.*, 2007a; 2007b). Mussel culture is also practised in many Mediterranean coastal lagoons, mainly with longline systems, though in some regions fixed culture systems are still preferred.

The Pacific cupped oyster has been cultured in lake Mellah (Algeria) for several years (Algeria country report) and is still reared in small-scale culture activities in Sardinian lagoons (Marino et al, 2009) and in the Orbetello lagoon (Italy). French coastal lagoons produced 8 825 tonnes of oysters in 2010, though there has been a high mortality of young oysters since 2009, the origin of which has not yet been completely determined. This crisis has led 20 percent of the producers to change their strategy by increasing/starting the production of Mediterranean mussels (*Mytilus galloprovincialis*) (France country report). French Mediterranean lagoons produced 4 180 tonnes of mussels in 2010. The northern part of the Thau lagoon is divided in three zones dedicated to an intensive shell farming activity carried out by 566 producers (France country report). In Italy, the Venice lagoon has been the first mussel producer until the early 1980s with 100 licences and a production of 30-35 000 tonnes/year, which represented about 60 percent of Italian mussel production. A progressive decline followed and mussel cultures have been moved offshore along the Venetian coast to find larger spaces and better water quality, which favored highest growth rates. At present, mussel production in the Venetian lagoons reaches around 1 500–2 500 tonnes/year. Mussels are also produced in Sardinia on floating facilities called "*zattere*", as well as in the Varano (Apulia) and Sabaudia lagoons (Lazio) (Italy country report). In Albania, mussel culture is only practised in the Butrinti lagoon, with a production of 1 410 tonnes in 2010 (Albania country report). Mussel culture has also been carried ou in lake Mellah in the early 1990s, with a production that reached 17 672 tonnes in 1992.

Mussel culture in the Tortolì lagoon (Sardinia, Italy), photo ©D. Crosetti, 2011

Concerning clams, two species are present and harvested today in the Mediterranean region: the grooved carpet shell (*Ruditapes decussates*), a Mediterranean endemic species, and the Japanese carpet shell also called Manila clam (*R. philippinarum*), an Asiatic species introduced in 1983, which has displaced the endemic species in many areas and currently makes up most of the Mediterranean clam production.

In Sardinia (Italy), strict rules have been established in order to guarantee the sustainable management of the local grooved carpet shell stocks and avoid the overexploitation that has led to the disappearance of the species in several Italian lagoons. In the lagoons of Sacca di Goro and Scardovari (Italy) for instance, the grooved carpet shells started to be exploited in 1969 with an annual production of 1 200 tonnes, but the stocks were soon depleted, also of their younger specimen (200 tonnes in 1970 and 70 tonnes in 1974); despite the introduction of catch quotas per fisher, stocks have never recovered. The Sacca di Goro lagoon now produces *R. philippinarum* and its yields represent over half of the Italian Japanese carpet shell production, mostly carried out in Italy in the northern Adriatic lagoons. The spawning of the Japanese carpet shell is induced and performed in hatcheries: about two thirds of Italian farmers collect the seed in the wild and roughly one third buy the seed from fishers, while less than 0.1 percent buy hatchery spat (Marino *et al.*, 2009).

Crustaceans (prawns, shrimps and crabs) are also commonly found in Mediterranean lagoons and some species have a great commercial value. This is the case of the Caramote (*Penaeus kerathurus*), harvested in Morocco, in the Nador lagoon, and exported to the Spanish market (Malouli Idrissi *et al.*, 2003; Morocco country report), along with the peregrine shrimp (*Metapenaeus stebbingi*), the Kuruma prawn (*Penaeus japonicas*) and the green tiger prawn (*P. semisulcatus*) exploited in Egyptian lagoons for a total production of Penaeids that reached 5 132 tonnes in 2009 (Egypt country report). Culture trials of Caramote have been performed in the late 1980s but with no follow-up (FAO, 2011).

In northern African coastal lagoons, the grooved carpet clam has been cultured in Mellah lake in the 1990s with a maximum production of 27 622 tonnes reached in 1998, but the production experienced a collapse in the following years (Algeria country report). In Tunisia, in the lagoons of Bizerte, Tunis and El Bibane, clams are usually collected by women by means of traditional archaic fishing gear and, after depuration processes carried out in accordance to EU rules, most of the production is exported to Italy and Spain (Hadj Ali Salem, *pers. comm.*).

The crab species *Carcinus mediterraneus* is harvested in the Venice lagoon when moulting (soft-shell crab culture). Soft shell crabs are considered as an expensive culinary delicatessen and can fetch a price of over 80 €/kg. This traditional harvesting activity of is locally called "*molechicoltura*" (from *moeche* or *moleche*, soft-shell crab) and is strictly confined to this area of Italy. The particular skill, handed over from father to son, consists in selecting the crabs that are going to moult in short time – recognizable by some specific morphological characteristics – from those that will not turn soft and that fishers traditionally call "crazy crabs". Nowadays, very few fishers (around 210) carry out this activity, which has remained virtually unchanged since hundreds of years and is half way between the exploitation of wild resources and farming (see paragraph 3.1 and Italy country report).

Several crab species are also exploited: for example, the *Portunus pelagicus* crab is captured in Egyptian lagoons (Egypt country report), *Carcinus mediterraneus* is harvested in the Venice lagoon and *Upogebia pusilla* (locally called "*kanjoč*") is manually collected in Montenegro, in the Tivat Salina lagoon, and used as a bait in sparids longline fisheries (Montenegro country report).

Soft crabs selection in the Venice lagoon (Italy), photo ©T. Galvan, 2011

In addition to fishery resources, other uses[7] such as collecting small fish for local consumption, worms to be used as baits for fishing and algae as fertilizers, for alginates or pectin production (see paragraph 2.3) are additional sources of income for fishers; unfortunately, however, the traditional activities to collect these resources, often carried out on an occasional basis and with artisanal means, are slowly disappearing among lagoon communities.

2.4.2 Assessment of lagoon production

It is difficult to obtain reliable and updated production data for Mediterranean coastal lagoons: very often, national official statistics do not report separate data for brackish water production; data are not updated, although coastal lagoon conditions can greatly vary, and production data on both extensive aquaculture and intensive culture within the lagoon surroundings are pooled together. Furthermore, coastal lagoon production does not easily fit into the usual marine and inland groupings under which many national fisheries departments categorize the production. Moreover, most of the catch from traditional artisanal fisheries is sold locally, and only the most valuable products are taken into account in national statistics (Kapetski, 1981). However, it is recognized that Mediterranean coastal lagoons' productivity varies from a few to several

[7] An interesting table on various products from Italian coastal lagoons is shown in the Italian country report.

hundred kilograms per hectare per year (kg/ha/year) and differ according to the lagoon typology and ecology (e.g. water circulation, depth, salinity, management, etc.).

Perez-Ruzafa *et al.* (2007) examined fishing yields on a comparative basis, expressed as annual fishing catch per lagoon surface (kg/ha/year), and related these data to some hydrographic and geomorphologic parameters of the lagoons; catches showed a significant positive correlation with the total length increase of inlets and of chlorophyll *a* concentration while they were negatively correlated to the increase of lagoon depth and maximum salinity as well as, to a lesser extent, minimum phosphate concentration in lagoon waters. These observations could be explained by the fact that currents and hydrodynamics in lagoons are closely related to the bottom topography and, in shallower lagoons, the bottom is usually well irradiated and winds affect the entire water column promoting the resuspension of materials, nutrients and small organisms from the sediment to the surface – a process that increases global lagoon productivity (Conde *et al.*, 1999; Gamito *et al.*, 2005; Perez-Ruzafa *et al.*, 2007). These findings support the empirical observation that a great variability in fish productivity and catch composition exists between different lagoons featuring different morphologies.

At present, estimating the total production of the most important Mediterranean coastal lagoons remains difficult for all these reasons. A tentative figure as deduced from the country reports (Part 2) adds up to around 156 000 tonnes per year.

Mean production of Italian lagoons amounts to about 50 kg/ha (Cataudella *et al*, 2001), although in some Sardinian lagoons production has reached 300 kg/ha in the 1980s and 600kg/ha in the lagoon of Tortolì (Ciccotti *et al*, 2012; Italy country report). Albanian lagoons have produced up to 139 kg/ha/year over the period 1980–1990 (Albania country report). The lake Mellah has had a production of 30 kg/ha/year (calculated from data in Algeria country report). Greek coastal lagoons have an average production of 32 kg/ha/year (Greece country report). Production in Turkey ranges from 43 kg/ha/year in the Dalyan and Pyraz lagoons to 64 kg/ha/year in the Koycegiz lagoon (Turkey country report). In specific conditions, the high fish productivity could be due to a massive migration of marine fish with good commercial size, caught subsequently to their entrance in the lagoon from the adjacent sea.

2.4.3 Environmental quality and lagoon production

Regardless of the intrinsic variables of lagoon production, one can reasonably affirm that a decreasing trend in yields has been observed in all Mediterranean coastal lagoons over the last 30 years and important environmental occurrences have certainly contributed to this reduction. In fact, contrary to what has been observed in the pelagic marine ecosystem, where the decline of catch is mainly due to the overexploitation of living resources, the production decline in lagoons is primarily due to habitat degradation and to changes of the lagoon's ecological conditions in general (Mediterranean Wetlands Observatory, 2012).

Anthropogenic coastal activities are responsible for important ecosystem alterations in several ways: eutrophication, bacterial contamination, algal blooms (toxic or not), anoxia and fish mortality can influence the productivity, and sometimes the conservation and even the survival of lagoon living resources. Other causes that can affect the productivity of lagoons are: reduced juveniles recruitment due to increased fishing activities along the coasts; altered colonization dynamics and rates due to the reduction of seawater and freshwater flows; and effects of predators such as ichthyophagous birds, which have caused a significant reduction in the yields of Mediterranean coastal lagoons, especially in the last years (see paragraph 2.6.5). Additionally, a more careful and ecological management of wastewater from agriculture and urban settlements has contributed, within a certain limit, to the increase of dystrophic trends in lagoon production. Constraints affecting fisheries and aquaculture in coastal lagoons are very well known and have been extensively described in several reviews (e.g. Ardizzone *et al.*, 1988; Marino *et al.*, 2009).

In the lagoon of Lesina (Italy), the average production has decreased from 120–140 kg/ha in the 1940s to less than 60 kg/ha in the 1960s and to 20 kg/ha at present (Italy country report). The Tunis lagoon has been highly productive until the 1980s (up to 1 000 tonnes/year), when untreated urban waste waters were removed from the lagoon and production decreased to around 200 tonnes/year (Tunisia country report). In the Akyatan lagoon, productivity has decreased from 65 g/ha in the late 1970s to the current 4.6 g/ha (Turkey country report). As a consequence of reduced fish production, in some lagoons (e.g. Thau in France, Venice and Sacca di Goro in Italy) shellfish harvesting, a culture-based activity, has integrated and sometimes replaced traditional fisheries, at least from the socioeconomic point of view, hence becoming the main activity (Perez-Ruzafa *et al*, 2007).

2.5 Management of fishing activities in coastal lagoons: capture fisheries and aquaculture

Fishing and extensive aquaculture have always been practised in Mediterranean coastal lagoons for the abundance of trophic resources and for the relative easiness of fishing activities, which occur in a confined and rather protected environment compared with open sea. Coastal lagoon fisheries mainly rely on the capture of euryhaline fish species migrating between the sea and the lagoons during their seasonal movements: mounting of juveniles to the lagoons where conditions are suitable for growth, and returning of adult fish to sea to spawn.

In many cases, artisanal fisheries are well developed, whereas management is simple and mostly based on natural recruitment, a characteristic of a large number of Mediterranean lagoons. However, simple fishing models have evolved more or less gradually over time towards more sophisticated lagoon management schemes. The history of lagoon exploitation for fishing purposes is therefore closely intertwined with the rise of aquaculture practices, from the set-up of permanent capture systems to intercept the seasonal migration of several species to the enhancement of natural trophic webs to increase lagoon productivity, and hence that of selected target species and to the management of hydraulic flows to control environmental factors in lagoons.

Lagoon fisheries often merge typical aquaculture with capture fisheries management schemes and are sometimes described as “enhanced fisheries”, “capture-based aquaculture” or “extensive aquaculture”. Welcomme (1997) classifies within the aquaculture category all fisheries practices carried out in coastal lagoons. The FAO defines aquaculture as “the farming of aquatic organisms in inland and coastal areas, involving intervention in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated”. According to this definition, it can be inferred that those coastal lagoons which are characterized by the presence of hydraulic control systems (both freshwater and seawater), fixed traps at lagoons mouths for the capture of migrating fish or by exclusive production ownership can all be considered as “extensive aquaculture systems”.

For instance, fish stocking practices (see paragraph 2.5.2) have been traditionally carried out to sustain the fish production of Mediterranean lagoons in specific confined areas such as in the northern Adriatic *valli* or in the Egyptian *hoshas*[8].

[8] Ponds devoted to aquaculture inside a lagoon (Egypt country report) usually built with mud and reed dykes (FAO, 1988).

These stocking practices represent management models that can be ascribed to privately owned extensive aquaculture. On the contrary, enhanced capture fisheries through restocking in open waters are generally operated by public administrations.

In light of this, it is clear that the major distinction between capture fisheries and aquaculture becomes more than ever difficult in coastal lagoons. Historically, these two different management forms have taken advantage one from the other and developed together into unique forms of exploitation that coexist at present within the very same environment and rely on the same trophic resources.

Fish harvesting in Veta La Palma (Spain), photo ©PIMSA, 2011

2.5.1 *Artisanal and fixed fishing gear*

The physical confinement of coastal lagoons, consequent to natural events or human interventions, as well as the need to intercept as many fish as possible, have driven in time traditional capture fisheries to integrate with simple forms of aquaculture, at first, and then to develop into more complex fishing systems. At present, capture fisheries in lagoons can still be considered as forms of artisanal fisheries which target more than one species (multispecies fisheries) and make use of a wide variety of fishing gear such as: fyke nets, baskets, traps (fixed), trammel and gillnets (not fixed). Fishing gear design reflects not only local traditions and skills but also a deep knowledge of species biology (e.g. reproduction timing, migrations, seasonal or daily movements due to tides, etc.).

Fisher at dusk (Veta La Palma, Spain), photo ©K. Rodriguez, 2011

Fyke nets in the Bages lagoon (France), photo ©H. Farrugio, 2011

In colder Mediterranean lagoons, most captures of euryhaline fish take place in winter, in coincidence with seaward migrations; as the water temperature drops, fish attempt to move to the sea where temperatures are milder. Commercial size fish are retained and captured thanks to the barriers. In the northern Adriatic *valli*, non-market sized fish are led to wintering ponds (Italian *peschiere*), where the depth, shape and geographical orientation towards the dominant winds keep the pond temperature above 4–5°C and fish can survive. Wintering channels with an average depth of less than one meter are also present in Greek estuaries (Makridis and Papazi, 2008).

The development of fixed structures, such as barriers and weirs, to enclose and trap fish in confined areas within lagoons and facilitate their capture can be considered as one of the first steps towards aquaculture. Several manworks to improve coastal lagoon exploitation were already built by the Etruscans and the Ancient Romans and some of these remains can be observed today along the Italian western coast (Giacopini *et al.*, 1994). The basic principle of the functioning of artificial structures in lagoons is the interception of fish when trying to return to the sea.

Some of the most famous lagoon devices are the V-shaped fish traps called "barriers" (the Italian *lavorieri* or the French *bordigues*), which allow fish to enter in the lagoon while at the same time preventing their exit. The structure (shape and number of chambers), size, design, building materials (reeds, concrete or metal) of these fixed devices have greatly evolved through centuries and differ among countries according to the local traditions and to the degree of technology achieved; however the fishing efficiency of any of these structures can be considered to reach 100 percent.

Pauly and Yáñez Aranciribja (1994) have carried out a detailed study on the role of Mediterranean fish barriers in the context of lagoon fisheries evolution and confirmed that these structures were an important tool for lagoon management and a key element that had progressively led to sophisticated fisheries regimes implying cooperation and high management skills.

Italian *lavoriero* in the Cabras lagoon (Sardinia, Italy), photo ©F. Massa, 2011

2.5.2 *Stocking and restocking practices*

Since the natural entrance of fry and juveniles into the lagoons has decreased in recent times, also as a result of the transformation of the surrounding territory and the control of water flows, fishers have felt the need to start increasing fish biomass by integrating the natural lagoon population through restocking[9] and stocking[10] practices. Juveniles of selected species are harvested in the wild. Coastal areas and estuaries are fishing grounds that are exploited by specialized fish fry fishers (in due time according to their life cycle). The development of new means of equipped transport has enabled to collect fry and juveniles far away from the lagoons that are to be restocked.

Restocking practices have become very important in the northern Adriatic v*alli* as the communication of these complex lagoon systems with the open sea as well as the number of mounting fish able to return to the lagoons have progressively decreased in time. In the late 1990s, the *valli* were annually stocked with around 40 million grey mullet fry, 3 million gilthead seabream and 3 million European seabass captured in the wild (Franzoi *et al*, 1999).

Restocking usually relies on fry and juveniles belonging to several species. Restocking programmes should always keep in consideration the lagoon food chain structure, which is site-specific; moreover, the number of omnivorous (e.g. grey mullets) and predator species (e.g. gilthead seabream, European seabass and eel) should be ecologically balanced. Ardizzone *et al.* (1988) have reported several examples of restocking programmes in the northern Adriatic *valli*: (i) 3 875 fish/ha (3–7 kg/ha) of which 80 percent of grey mullets, six percent of gilthead seabream, six percent of European seabass, eight percent of yellow eels; (ii) 1 000 juveniles/ha of which one percent gilthead seabream, three percent European seabass, 120 yellow eels

[9] Restocking (or stock enhancement) is the practice of putting artificially reared young fish into their natural environment to let them grow (Cooke, 1984; FAO, 2003).

[10] Fish stocking is the process of moving live organisms to a rearing unit (e.g. nursery ponds, fattening ponds) so that ongrowing or reproduction (e.g. in spawning ponds) may take place (AQUALEX, 1998).

(50 specimen/kg) and grey mullets. Ravagnan (1978) reported a restocking event where 70 percent of the fry had been lost immediately after being released in the lagoon due to the stress caused by capture and transport: only 2–3 percent survived and contributed to the restocking of the lagoons. However, Cataudella *et al.* (2001) reported higher survival rates, up to 15–20 percent for grey mullets and 30–80 percent for seabream.

In Italian lagoons, to increase the survival rate of fry, grey mullet fry captured in fall is often overwintered in land-based ponds and released into the lagoon in spring when the fish have reached a larger size and have more chances to survive as they are subject to lower predation. However, fry survival rates remain difficult to be determined in extensive systems (Ardizzone *et al.,* 1988).

Recently, the availability of fry captured in the wild has also decreased and most restocking is carried out with hatchery-produced fry, fingerlings and shrimp post-larvae, which enables a constant supply to the semi-intensive ponds located in the coastal lagoon areas. Nevertheless, some of the production obtained with traditional restocking from hatcheries had to be discarded over time due to a high rate of malformed fish raised. In order to lessen these events, restocking in some lagoons has been carried out with wild-like type of fry and juveniles, which are released from the hatcheries into the aquatic mesocosms[11] (Cataudella *et al*., 2002); during this phase a certain degree of natural selection is wielded on the juveniles and only those fish which survive (wild-like fish) are released into the lagoon.

Fish fry collection in the Venice lagoon (Italy), photo ©R. Lazzarini, 2011

In Egypt, wild marine fish fry for aquaculture is collected by licensed fishers under the supervision of the General Authority for Fisheries Resources Development (GAFRD). The quantity of fry provided through this channel ranges from 90 to 120 million fry per year, most of which are grey mullet although other marine fish species such as meagre, gilthead seabream and seabass can also be found. Stock enhancement programmes are also performed with freshwater species in low salinities lagoons; Burullus and Edku have been restocked from 2004 to 2007 with fish seed from governmental hatcheries, 3 millions of grass carp fry (*Ctenopharyngodon idella*) (which do not reproduce in the wild in Egyptian waters), 8 millions of Nile tilapia fry (*Oreochromis niloticus*) have been released in the Burullus lagoon and about 4 millions Nile tilapia fry in the Edku lagoon; however no data are available on the success of this restocking (Sadek, 2001).

[11] Specific pools designed to provide a limited body of water with close to natural conditions, in which environmental factors can be realistically manipulated.

2.5.3 Hydraulic management

A correct hydraulic management helps control and maintain the ecological characteristics of lagoons and hence boost the production. Mediterranean climatic conditions favour natural water exchange mostly in spring, when circulation between the lagoon and the sea increases, contributing to enhancing the trophic migration into the lagoons of euryhaline fish living at sea. In summer, with hot sunny days and low precipitations, the water evaporates and the salinity increases, thus reducing water layers mixing and the death of macrophytes. This process could lead to an excessive eutrophication and to qualitative and quantitative changes in the vegetation composition and, eventually, to macro- and micro-algal blooms. In such conditions, the vegetation mass at the surface layer prevents the sunlight from penetrating into the lagoon, precluding photosynthesis in deeper layers where the degradation of organic matters becomes anaerobic.

In general, with low tide regimes, water exchange with the sea, either periodically or all year round, is quite limited, and a correct hydraulic management through human intervention becomes thus more than ever important. For example, in emergencies, when water circulation and exchange have to be enhanced, hydraulic devices allow water to be artificially pumped into lagoons in order to avoid dystrophic crises (e.g. in the Orbetello lagoon, Italy). Additionally, as movements of sediments by currents and wave action along the coast cause a siltation of the mouth, continuous cleaning of communications channels between the lagoon and the sea is required. Hydraulic management not only facilitates water circulation within the lagoon and between the lagoon and the sea, but also contributes to enhance the distribution of trophic resources and the migration of juveniles into the lagoons and attract fish during the migrating phase, thus stimulating a positive rheotaxis[12] behaviour of many fish species (Ardizzone *et al.*, 1988).

Hydraulic works related to coastal lagoons date back to pre-Roman and Roman times, as revealed by the remains that can still be observed in some Italian coastal lagoons (Giacopini *et al.*, 1994). Nowadays, in the most equipped lagoons, hydraulic management consists in the opening/closure of communications with the sea through sluice gates to control the water flow inside the coastal lagoon and thus partly regulate environmental parameters such as temperature, dissolved oxygen, salinity and nutrient content, in particular during periods of freshwater input (if any). Sometimes, lagoon openings are prone to clogging, and dredging operations are very expensive and can absorb up to 80 percent of the total maintenance costs (e.g. Egyptian lagoons in the Nile delta, Egypt country report). Nevertheless, in several Mediterranean coastal lagoons, no hydraulic management is performed and the water flow merely depends on tide, winds, sea storms and rainfalls.

The the Orbetello lagoon (Italy) has undergone five extensive dystrophic crises in the last 30 years (Lenzi *et al,* 2011). In Greece, almost 50 percent of the coastal lagoons do not receive a direct freshwater input and the increased damming of rivers has led to reduce river flow and terrestrial sediment input; anoxic conditions and the release of hydrogen sulphide have caused a massive mortality of fish and shellfish communities in the Papas Lagoon, in the Ionian Sea (Greece country report). In the lagoon of Nador (Morocco), a new gateway was built in 2010 to increase the exchange of marine water between the sea and the lagoon from 12 million m^3/day (old gateway) to 22 million m^3/day (Morocco country report). The Bardawil lagoon (Egypt) represents an extreme case where the absence of hydraulic management could cause the complete dry up of the lagoon (Ben Tuvia, 1979).

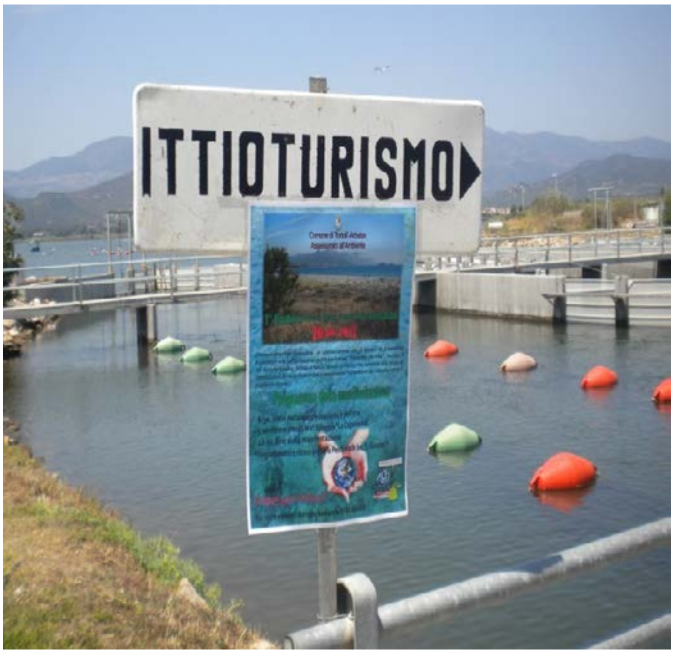
[12] Positive rheotaxis is a form of taxis seen in many aquatic organisms, such as fish, whereby they (generally) turn to face into an oncoming current (Montgomery *et al*, 1997).

The role of hydraulic management strongly supports the evidence that the survival of coastal lagoons over time is closely related to human interventions that enable to safeguard their existence but could also cause their disappearance from the coastal landscape if other types of landscape interventions are conducted. Indeed, land reclamation, and more generally the intensive use of flood plains, deeply modify lagoon ecosystem boundaries: flow control modifies sand supplies and sedimentation, altering the natural dynamics that have regulated and shaped coastal water bodies for thousands of years.

Sluice gate in the Tortolí Lagoon (Sardinia, Italy), photo ©D. Crosetti, 2011

2.5.4 Other uses of coastal lagoons

Coastal lagoons are important drivers for regional economies, not only for the income derivating from fisheries and aquaculture, but also for their touristic appeal. Tourism development of coastal lagoon areas includes the expansion of urban settlements, the widening of channels to be used as boat harbours and even the creation of artificial beaches (Perez-Ruzafa *et al.,* 2010). In parallel, various activities such as swimming, diving, sailing, sightseeing on boats, bird watching, recreational fishing, trekking along natural paths around coastal lagoons shores, hunting, wildlife protection, reed harvesting, cattle grazing, leech collection, research and training (see also Turkey country report) can be developed and increased in order to enhance the economic value of the area.



Coastal lagoons also offer an important opportunity to promote the protection of the environment and aquatic resources through ecotourism activities involving fishers, such as, for instance, fisheries tourism in Turkey (Turkey country report), *ittioturismo* and *pescaturismo* in Sardinia and Tuscany (Italy country report). The aim of these forms of ecotourism is to diversify exploitation focusing on the integration of fishing within naturalistic, educational and recreational activities and to reduce fishing effort while providing a supplementary income for fishers.

A sign indicating tourism fishing activities in the Tortolí lagoon (Sardinia, Italy), photo ©D. Crosetti, 2011

Public participation in leisure activities as well as information and communication about fishing culture in coastal lagoons certainly contribute to a correct use of aquatic lagoon ecosystems, fisheries resources and aquaculture, improved awareness of the sociocultural aspects connected to lagoons fisheries and the preservation of the lagoons' cultural heritage.

The laws and regulations in force in Mediterranean countries suggest that a further development of fishing ecotourism activities is to be expected. In Italy for example, specific laws lay out frameworks for fishing tourism as a diversification measure (Law n. 96 of 20/02/2006; Legislative Decree n. 4 of 09/01/2012). Moreover, within the wetlands enhancement project called "Zoumgest", developed within the framework of the Operational Programme "Italy – Maritime France 2007–2013" some interesting guidelines addressed to all fishing operators in coastal lagoons who are pursuing or wish to pursue multifunctional activities for ecotourism, fishing and recreational tourism have been published (Saba, 2012).

Coastal lagoons situated within national or regional parks benefit from the parks' strict regulations aimed at protecting and preserving wildlife and biodiversity and preventing any consumptive use of the area. The Pontinian coastal lakes – Monaci, Fogliano and Caprolace – on the west coast of Italy are an example: they are located within the boundaries of the Circeo national park where capture fisheries are now banned. In other Italian parks, fishing activities are still practised, as in the Lesina lagoon (Gargano national park), or in the *valli* of Comacchio (Parco Regionale delta Po), where fishing activities are permitted with the aim of preserving and handing on the local cultural heritage (Italy country report).

2.6 Environmental issues in coastal lagoons

As probably the most densely populated areas in the world (Papayannis and Salathé, 1999), the Mediterranean coastal zones exemplify the conflict between the human exploitation of water resources and the ecological needs of aquatic ecosystems (Thompson and Flower, 2008).

In such a context, coastal lagoons have become a matter of concern due to the detrimental impact of several human activities over recent decades. The close relationship of lagoons with terrestrial ecosystem boundaries make these environments very vulnerable to hydrological modifications (freshwater diversions or drainage discharges), water pollution and habitat loss (Gamito *et al.*, 2005; Pérez-Ruzafa *et al.*, 2000, 2002, 2005b), which deeply change the structure of the lagoons' ecological dynamics.

Aerial view of the lagoon area, bay of Cadiz (Spain), photo ©J.C. Macias, 2011

Coastal lagoons undoubtedly play a major role in regional economies, but increasing human pressure brings about ecological disturbances that could limit or suppress the economic and ecological services provided by these ecosystems (Troussellier and Gattuso, 2007). The degradation of the lagoon environment affects not only fishing activities, but also those related to recreation and ecotourism (see paragraphs 2.4.3 and 2.5.4), creating damages for the entire coastal community.

2.6.1 Deterioration of land surrounding lagoons

Some changes in the lagoons' environment are historically related to the use of the surrounding land. The intensification of urbanization and litoralization, with a shift of many industrial activities to the coastal zones, as well as the increase of interventions aimed at implementing tourism-related facilities and agriculture practices have a strong impact on the lagoons' ecosystem. For example, agriculture activities in the watershed often imply agricultural wastes and nutrient input into the lagoons as well as wastewater that may be contaminated with pesticides and contaminants, especially in those areas with intensive agriculture or industrial activities. Frequently, lagoons have even been considered as dumping areas for urban and industrial wastes (De Wit *et al.*, 2011).

The deltaic lagoons of Egypt are the most polluted areas of the country, as they receive great amounts of untreated industrial, municipal and agricultural wastewater (Egypt country report). The Porto Marghera industrial zone, in the Venice lagoon, is also well known: in the early 1920s, a harbour along with many industries was built and industrial activities have carried out in the proximity of the lagoon borders for more than fourty years (Comune di Venezia, 2012).

At present, great efforts and investments are made to process industrial and urban wastewater before it enters the lagoons or their surrounding areas, in order to maintain lagoon waters in safe and adequate conditions and to support the fishing activities. For example, in the Orbetello lagoon, a glue and fertilizers factory was closed in 1992 (Lenzi, *pers. comm.*) and the most polluted section of the lagoon was isolated in order to keep chemicals and industrial residues inside a restricted area.

2.6.2 Eutrophication, changes in hydrology and salinity

Severe and widespread environmental problems experienced in many coastal zones are associated with an excess of nutrients. Eutrophication is a common phenomenon observed in many Mediterranean coastal lagoons. When this nutrient enrichment reaches unsustainable levels, it triggers anoxia and widespread die-offs of organisms, with serious impacts on the environment of the lagoon and therefore on its economic activities (Magni *et al.*, 2009). The constant risk of eutrophication events in lagoons imposes the need of adopting measures that often require high energy and costs but are able to prevent and limit efficiently lagoon dystrophic crises (see paragraph 2.5.3).

In addition, water salinity increase and the salinization of lagoons surrounding areas often occur, mostly in the heavily populated semiarid coastal zones of the southern Mediterranean. In these areas, coastal lagoons are located downstream of inland drainage systems, and hence are particularly sensitive to changes in freshwater inflows as a result of water management. In North Africa, where freshwater resources are generally scarce, the growing demand of water for agriculture and industry and to serve an expanding population have placed coastal lagoon management requirements in direct competition with other human activities.

2.6.3 Alien species

The introduction of allochthonous (or alien) species in the aquatic environment can be due to several reasons: they can be accidentally introduced by human activities, e.g. through vectors such as ship hulls and shells, or voluntary introduced in the environment, e.g. for farming purposes. The spreading of alien species in the aquatic ecosystems in various regions of the world is also recognized as a consequence of global climate change which affects the species distribution and resource dynamics in aquatic ecosystems (Occhipinti-Ambrogi, 2000; 2007). In general, alien species can have different (negative) impacts on their new environment: i) they can actively compete with autochthonous species (and in some cases eradicate them); ii) they can be a vector for viruses and germs and favour epidemies, iii) they can become invasive and create environmental problems.

In the Mediterranean lagoon environment, alien species that have often been voluntarily introduced have sometimes replaced autochthonous ones; nevertheless, besides this negative ecological impact, some beneficial effects of these new species have been claimed, since they have sometimes significantly contributed to the increase in fisheries production. For example, the oyster *Ostrea edulis* has been replaced by the Asian *Crassostrea gigas* (Thunberg, 1973) and the Japanese carpet shell, *Ruditapes philippinarum*, introduced in 1983 from south-eastern Asia in some Italian coastal lagoons, has displaced the local grooved carpet shell, *R. decussates,* in several areas (see paragraph. 2.4.1). Indeed *R. philippinarum* has proved to be more resistant to temperature and salinity changes, to adapt to a greater variety of substrates, and to show a faster growth rate.

In Egypt, the freshwater crayfish *Procambarus clarkii* used to be imported by a private company for aquaculture purposes but has soon been released in the wild as the sale of this species on the Egyptian market failed. The species grew and reproduced in the Nile river and in its tributaries and invaded all the freshwater bodies from southern to northern coastal lakes, causing serious environmental problems such as the weakening of river and canal banks due to its burrowing behaviour and the destruction of tilapia (*Oreochromis niloticus*) nests due to its voraciousness. At present, scientists and public authorities are still trying to eradicate this alien species (Egypt country report).

The controlled introduction of allochthonous species for aquaculture purposes can lead to a parallel introduction of other undesirable alien species. In the Thau lagoon, in France, 20 percent of macroalgae are alien species and some of them have become invasive and modified the local biodiversity patterns. These macroalgae, originating from Japanese coastal zones (Boudouresque *et al.*, 2011), have been probably introduced by means of alien oysters. In Egypt, the shrimp *Penaeus indicus* was introduced in 2011 from Thailand in the north-western area of the Manzala lagoon, for fishing purposes and strict measures to prevent the introduction of viral or bacterial pathologies were adopted (Egypt country report).

Lagoon fishers in Egypt, photo ©S.H. Abdel-Rahman, 2011

Another alien species that was accidentally introduced, possibly from Australia (transported on ships hulls or on commercial mollusc shells), is *Ficopomatus enigmaticu*, a 4–25 mm long worm (Polychaeta) that builds and lives in a carbonate tube. The accumulation of the carbonate tubings results in recifs of several tens of meters height, comparable to coral-like encrustations (Grillas *et al.,* 2006), causing many problems in Mediterranean lagoons.

Local climate variations can also be responsible for the invasion of unusual species in lagoons: for example, the presence of the jellyfish *Aurelia aurita* and *Rhizostoma pulmo* has been reported in many Mediterranean coastal lagoons, such as in the lagoon of Varano and in the Sabaudia coastal lake (Italy country report). It is difficult to understand clearly the blooms of these organisms; these are probably due to various factors such as low rainfalls, high temperatures, high atmospheric pressure and increased nutrients. Species that have been sporadically present in lagoons may suddenly show a significant increase in number, or newly introduced species can find local conditions extremely favourable, creating an uncontrolled population explosion. These blooms may affect tourism-related activities and have a potential impact on fishing activities in lagoons, hampering capture operations and reducing the efficiency of fishing gear, or even have an effect on the fish commercial value (Molinero *et al.*, 2009).

2.6.4 Ichthyophagous birds

Ichtyophagous birds can create environmental issues in the environment of lagoons since their voracious fish hunting behavior often generates conflicts with fisheries and aquaculture, and in several cases (e.g. in the northern Adriatic *valli*), as a consequence of the impact of birds on fish stocks, fish farmers have abandoned extensive aquaculture activities.

In the Mar Menor (Spain), the great cormorant has become the dominant species together with crebes and Eurasian coots (*Fulica atra*) (Aymerich and Cedran, 2011). In Sardinian lagoons, ichthyophagous birds have a density of 5 specimen/ha, for a consumption of 111 t/year in the Cabras, Maerceddi and S. Ena lagoons (Marino *et al*, 2009). In Egypt, more than 6 percent of fish production was predated in the 1989/90 winter in the Bardawil Lagoon where up to 30 000 specimens of great cormorants are estimated to winter (Khalil and Shaltout; 2006 Egypt country report).

In particular, the great cormorant (*Phalacrocorax carbo*) can eat 400–600 g of fish/day, i.e. more than 300 000 tonnes of fish captured from European waters every year. The cormorant issue has been thoroughly reviewed by Kindermann (2008) who pointed out that "the total population of great cormorants has grown twenty-fold over the last 25 years and is now estimated to comprise at least 1.7 to 1.8 million birds. Cormorants have caused proven permanent damage to aquaculture undertakings and stocks of many wild fish species in the inland waterways and along sea coasts in many member States of the European Union. As the cormorant is not included in the lists of species whose hunting is permitted by the Wild Birds Directive, regular hunting is impossible [...]. However in recent years there have been various examples […] of derogation measures […] restricted in space or time: e.g. shooting permits for certain areas (Italy), for certain periods or for fixed quotas (France and Slovenia); in particular cases approval has also been granted for intervention in breeding colonies (felling of nesting trees, rendering eggs infertile)".

In fact, suspending physical barriers has proved to be effective to prevent predation by cormorants only above intensive small culture fish ponds, since these structures cannot be applied to larger surfaces such as those dedicated to extensive aquaculture systems (Kindermann, 2008). In the Mediterranean, some fishers have thus considered hunting practices as the only mean to contrast the negative environmental impacts of birds on their activities and, in some cases, controlled hunting has contributed to preserve wetlands and, indirectly, biodiversity.

Figure 3. Logo of the "Save the fish" campaign promoted by Italian fishers

The debate between conservation and hunting is still open although the prevailing position of the public opinion is to consider the conservation of birds as a priority and to contemplate lagoons as protected areas to preserve wildlife.

2.6.5 Climate change

Lagoon environmental features such as depth, connections with the sea, sediment dynamics, size, as well as water temperatures and productivity, shall all be affected by global climate change and the rise of sea level (Bianchi and Morri, 2004; de Wit, 2011; Nicholls *et al.*, 2007). Although there is a continuous debate about the consistency and potential impacts of climate change worldwide and in particular in the Mediterranean area, it will certainly (directly or indirectly) affect the region and some economic activities such as agriculture and the exploitation of natural resources in the marine domain and in coastal lagoons. Climate change will probably cause variations of the physical and chemical parameters of water (e.g. temperature, pH, salinity), increase erosion, air temperature and UV radiation, the latter two being predicted to increase of about 3°C and 20 percent respectively in 2100 with respect to the present situation (Brochier and Ramieri, 2001; Coll *et al.*, 2004).

Altogether, these environmental changes could contribute to the degradation and loss of critical habitats in lagoons (e.g. nursery areas and seagrass meadows) due to the intensification of eutrophication processes and to frequent algal blooms. Changes in water temperature and salinity may increase the spread of allochthonous species, alterate interspecies relations and the ecological balance of lagoons' ecosystems as well as modify the distribution patterns of living resources. For example, the seagrass *Zostera marina* has its southern distribution limit in the Mediterranean Sea, and an increase in mean water temperature could bring about the rarefaction and disappearance of this species from the Mediterranean coastal lagoons, with potential dramatic impacts on biodiversity. All these effects could be even more marked in shallow lagoons, with important consequences on the pelagic food web (Vidussi *et al.*, 2011).

Cabras lagoon in Sardinia (Italy), photo ©I. Viale, 2011

One of the more evident effects of climate change, in particular for an enclosed basin such as the Mediterranean Sea, is the sea level rise, the current rate of which is already much faster than that observed over geological time (Brochier and Ramieri, 2001). In fact, coastal lagoons have formed during periods of transgression under sea level rise, but the natural processes that have shaped lagoons and conditioned their lifetime are currently being accelerated and exasperated by the increased rate of sea level rise. Sea level rise could jeopardize the ultimate existence of Mediterranean coastal lagoons, in particular the deltaic lagoons of Egypt, France and Northern

Italy. It is difficult to predict in which direction the lagoon fate shall evolve. Rising sea levels and increasing erosion of sand spits (*lido*) and barrier islands may hasten the disappearance of lagoons at the land and seascape level, as they may be converted to open bays. Moreover, the *lido* and waterbody of lagoons may move inward, leaving the possibility for a lagoon setting; in fact inward moving of lagoons is a natural phenomenon during periods of seawater level rise (de Wit, 2011). This possibility depends on the geomorphological and physical conditions of the land and seascape. One can suppose that in many coastal areas of the Mediterranean, an inward moving trend shall be hampered by shoreline urbanization, due to increased demographic load and litoralization, or hindered by man-made structures built to protect the land from erosion and/or flooding.

Finally, another important effect of global climate change is ocean acidification; seawater has usually a mean pH of 8.2, which has currently decreased to 8.1 and is expected to further decrease to 7.9 (Fowler, 2008; de Wit, 2011). Such a pH shift may have important consequences on marine ecology, as acidification is detrimental for calcifying organisms like phytoplankton (e.g. coccolithophorids) and shell-forming bivalves (Orr *et al.*, 2005). However, it can be assumed that many coastal lagoons could have the capacity to buffer acidification owing to the presence of calcareous sediments.

2.6.6 Effects of lagoon exploitation

Usually, management measures in response to fish yields decline in lagoons (see paragraph 2.4.2), regardless of the reason, consist of shifting the production towards culture-based activities. The intensification of these activities has often increased the pressure on lagoon ecosystems, introducing additional unbalancing factors such as biological and chemical effects on the environment. Recently, conservation agencies and projects have started to raise public administrations and NGOs' awareness on coastal lagoons in order to include conservation issues within the management of fisheries in the lagoons.

For example, intentional restocking actions (see paragraph 2.5.2) to enhance lagoon production or accidental escapes from intensive culture facilities could generate genetic pollution in coastal lagoon fish communities. At present, restocking is often carried out with hatchery fry, often originated from broodstock of unknown origin; therefore, in this case, restocking introduces specimens that genetically differ from the local population.

The impact of land-based farms is certainly lower than that of culture cages due to the physical confinement of culture ponds from the lagoon. However, it is difficult to assess the genetic impact of aquaculture for a number of reasons such as the lack of basic genetic information on natural populations, the relatively low genetic structure of euryhaline fish species, the lack of traceability of many culture practices and, last but not least, non-compulsory declaration of restocking actions or escape events to public authorities in several countries (Svaasand *et al.*, 2007).

Additionally, pathologies can easily spread from culture facilities to the wild by means of both contaminated waters and infected fish that escape and act as vectors. In the Orbetello lagoon (Italy) for instance, grey mullets have been affected by the germ *Pasteurella* spread from seabass and seabream intensive aquaculture farms located around the lagoon (Fisichella *et al.,* 1991; Italy country report). Moreover, the introduction of allochthonous fish species for culture purposes can also unintentionally introduce allochthnous pathologies (see paragraph 2.6.4).

The changeover to non-indigenous species that has occurred, for instance, in shellfish farming has resulted in increased production capacity (due to better performance obtained with these new species) but has had several ecological impacts. As an example, the Venice lagoon has been totally altered by the use of dredges to harvest the introduced Japanese carpet shell (*Ruditapes philippinarum*), whereas the collection of the local clams used to be carried out before with artisanal means. The dredging practice has strongly affected the bottom and the water column as most of the sediments have been lifted by fishing gear, suspending and resettling in different parts of the lagoon; then, they have been partly transported to the sea through inlets, creating an overall increase of silting in the lagoon channels. It is estimated that Japanese carpet shell harvesting has caused the loss of one billion cubic meters of sediments per year in the Venice lagoon. These direct effects on the sediments may have indirect effects on the aquatic organisms and ecosystems. Many studies (Pranovi and Giovanardi, 1994; Fontolan *et al.*, 1995; Pranovi *et al.*, 1998; Province of Venice, 1998) have reported that the action of gear used for clam harvesting has caused a general depletion of the number of species and total biomass in the benthic lagoon community.

However, it is also possible to observe positive relationships between aquaculture activities and the environment. For example, the management of northern Adriatic *valli,* in Italy, foresees a number of interventions, the aim of which is ultimately to preserve habitats and wildlife and to maintain the environmental and naturalistic value of this area, where hunting activities and extensive aquaculture have always been practised (Donati *et al.*, 1999). In the *valli*, maintaining ecological conditions has been for centuries at the basis of long-term profitability (Ardizzone *et al.*, 1988). At present, about 30 percent of maintenance works carried out in a *valle* are estimated to provide an ecological service preserving the environmental value of the area (Italy country report).

Flamingoes in Veta La Palma (Spain), photo ©M. Medialdea, 2011

2.7 Institutional and legal frameworks for the environmental protection of coastal lagoons

The protection of coastal wetlands, including lagoons, has become a priority objective in resource conservation policies of the Mediterranean region. Due to the multifunctional nature of lagoon ecosystems – the main uses of which are based on environmental conservation – several international intruments aimed at regulating the life of coastal lagoons in all Mediterranean countries have included preservation concerns as part of their objectives. The first of these instruments, in chronological order, is the Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat[13] (1971), an intergovernmental treaty that embodies the commitments of its member countries to maintain the ecological character of wetlands and

[13] Convention on Wetlands of International Importance especially as Waterfowl Habitat, Ramsar (Iran), 2 February 1971. UN Treaty Series No. 14583. As amended by the Paris Protocol, 3 December 1982, and Regina Amendments, 28 May 1987.

plan for their "wise use"[14]. It was adopted at an international meeting in Ramsar (Iran) on 2 February 1971, and came into force on 21 December 1975 (Ramsar web site, 2012). This convention makes explicit reference to the fact that "the landscapes and wildlife of wetlands result from complex interactions between people and nature over the centuries."

The Ramsar List of Wetlands of International Importance, according to Article 2 of the treaty text, is the keystone of the Ramsar Convention. In the strategic framework's "vision for the List", the chief objective is in fact to "develop and maintain an international network of wetlands which are important for the conservation of global biological diversity and for sustaining human life through the maintenance of their ecosystem components, processes and benefits/services".

In February 2013, the Ramsar Convention had 164 Contracting Parties from all over the world, with 2 098 sites designated for the Ramsar List and a total surface area of 205 042 613 ha. Among these, 338 sites are located in the Mediterranean region, representing a total surface of 9 000 206 ha. Among Mediterranean Ramsar sites, 74 are coastal lagoons[15] (21.8 percent of the total), covering a surface of 533 609 ha (Table II). In some countries, coastal lagoons are the most representative Ramsar sites, both in number and in surface. In Italy, for instance, they represent more than half of the total number of Ramsar sites in the country and about 83 percent of the total Italian Ramsar sites by surface.

Although wetlands are ecosystems that are very rich in biodiversity, their role as reservoirs of biodiversity is under siege. The Millennium Ecosystem Assessment[16] has found that damage to and loss of wetlands was more rapid than that of other ecosystems. As a result, species that are dependent on both freshwater and coastal wetlands are declining faster than those relying on other ecosystems.

More recently, the Birds Directive (79/409/EEC) and the Habitats Directive (92/43/EEC) have been instrumental to protection of biodiversity. The implementation at the national level of the Habitat Directive, which targets the protection of 194 threatened species and of all migratory bird species through the Natura 2000 network, has led to the identification of a number of sites of community interest (SCI) and special protection areas (SPAs) in many Mediterranean lagoon environments. SPAs are have been identified as critical for the survival of target species and form part of Natura 2000, the EU network of protected nature sites which was established in 1992. The designation of an area as a SPA enables a higher level of protection from potentially damaging developments.

Most Mediterranean countries are contracting or signatory Parties to the African-Eurasian Waterbird Agreement (AEWA), which brings together 119 countries to protect 255 bird species that are ecologically dependent on wetlands for at least a part of their annual cycle (UNEP/AEWA, 2012).

[14] "At the centre of the Ramsar philosophy is the "wise use" concept. The wise use of wetlands is defined as "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development". "Wise use" therefore has at its heart the conservation and sustainable use of wetlands and their resources, for the benefit of humankind." (from the Ramsar Convention web site)

[15] "The Convention uses a broad definition of the types of wetlands covered in its mission, including lakes and rivers, swamps and marshes, wet grasslands and peatlands, oases, estuaries, deltas and tidal flats, near-shore marine areas, mangroves and coral reefs, and human-made sites such as fish ponds, rice paddies, reservoirs, and salt pans" (Ramsar Convention web site).

[16] "The Millennium Ecosystem Assessment, released in 2005, is an international synthesis that analyses the state of the Earth's ecosystems and provides summaries and guidelines for decision-makers. The Millennium Ecosystem Assessment assessed the consequences of ecosystem change for human well-being. From 2001 to 2005, the MA involved the work of more than 1 360 experts worldwide. Their findings provide a state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they provide, as well as the scientific basis for action to conserve and use them sustainably." (Millennium Ecosystem Assessment, 2005).

Table II: Ramsar sites in Mediterranean countries
(www.ramsar.org, February 2013, integrated and compared with country reports)

Country	Entry into force	Ramsar sites n.	Surface area (ha)	Mediterranean coastal lagoons in the Ramsar list	
				n.	surface area (ha)
Albania	29/02/1996	3	83 062	2	33 200
Algeria	01/03/1984	50	2 991 013	1	2 257
Bosnia and Herzegovina	01/03/1992	3	56 779	0	0
Croatia	25/06/1991	5	92 327	0	0
Cyprus	11/11/2001	1	1 107	1	1 107
Egypt	09/09/1988	4	415 532	2	105 700
France	01/12/1986	42	3 514 060	5	93 799
Greece	21/12/1975	10	163 501	6	119 231
Israel	12/03/1997	2	366	0	0
Italy	14/04/1977	53	60 296	31	49 792
Lebanon	16/08/1999	4	1 075	0	0
Libya	05/08/2000	2	83	2	83
Malta	30/01/1989	2	16	1	11
Monaco	20/12/1997	1	23	0	0
Montenegro	03/06/2006	1	20 000	0	0
Morocco	20/10/1980	24	272 010	1	11 500
Slovenia	25/06/1991	3	8 205	1	650
Spain	04/09/1982	74	303.09	14	62 539
Syrian Arab Republic	05/07/1998	1	10	0	0
Tunisia	24/03/1981	40	837 753	4	46 800
Turkey	13/11/1994	13	179 898	3	6 940
Total		338	9 000 206	74	533 609

Another potentially important instrument for coastal lagoon management in European countries (see paragraph 2.3) is the European Water Framework Directive (*2000/60/EC of 23 October 2000,* WFD), defined in Natura 2000 to qualitatively and quantitatively protect community waters and to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater. Its main objective is to achieve a "good ecological status" for all the European waters. The Water Framework Directive (WFD) integrates the previous water legislation scattered throughout several EU directives into a common and coherent framework (Borja, 2005). The WFD brings an innovative perspective on water resources management in Europe since, for the first time, water management is mainly based upon biological and ecological aspects – such as composition, abundance of phytoplankton, aquatic flora, benthic invertebrate and fish fauna – rather than on merely physico-chemical elements, as it was previously the case with management decisions that were supposed to focus on ecosystems (Borja *et al.,* 2004a,b; Borja, 2005). Another important feature is that many of the underlying concepts of the WFD, in particular those referring to the sustainable development of fisheries and the ecosystem approach to resources management, coincide with the ecosystem approach to fisheries (EAF), in particular as far as the ecosystem approach to the management of aquatic resources and fisheries is concerned (Cataudella and Tancioni, 2007).

Aquatic ecology scientists have been challenged by the need to put WFD principles and approaches into practice, and important experimental efforts have been deployed to monitor and preserve aquatic ecosystems. Despite the multitude of scientific papers published on the WFD, the methodological approaches proposed for its implementation and its actual application remain at present a challenge, in particular because it is difficult to define the "optimal status of an ecosystem". However, a general and coherent classification system for all European aquatic ecosystems is still to be developed (Basset, 2010).

Aerial view of the Bages lagoon (France), photo ©H. Farrugio, 2011

2.8 Conclusions: integrating management with coastal lagoons conservation in the GFCM area

The work carried out within the LaMed-2 project has highlighted the main issues regarding the ecological features of Mediterranean lagoons in light of their intrinsic fragility as well as the environmental concerns recently raised and the management strategies applied in different countries and at different times. Management models have in fact been developed throughout the Mediterranean area, thus making it possible to identify strategies which have been either successful or detrimental. Traditional management patterns include artisanal capture fisheries typically targeting high-value euryhaline fish. These fisheries are generally supported by natural recruitment, although restocking practices may sometimes be applied to enhance fisheries production thus creating an overlap between artisanal capture fisheries and traditional aquaculture practices.

A common feature of all coastal lagoons in the Mediterranean – and generally the result of increasing pressure on the coastal zones and on lagoons ecosystems – is the progressive decrease of productivity and consequently yields that is caused by the combination of overexploitation and environmental constraints as well as a shift in captures species composition. This has sometimes led to a declining interest shown towards fisheries and lagoon management schemes, not to mention in particular disregard for hydrological interventions. In other situations, socioeconomic factors have fuelled an intensification of exploitation patterns that increasingly favours more specific aquaculture models, often intensified or targeted to new productions.

In both cases, the effects are now tangible in many Mediterranean coastal lagoons at both the ecological and the socioeconomic level, often resulting in further deterioration or even new environmental problems, e.g. the loss of biodiversity. Gaps in the collection of statistical data on production and yields as well as the lack of monitoring programmes in many areas hamper the gathering of exhaustive information to fully assess the status of lagoon fisheries. Moreover, there are increasing reports of conflicts among users of coastal zones and lagoons having sometimes opposite interests.

Against such a backdrop, there is currently a very real risk that many countries of the GFCM area will witness a gradual disappearance of the traditional artisanal fisheries and aquaculture models – which have remained unchanged for centuries and have always been vital local economies and fishing communities.

A contributing factor to the loss of interest towards traditional activities in coastal lagoon management is often a lack of public awareness of the importance of capture fisheries and aquaculture in these areas and a general lack of consensus due to scarce information on the role played by active coastal lagoons management in environmental conservation.

In many cases, this lack of awareness is also due to a scarce involvement of local communities and stakeholders. In some Mediterranean coastal areas, lagoon management regulations or management plans have been sometimes introduced without taking into consideration the local conditions of coastal communities, and participatory policies have rarely been applied, thus generating conflicts among different users.

Throughout the Mediterranean area, however, the importance of coastal lagoons and the need to balance the use and exploitation of natural resources with their conservation are increasingly recognized. The Mediterranean experience shows that there are cases where specific attention has been dedicated to lagoon management, which has sometimes been rediscovered, also taking into consideration conflicting uses of surrounding areas for agriculture, urbanization and tourism purposes.

There are examples where management practices have been wisely kept based on traditional models or have shifted towards a multifunctional approach integrating fisheries/aquaculture, tourism, nature conservation, recreational activities and involving all stakeholders, fishers in particular. These experiences have helped safeguard or restore the ecological integrity of coastal lagoons, thus giving the possibility for lagoon ecosystems to provide ecological services that are in their potential. For example, greater attention and investments have been dedicated to complex management systems such as the northern Adriatic *vallicoltura* compared to other coastal lagoons in the southern and northern Mediterranean countries – for a series of historical reasons and due to a regime of exclusive property (that has been recently questioned by a judgment of the Italian Court of Cassation[17)]. Hence, it can be inferred that fish production in the northern Adriatic area have historically contributed to the conservation of these natural environments.

The same considerations apply to traditional management models in other areas. In France, Spain, Greece, Tunisia, Algeria, Morocco, Egypt and Turkey, different levels of human intervention in coastal lagoons show that it is possible to find convergent approaches to save these ecosystems by producing seafood in a natural land-based environment. Such kind of management models have brought about a deep manipulation of lagoon environment by man; the valli and similar lagoons where strong human intervention has occurred should therefore be considered as "modified water bodies" characterized by a high degree of "naturalization". This kind of environmental-oriented management approach and the development of sustainable productive activities lead to consider these semi-natural lagoons both as conservation areas (especially for birds) and as reference models for production while preserving wildlife.

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[17] Sentenza resa dalle Sezioni Unite della Cassazione in materia di demanio statale (numero 3813 del 16 febbraio 2011).
http://www.demaniocivico.it/public/public/914.pdf.
http://www.diritto.net/blog-veneto-ius/11812-la-corte-di-cassazione-dice-che-le-valli-da-pesca-della-laguna-veneta-sono-beni-demaniali-per-luso-collettivo.html

Such situations, when achieved, fully meet the principles identified in international instruments defining standards for the conservation and sustainable management and use of living aquatic resources and associated ecosystems (e.g. the Convention on Biological Diversity in 1992, the FAO Code of Conduct for Responsible Fisheries in 1995, etc.) and in ecosystem-based management approaches (EAF and EAA) that account for the ecosystem, its associated resources and human activities as a whole. Moreover, the need for an ecosystem approach in the management of any activity where fishing and aquaculture overlap is even more evident in the case of coastal lagoons.

Mediterranean countries have unanimously recognized that a common Mediterranean strategy and a cooperative approach for the sustainable management and use of coastal lagoons in the GFCM area where highly needed. Consistent with this objective and with the main outcomes of the LaMed-2 Expert Network meeting (Italy, 2011) (see paragraph 1.3), the GFCM promoted at its thirty-sixth session (Morocco, 2012) the elaboration of guidelines for a management plan for Mediterranean coastal lagoons, in particular to: (i) acknowledge the crucial environmental and socioeconomic role of coastal lagoons; (ii) address the conservation of traditional aquaculture and artisanal capture fisheries; (iii) prevent any further degradation of coastal lagoons; and (iv) restore and monitor these productive ecosystems.

These elements also concur with the GFCM approach aimed at achieving a balance between the development of aquaculture and the environmental conservation of coastal lagoons (GFCM, 2012). The GFCM has thus indicated that guidelines for the sustainable management of coastal lagoons in the Mediterranean should address inter alia:

- The identification of models of sustainable use of costal lagoons in the GFCM area, also based on artisanal capture fisheries and traditional aquaculture, in order to preserve the role of these environments in providing food, income and livelihood to local communities;
- The conservation of traditional aquaculture and capture fisheries, with specific reference to artisanal exploitation patterns and to the preservation of the traditional knowledge of coastal communities;
- The transition, based on socioeconomic considerations when possible, towards traditional artisanal models of exploitation and use, and the curtailment of management models focused on intensified production levels and on the introduction of non-native species;
- The prevention of the further of degradation coastal lagoons and/or the recovery of their ecological integrity, reducing habitat loss, improving their quality and recovering the overall system resilience;
- The conservation of biodiversity through responsible capture fisheries and aquaculture practices;
- The interaction between species, also taking into account ichthyophagous seabirds and other non-marine species that play a relevant role in coastal lagoons management due to their impact on fish communities while contributing at the same time to the overall biodiversity and aesthetic value of coastal lagoons;
- The restoration of ecosystems associated to coastal lagoons in the GFCM area, focusing on programmes aimed at recovering the ability of ecosystems to provide goods and services, also taking into account the need to mitigate possible effects of global changes, in a broader perspective.

The development of guidelines for the management of coastal lagoons encompassing these principles would guarantee lagoon productivity through extensive aquaculture and artisanal fisheries while ensuring the conservation of biodiversity and local knowledge and preserving the cultural heritage of Mediterranean coastal lagoons for future generations.

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PART 2

COUNTRY REPORTS

1. ALBANIA

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1.1 Introduction

The Republic of Albania is situated in the south-eastern region of Europe, southwest of the Balkan peninsula, along the Adriatic and the Ionian Sea. It is positioned between these geographical coordinates: 39° 38′ (Konispol) and 42° 39′ (Vermosh) south-north, 19° 16′ (Sazan Island) and 21° 40′ (Vernik village, Korca) west-east.

The territory of Albania is 28 748 km^2 wide. The administrative division of the country consists of 12 prefectures, 36 districts, and 374 communes/municipalities. The Albanian population adds up to 2 831 741 inhabitants. The gross domestic product (GDP) according to the 2011 estimation is US$ 25 035 billion, and income per capita is US$ 7 780. Total capture fisheries and aquaculture production was 6 206 tonnes in 2010. Per capita consumption of fish products was 2.34 kg in 2010. This figure corresponds to the legal fish consumption, though undetermined illegal fishing and aquaculture certainly increase the per capita fish consumption (Word Bank and Fishery Directorate, 2011).

The Albanian coast is 427 km long. There are two distinct zones: the Adriatic and the Ionian. The Adriatic coast is 273 km long, has shallow water and long sandy beaches (up to 5 km). Much of the coast is covered with pine forests. The southern Ionian coast is 154 km long.

The Adriatic and Ionian Sea feature quite distinct physical and chemical characteristics: the Adriatic Sea shows large seasonal variations in temperature and productivity, with levels of nutrients and salinity largely controlled by freshwater inputs. The Ionian Sea has instead a more uniform physical and chemical oceanography throughout the year.

1.2 Generalities on coastal lagoons

Albanian lagoons represent a very important environment. These lagoons present multiple assets, both at the ecological and economic level. It is estimated that coastal lagoons are the most productive ecosystems, owing to their position between land and sea.

In countries with high biodiversity, such as Albania, the contribution of wetlands is essential. Their protection and their preservation have been identified as a priority not only by environmental institutions, but also by numerous non-governmental organizations. International technical and financial assistance is necessary to support efforts towards the preservation of Albania's natural heritage.

Coastal lagoons are particular aquatic sites within the Albanian hydrographic network. They typically stretch along the coastline and they are separated from the sea by a narrow strip of land, of alluvial origin, which in most cases appears as a long cord with littoral sand dunes. The coastal lagoon shaping process is closely linked to the continuous accumulation of sediments that are carried and shed from rivers to the sea.

The main Albanian coastal lagoons are Karavasta, Butrinti, Narta, Kune-Vaini, Orikum, Patogu and Viluni. There are some other small lagoon areas, like Kallenga and Lumi I Kripur near Narta, and Murtemsa near the Viluni lagoon.

In general, the depth of Albanian coastal lagoons is relatively low. The limnology regime of coastal lagoons can mainly be determined by dynamic processes of communication between the sea and lagoons through several channels.

The eight Albanian coastal lagoons are located in two distinct geographic areas: the Adriatic and the Ionian Sea coastal areas. Seven lagoons (from north to south: Viluni, Kune, Vain, Patog, Karavasta, Narta and Orikumi) are situated along the Adriatic coastline and only one (the Butrinti lagoon) belongs to the Ionian coastline.

The climate of the Albanian littoral lowlands is typically Mediterranean. Annual precipitation rates range from 930 to 2 200 mm; annual temperatures vary between 15–16.5°C, increasing from north to south and from west to east. The number of frosty days is 5–30 every year, maximum temperatures are 42.2–43.9°C and minimum ones range from - 3.5 to -7.2°C.

Figure 1. Most important wetland areas for migratory birds in Albania

Table I: Distribution of Albanian natural wetlands according the administrative region (Inventory of Albanian Wetlands, ECAT Tirana, 2003)

Administrative regions	Lagoons		Estuaries		Marshes		Total
	n.	surface area (ha)	n.	surface area (ha)	n.	surface area (ha)	surface area (ha)
Shkodra	1	1 633.0			3	1 244.0	2 877.0
Lezha	3	7 142.5	2	610			7 757.5
Fieri	1	9 352.2	2	8188	1	43	17 540.2
Vlora	4	7 113.5			2	63	7 176.5

The most important lagoons for their fisheries and aquaculture production are the Karavasta, Narta and Butrinti lagoons.

Table II: Albanian lagoons, surface and fish production (1990 and 2010)

		Production (tonnes) fish		Production (tonnes) shell fish	
Lagoon name	Surface area (ha)	1990	2010	1990	2010
Karavasta	9 352	289	110	110	
Butrinti	2 301	120	8	2 500	150
Narta	5 914	209.4	20	20	
Kune	250	26.9	29.5	29.5	
Vaini	850	71.6	64	64	
Orikumi	799	2	8	8	
Patogu	4 688	22	40	40	
Viluni	1 244	10	23		
Total	***25 398**	**768**	**307**		

*This surface also includes wetlands and marshes. Source: Fishery Directorate

The Adriatic coastal lagoons continuously undergo erosion processes affecting not only their structure but also their communication with the sea. As a result of this poor communication between lagoons and the sea, some lagoons are affected by salinity increase (Narta and Karavasta lagoons) and high levels of eutrophication (Vaini and Karavasta lagoons). Moreover, decreasing freshwater flows into the lagoons have damaged the fragile equilibrium of the lagoon mouth. This phenomenon is typical in the Karavasta, Narta and Vaini lagoons. The Ionian coastal lagoons, like Orikumi and Butrinti, are not affected by this problem thanks to the rocky structure of the area.

According to their origin, Albanian cosatal lagoons can be divided as follows:

- Alluvium sedimentation from the rivers: Viluni, Vaini, Kune, Patogu, Narta and Karavasta lagoons
- Tectonic: Knalla, Orikumi andButrinti lagoons.

Albanian coastal lagoons are important for coastal communities, in particular as far as fisheries are concerned, but they also offer opportunities for agriculture, forestry, hunting, ecotourism and cultural activities. Karavasta, Narta and Brutrinti are among the most representative lagoons.

All Albanian lagoons are national resources and are managed by the State.

Table III: Environmental institutional framework of Albanian lagoons
Source: Biodiversity Directorate. Ministry of Environment, Forestry and Water Administration IBA (International Bird Area), SPA (Specific Protected Area)

Lagoon name	Environmental status
Viluni	Part of Protected Landscape and Ramsar area, IBA (By Council of Ministers Decision, N0. 682, of date 02.11.2005)
Vaini	Natural Managed Reserve, IBA (By Council of Ministers Decision, N0. 432, of date 28.04.2010)
Kune	Natural Managed Reserve, IBA (By Council of Ministers Decision, N0. 432, of date 28.04.2010)
Patogu	Natural Managed Reserve, IBA (By Council of Ministers Decision, N0. 995, of date 3.11.2010)
Karavasta	Part of NP Divjaka-Karavasta and Ramsar area, IBA, SPA (By Council of Ministers Decision, N0. 687, of date 19.10.2007)
Narta	Part of Protected Landscape land-water, IBA (By Council of Ministers Decision, N0. 680, of date 22.10.2004)
Orikumi	IBA, SPA (By Council of Ministers Decision, N0. 680, of date 22.10.2004)
Butrinti	Part of Butrinti NP and Ramsar area, IBA, SPA (By Council of Ministers Decision, N0. 693, of date 10.11.2005)

The main laws related to lagoon areas in Albania are the following:

- Law n. 7908, date 5.4.1995 on “Fishery and Aquaculture”;
- Law n. 10431, date 9.6.2011 on “Environment protection”;
- Law n. 9584, date 20.7.2006 on “Biodiversity protection”;
- Law n. 9867, date 31.1.2008 on “Rules and procedures determining on international market of endangered wild fauna and flora species”;
- Law n. 10006, date 23.10.2008 on “Wild fauna protection”;
- Law n. 9385, date 4.5.2005 on “Forestry and forestry unit mission”;
- Law n. 10253, date 11.3.2010 on “Hunting”, etc.

1.3 Living resources

Albanian coastal lagoons offer adequate conditions for the variety of living organisms, in terms of species and biomass. They feature feature a complex and varied biodiversity and provide habitats for vertebrates, wintering and nesting birds, marine finfish, mammals, reptiles and amphibians.

In general, lagoons flora and fauna include a great number of species: 363 plant, 71 mammal, 144 fish, 307 bird, 45 amphibian and reptile species have been so far recorded in Albanian wetland areas, of which coastal lagoons represent an important part. Concerning migratory birds, an average of 130 000 wintering birds has been recorded, in particular in the Karavasta, Narta and Butrinti lagoons. The birds wintering community is dominated by *Anas Penelope* and *Anas crecca*. Areas such as Karavasta and Narta are of global importance for nesting birds, namely *Pelecanus crispus, Sterna albifronts* and *Glareola pratincola*. The Viluni lagoon (Velipoja area) is the only area where the globally endangered species *Aythya nyroca* still breads. In the delta of the Buna river (close to Viluni), a threatened species (*Phalacrocorax pygmaetus*) can also be observed during the breeding season.

As far as marine fish species are concerned, the main fiheries in Albanian coastal lagoons are grey mullet, European eel, seabass and seabream. Among critically threatened a species, from a bioversity point of view, it is worth mentioning the presence of sturgeon (*Acipenser sturio*).

Table IV: Endemic/subendemic species in Albanian wetlands
(Inventory of Albanian Wetlands, ECAT-Tirana)

Plants	Fish	Other
Ranunculus degenii	*Alosa fallax lacustris*	*Orientalia curta*
Oetasites doerfleri	*Chalcalburnus chalcoides tiranensis*	*Ancylus spp*
Orchis albanica	*Rhodeus sericeus amarus*	*Gyraulus spp*

Table V: Globally threatened vertebrate species in Albanian wetlands
(Source: ECAT-Tirana. Inventory of Albanian Wetlands ECAT-Tirana)

Nr	Name	Category of threat					
		CR	EN	VU	LR		DD
					cd	nt	
	MAMMALS						
1	*Rinolophus euryale*			X			
2	*Rinolophus hipposiderus*			X			
3	*Rinolophus ferrumequinum*				X		
4	*Rinolophus blasii*					X	
5	*Myotis bechsteini*			X			
6	*Myotis capaccinii*			X			
7	*Myotis emarginatus*			X			
8	*Myotis myotis*					X	
9	*Minipterus schreibersi*					X	
10	*Nyctalus leisleri*					X	
11	*Microtus felteni*					X	
12	*Microtus thomasi*					X	
13	*Mus spicilegus*					X	
14	*Canis lupus*			X			
15	*Monachus monachus*	X					
16	*Bubalus bubalis*		X				

Nr	Name	Category of threat					
		CR	EN	VU	LR		DD
					cd	nt	
17	*Stenella coeruleoalba*					X	
	BIRDS						
18	*Pelecanus crispus*			X			
19	*Phalacrocorax pygmeus*					X	
20	*Aythya nyroca*			X			
21	*Branta ruficollis*			X			
22	*Marmoretta angustirostris*			X			
23	*Oxyura leucocephala*			X			
24	*Aquila clanga*			X			
25	*Aquila heliacal*			X			
26	*Falco naumanni*			X			
27	*Haliaeetus albicilla*					X	
28	*Circus macrourus*					X	
29	*Crex crex*						
30	*Tetrax tetrax*					X	
31	*Numenius tenuirostris*						
32	*Gallinago media*					X	
	REPTILES						
33	*Emys orbicularis*					X	
34	*Dermochelys coriacea*		X				
35	*Caretta caretta*		X				
36	*Chelonia mydas*	X					
37	*Elaphe situla*						X
	AMPHIBIANS						
38	*Triturus cristatus*				X		
39	*Hyla arborea*					X	
	FISH						
40	*Lampetra fluviatilis*					X	
41	*Acipenser naccarii*			X			
42	*Acipenser sturio*	X					
43	*Alburnus albidus*			X			
44	*Atherina boeri*						X
45	*Leuciscus illiricus*			X			
46	*Hippocampus ramulosus*			X			
47	*Barbus graecus*						X
48	*Chalcalburnus belvica*					X	
49	*Chalcalburnus chalcoides*						X
50	*Pachychilon pictum*					X	
51	*Misgurnus fissilis*					X	
52	*Alosa fallax*						X
53	*Cyprinus carpio*						X
54	*Paraphoxinus minutus*						X
55	*Paraphoxinus pstrosi*						X
56	*Paraphoxinus epiroticus*						X
57	*Aphanius fasciatus*						X
58	*Carassius carassius*					X	

** CR= critically endangered; EN=endangered; VU= vulnerable; LR= lower risk; cd= conservation dependent; nt= near threatened; DD= data deficient;*

1.4 Land and water management

Albanian wetland ecosystems have been characterized, until the 1940s, by a complex network of interlinked and rich areas.

In the early 1950s, the coastal areas of Albania included 250 000 ha of natural areas, of which 60 000 ha consisted in marshland (Gjiknuri and Peja, 1992). After this period, these areas have been altered within the framework of reclamation and agricultural land has been expanded against riparian woodland. More than 50 percent of coastal wetlands have been due to the development of drainage activities. This has resulted in a loss of surface and in a degradation and fragmentation of habitats that negatively affected flora and fauna.

Until 1990, lagoons were mainly used as military areas and communication channels between lagoons and the sea were managed through dredger boats placed at the mouth of the channels. Only authorized fisheers were allowed to exploit lagoon resources using fish barriers and various fishing nets.

After 1990, the State invested to maintain lagoon mouths and, in 2005, undertook a reform to change fishing licences. More recently, uncontrolled urban development due to important demographic settlements and illegal fishing practiced have seriously damaged lagoon surrounding areas and natural resources.

1.5 Lagoon exploitation

Since Illyricum times, lagoon fisheries have been very important in coastal zones providing local populations with an important source of food. Remnants of fishing activities in Illyric tribes dwellings (fish bones, fishing tools, bone and bronze hooks, iron and bone harpoons, boats, etc.) witness the existence of ancient fisheries cultures.

1.5.1. Aquaculture and capture fisheries facilities

Fishing boats

Nowadays, different kinds of fishing boats are used according to the physical features of lagoons (water depth, water flow, etc.). For example, in the Shkodra lagoon the so-called "*take*" and "*patogu*" boats are used: the first is a thin and long shaped boat while the second is relatively short and wide. These fishing boats can be with or without engine, depending on the distance to the fishing grounds.

Fishing gear

The main fishing gear used in Albanian lagoons includes fish barriers ("*dajlan*") installed in front of the water current. This is a generally artisanal gear similar to the gear historically used in Mediterranean lagoons composed of natural and/or plastic cans combined with wooden poles. Their contruction and use are regulated by law, according to fishing periods, and the areas close to fishing barriers are forbidden to external users.

Gillnets, entangling (trammel) nets and hooks are commonly used in Albanian lagoon areas. Harpoons were used during the 1990s but are now forbidden.

Fyke nets are also a very common fishing gear for eel fisheries in all Albanian lagoons. These can be made of one or or more traps and are called "*gogola*".

In the Vaini and Patogu lagoons, fishers also catch along the coast using fix articulated fishing traps acting as an obstacle net system in which the fish is captured into several conic-shaped or pyramid-shaped rooms. This fishing method is a heritage from previous cooperation between Albania and the USSR during the 1960s.

Employment

In Albanian lagoons fishing activities are carried out by fishers or fishers groups that are organized either in licensed companies or fishers groups (when fishweirs are used) or through a system of individual licenses.

At present, the only area where a producers' organization exist is the Narta lagoon (fishery management organization – FMO).

The number of fishers is as follows (census made by the author):

Viluni lagoon: 10 fishers
Kune lagoon: 15 fishers
Vaini lagoon: 30 fishers
Karavasta lagoon: 53 fishers
Orikumi lagoon: 6 fishers
Narta lagoon: 40 fishers
Patogu: 20 fishers
Butrinti lagoon (fish and production): 280 fishers

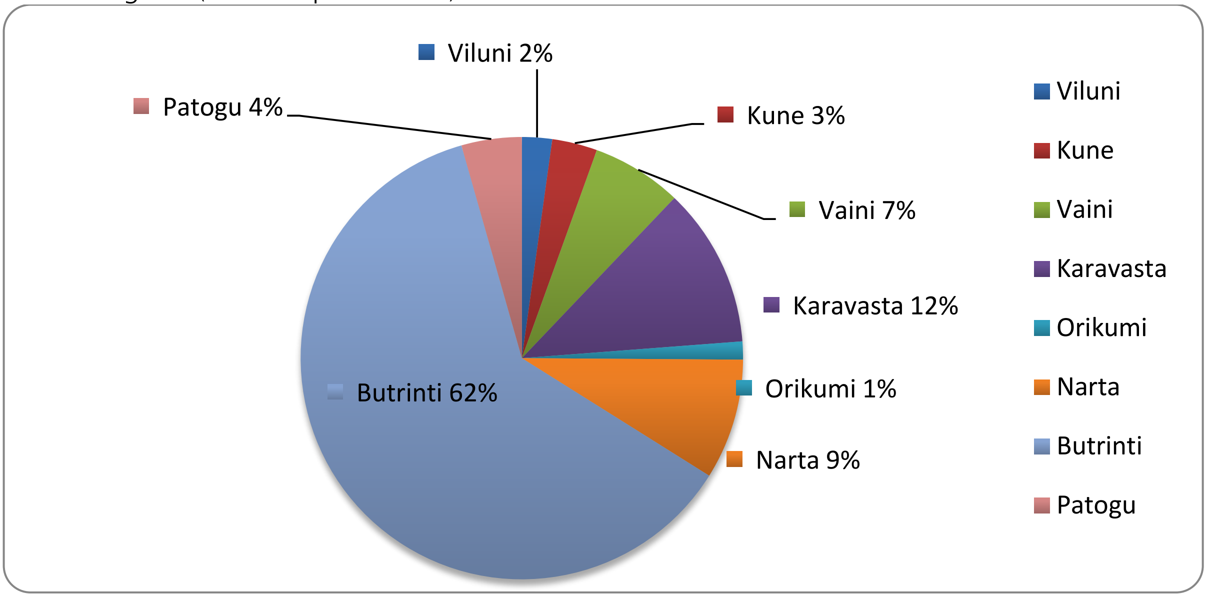

Figure 2. Employment (fishers) in Albanian lagoons

1.5.2. Aquaculture and capture fisheries management

In Albanian coastal lagoons, aquaculture is limited to extensive activities. In the Butrinti lagoon, mussels culture is carried using concrete poles and float lines.

In some lagoons such as Kune, Narta, Butrinti and Patogu, fishers have delimited through nets or pens fishing areas dedicated to fattening and wintering fish juveniles captured at the fishweirs. Fishweirs are present in many lagoons and their functioning is managed and regulated by the law.

Fishing in the communication channels and within a radius of 2 km from the outfall channel to the sea is prohibited.

According to the regulations in force, fishweirs must be open (no fishing function) as follows:

Shkodra	15 March to 31August
Viluni	15 March to 30 September
Merxhanit	10 March to 31July
Ceka	10 March to 31 July
Patog	15 March to 30September

Karavasta	5 March to 5 May
Narta	10 February to 10 April
Orikum	15 March to 15 June
Butrinti	1 April to 30 June
Prita e Rrezes	15 April to June 15

During these periods, fishing is forbidden except for hooks.

Moreover, it is forbidden in particular to:

- *place fishing canes (or plastic, metallic tubes, etc.) in the fishweir at a distance less than 12 m;*
- *fish with trawl nets and dredge;*
- *place fixed equipment closing the river stream to the sea to the lagoons;*
- *use gillnets and entangling/trammel nets with a mesh size less than 48 mm in coastal areas and 60 mm in coastal lagoons.*

1.5.3. Production

Production in costal lagoons between 1980 and 2010 is reported in the tables below, based on data from the Albanian Fishery Directorate and Fishery Research Institute.

Table VI: Coastal lagoon productivity in Albania (1980–1990)

Nr	Name of the lagoon	Average production (tonnes)	Production per hectare (kg/ha/year)
1	Karavasta	124-250	31.7-62
2	Butrinti	65-120	41-75
3	Narta	200-340	36-63
4	Kune	20-58	139
5	Vaini	31-64	62
6	Orikumi	1.5-2	11-15
7	Viluni	15-32	48
8	Patogu	12-32	25-67

Table VII: Fishing gear and catches structure in Albania (1980–1990)
(Data from the Strategy for Albanian Lagoon Management, compiled from PHARE Programme, December 2002)

Name of the lagoon	Fish barrier	Trammel and gillnets	Fyke nets and hooks
Karavasta	40%	30%	20%
Butrinti	70%	15%	12% & 3%
Narta	60%	30%	20%
Kune	-----	80%	20%
Vaini	11%	69%	20%
Orikumi	55%	30%	15%
Viluni	----	90%	10%
Patogu	----	90%	10%

Table VIII: Albanian lagoons production, years 1980–2000 (tonnes)
(Data taken from the Strategy for Albanian Lagoon Management, compiled from PHARE Programme, December 2002)

Lagoon Year	Karavasta	Butrinti	Narte	Vain	Kune	Orikum	Patog	Vilun
1980	-	-	-	65.3	60.1	-	-	-
1981	-	65	211	83.8	46	-	-	-
1982	-	68	216	75.3	47	-	-	-
1983	-	71	174	53.7	46	-	-	-
1984	-	75	173	42.4	20	-	-	-
1985	-	79	193	42.1	32.3	-	-	-
1986	162.7	64.8	286	44.6	29	-	-	-
1987	195.2	97.1	286	75	193	-	-	-
1988	294	96.2	339	98.1	49.5	-	-	-
1989	264.1	95.8	199	70.6	27.5	-	-	-
1990	289	119.9	209.4	71.6	27	-	-	-
1991	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	-
1993	-	-	-	-	-	-	-	-
1994	-	-	-	-	-	-	-	-
1995	-	-	-	-	-	-	-	-
1996	58	68	13	30	24	0.8	30	26
1997	56.8	56.8	11	30	24	0.5	30	20
1998	50	50	13.4	25	22	1	25	19
1999	-	50	14	51	20	1.02	25	20
2000	50	50.8	18	54	30	1.4	23	17

Table IX: Total production in Albanian coastal lagoons in 2000–2010 (tonnes)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Product from lagoons (fish)	110.4	240	235	175	428	270	282	331	360	336	122
Prod from Butrinti lagoon	150	150	350	860	684	1 250	1 360	1042	1000	950	1410

1.6 Interactions among aquaculture, capture fisheries and the environment in coastal lagoon management

In each Albanian lagoon, there are licensed fishers groups, the number of which depends on the number of channels communicating with the sea. Usually, lagoons have one communicating channel. Those fishers groups are the first and main users of the lagoon and are rather competent in using the structure. These groups are in some cases competent for fishing licences to recreational fishers, with or without fee. In close water areas such as lagoons, recreational fishing it is not permitted.

In the past ten years, some changes occurred in Albanian lagoons. These mainly concerned a number of physical parameters, such as water flow and sediment transport. Silting and/or erosion resulting from marine and inland water dynamics are the main processes that must be controlled in order to ensure the physical stability of coastal lagoons. Until 2005, the maintenance of lagoon mouths was supported by the national budget, but since then it has been placed under the responsibility of fishers, who have been incentivated by long-term fishing rights in lagoon exploitation. However, this strategy encountered several difficulties such as limited investments and unclear commitment of the different actors.

The lack of a clear distribution of responsibilities in the management of communication channels between lagoons and the sea and freshwater inlets has negatively affected hydraulic flows within the lagoons.

Albanian coastal lagoons represent a precious natural heritage. They provide in fact habitat to a rich fauna of invertebrates and vertebrates, including an interesting ichthyofauna and avifauna.

The precarious state of coastal lagoons and the lack of financial resources to ensure a proper management are widely recognized among administrators and scientists.

Coastal lagoons are seriously affected by several factors such as the lack of hydraulic management, pollution due to the urbanization of surrounding areas, overfishing and overhunting, illegal fishing and coastal erosion.

1.7 General considerations

Currently, there are no specific management plans for lagoon areas in Albania. However, there is growing awareneness among the main actors (e.g. Fisheries directorate, research institutes, Ministry of Environment, fisheries associations) about the need to implement specific strategic planning for each Albanian coastal lagoon, addressing among others the following issues:

- Major controls and stakeholders involvement to fight against overfishing and overhunting;
- Monitoring and interventions to reduce the effect of coastal erosion;
- Reduction of waste water;
- Grazing limitations to protect marshland and wetland habitats;
- Awareness raising of local populations, fishers, hunters and farmers to protect the environment;
- Regulation of fishing effort;
- Avoid the intensification of fishing and/or aquaculture activities.

Strategic planning could be take place by integrating specific measures towards lagoon management in the existing legislation, establishing an *ad hoc lagoon management body*, involving local administrations, organizations, associations and relevant stakeholders. Moreover, the new aquaculture legislation, currently under preparation, should consider only extensive aquaculture as a possible activity in lagoons in order to preserve biodiversity and ecosystems.

In particular, the newly established lagoon management body should have the following responsibilities:

- Preserve the diversity of natural habitats and landscapes keeping under control hydrological conditions;
- Ensure the management of lagoons (administration, rangers' service, surveillance);
- Develop research activities aiming at the conservation of species, identifying biological, physical and socioeconomic indicators, monitoring water quality including hydrographic networks, monitoring fisheries, aquaculture and hunting activities;
- Maintain the necessary conditions for species of patrimonial interests (rare, threatened and noteworthy);
- Promote Albanian wetlands at the national and international level as important sites for the conservation of habitats and species;
- Promote the sustainable use of natural resources keeping under control fishing, hunting, grazing, tourism, infrastructure and pollution;
- Include lagoons and wetlands area preservation in the socioeconomic context of the local economy, promoting eco-tourism activities, etc.

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2. ALGERIA

This country report was written by F. Seridi and A. Bounouni from the *Direction du développement de l'aquaculture, Ministère de la pêche et des ressources halieutiques* in Alger, Algeria.

2.1 Introduction

Algeria covers an area of 2 381 741 km^2, and has a population of 35 406 303 inhabitants (CIA, 2012). It borders Libya, Mali, Mauritania, Morocco, Niger, Tunisia and Western Sahara, with a coastline of almost 1 000 km length on the Mediterranean Sea. The territory is composed mostly of high plateaus and deserts, some mountains and a narrow discontinuous coastal plain.

Algeria's economy remains dominated by the state, with hydrocarbons as the backbone of the economy, accounting for roughly 60 percent of budget revenues, 30 percent of GDP, and over 95 percent of export earnings (CIA, 2012).

Aquaculture production totaled 1 758 tonnes in 2010 (203.55 tonnes in marine waters), with a total value of aquaculture production of 6 million US$ (SIPAM data, MPRH, 2010).

Aquaculture in Algeria is governed by the Ministry of Fisheries and Fish Resources and the Aquaculture Development Directorate (ADD), which was created in 2000 as a technical and administrative authority. The ADD consists of three Sub-Directorates: the Aquaculture Sites Development Sub-Directorate, the Aquaculture Potential Exploitation and Valorisation Sub-Directorate and the Environmental Conservation and Protection Sub-Directorate. The legal framework for the regulation of aquaculture is performed by Act n. 01-11 of 3 July on fisheries and aquaculture, through the Executive Decrees n. 03-280 of 23 August 2003; n. 04-373 of 21 November 2004; n. 04-188 and n. 04-189 of 7 in July 2004 (SIPAM data).

2.2 Generalities on coastal lagoons

Only one lagoon, El Mellah, is present on the Algerian coast. It is located near the city of El Kala, Wilaya El Tarf, and it communicates with the sea by a channel (ONDPA/SPA 2003).

Table I: General information of El Mellah lagoon

Name of lagoon	Country	Geographic coordinates	Surface (ha)
EL Mellah	Algeria	Longitude: 08° 20' E - Latitude: 36° 53' N	825

Competent authority	Ownership	Users
Ministry of Agriculture and Rural Development El Kala National Park	Public domain of the state	Agriculture Farmer Aquaculturists

Morphological and bathymetric characteristics

Lagoon shape: The El Mellah lagoon has an ovoid form, 4.79 km long, from the discharge system of the Bouaroug Wadi to the beginning of the channel.

Containment: The El Mellah lagoon is a coastal lake measuring approximately 864 ha, communicating with the sea by a channel. The hydraulic exchange is regularized by the tides, the movements of the sea and the variations of the lake level related to atmospheric precipitations.

The channel in communication with the sea was artificially arranged, facing over the years serious difficulties due to the progressive stranding, at a point that the persons in charge of lake aquaculture management made a second opening to the sea, and chose a strategy of consolidation of the dune formed on the old opening which previously came in contact with the sea only after strong risings:

- Maximum width is 2 603 km in the Northern half;
- Minimal width is 0.620 km in the Southern half;

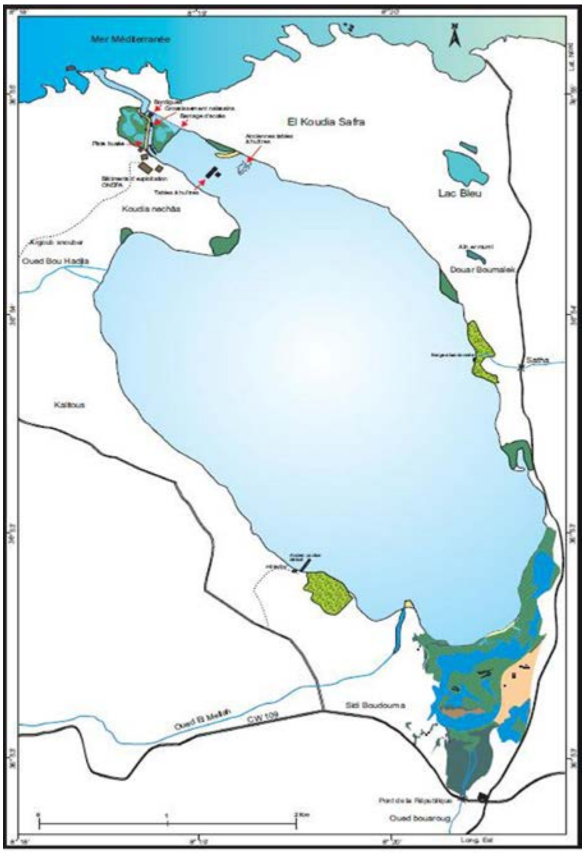

Figure 1. Map of the coastal lagoon of El Mellah

- The perimeter is 13.53 km and the length of the channel is 0.870 km;
- Its dispatcher is 15 meters approximately.

Bathymetry: Bathymetric measurements emphasize that the El Mellah lagoon is a not very deep lake:

- Maximum depth is 6.40 meters;
- Average depth is 2.7 meters.

Agricultural activity: The arable land surface borders 734 ha, which represents in absolute value 9 percent of the total surface of the catchment area. The breeding of bovine associated to groundnut culture is generally practiced.

Fishing activities: fishing activities are practised only in the peripheral belt of the lagoon down to 4 m depth, because captures are rare in the central part. The cause of this phenomenon is probably the lack of oxygen in these central zones.

Port of El kala: The fishing port in El-Kala has the following characteristics:

Length of the quays	800 m
Width of the pass of entry	70 m
Full ground	1.1
Drawing from water	4 to 5
Plane surface of water	3.6 ha

Legal framework

At the international level: The site is classified as an integral reserve in the El Kala National park with itsprotection ensured by the law of the environment and a decree fixing the National Parks Statute-type. In addition, the national park is classified as a Reserve of Biosphere of the MAB-Unesco Programme and a wetland of international importance according to the Ramsar Convention.

At the national level: The reinforcement of the legal framework was carried out by the development and the promulgation of Law n°01-11 from July 3 relative to fishing and aquaculture.

Relevant laws in force governing the exploitation of the lakes:

- Executive decree n° 03-280 of 23 August 2003 defining the mode of delivery and establishment of the domanial concession for the exploitation of the lakes Oubeira and Mellah.
- Executive decree n° 06-372 of 19 October 2006 fixing the book of the load-type for the exploitation of eel.
- Executive decree n° 04-189 of 7 July 2004 fixing measurements of hygiene and healthiness applicable to aquaculture and fishery products.
- Interministerial decree of 30 August 2009 laying down the procedure of the committee of follow-up and monitoring of the activities of exploitation of the lakes Oubeira and Mellah (MPRH, 2011).

Climatology: El Kala, one of the most sprinkled areas in Algeria, is located in the sub-wet bioclimatic stage and receives an annual average pluviometry of 910 mm and a maximum of 1.300 mm. The dominant winds from the northwest, with a mean velocity varying from 3.3 to 4.8 m/s, bring the most significant precipitations of the Atlantic. On the other hand, the Sirocco, which blows mainly in summer coming from southeast, drains the atmosphere and strengthens forests fires when temperatures are too high. The main evaporation rate is 889 mm/year.

Hydrology: It is influenced on the one hand by the movements of marine water penetrating through the channel, the exchanges between the lake occuring in a slow peripheral clockwise rotation, and on the other hand by the direct freshwater contributions at the time of the rains and, finally, by the water carted by the Oued.

Physicochemical characteristics of the water column

Temperature: The lowest value is recorded in January and the highest in August; there are two periods, one cold and the other hot, with relative temperatures ranging between 11.8°C and 20°C in winter and 20°C and 36.6°C in summer. During the cold period, there is a decrease of 5°C from October to January followed by a phase of growth during which a profit of 5°C is noted from February to April. Water temperature increases by 10°C in 4 months (from May to August). The difference of the temperature between the hottest month (August) and the coldest month (January) is 20°C.

Salinity (‰): The study shows an existence of a decrease in water, from September to January (28.7 and 22.5 g/l) followed by a phase of stabilization from February to May. From June, salinity increases with values ranging between 27 and 37.9 g/L.

pH: The lagoon water is alkaline, generally with a pH near 8. The water alkalinity shows that the lagoon is prone to a strong photosynthetic activity.

Dissolved oxygen: The lowest contents ranging between 3.9 and 5.45 mg/l are recorded in November, the highest contents oxygen reach 13.55 and 12.25 mg/l in December. The highest values are recorded between February and May (10.95– 13.1-12.75–12.85) respectively in the channel, the tables, the middle and the mouth of the Oued Souk Erguibet.

Nitrates: The exogenic nutritive salt contributions are rather weak, hence the contributions in nutriments necessary to the primary production come from the regeneration of salts starting from the sediments. The maximum contents nitrates raised in the El Mellah lagoon are definitely lower than the value guides of 5 mg/l for water of excellent quality.

Orthophosphates (Po4): The concentrations in ortho phosphates present differences: the lowest values are lower than 2.5 micromoles L^{-1} and are recorded in the channel, and in the mouth of Oued Belaroug the contents of ortho phosphates are close to 3 micromoles L.

Chlorophyll a contents: The results of the proportioning of chlorophyl, obtained starting from water samples taken monthly on the level of various sites of study, show that the concentrations in this pigment vary from one site to another and from one month to another. In the channel, chlorophyll *a* content is between 0.013 and 25.09 mg m^{-3}, rising in summer and autumn. In the central part of the lake, Chlorophyll contents do not exceed 5 mg m^{-3} except in November and August (more than 19 mg m^{-3}). The highest Chlorophyll content is in the summer and autumn. At the mouth of the Reguibet Oued, Chlorophyll content is lower than 5 mg.m^{-3} and increases from November to June. From July to October it ranges between 6 and 12 mg m^{-3}.

Suspended matter (MES): The maximum contents of MES (close relations of 140 mg l^{-1}) are found in December, in the channel and in the centre. However, values over 70 mg l^{-1} can be found in the mouth of Oued El Mellah and Belaroug in November, December and August.

Bacteriological quality of the medium: A weak concentration of germs in the lagoon water would be the result of a weak bacteriological pollution or a strong capacity of self-purification of this water, owing to the fact that it maintains the exchanges with the sea by means of the channel.

Geomorphology of the site: On the geological level, the site is made of sand and of laguno-marine clay of the Neopleistocene, results from the slope of silician deposits followed by successive depressions. With the old Neopleistocene, the sea penetrated largely in the depression of the Mellah.

The side located below the outfall of the lagoon consists of molasses calcareous navy and dunaire. The tertiary formations are represented by elements of the average Eocene (clays of numidie) and elements of the Miocene.

The soil pH is slightly acidic, the profiles are dominated by sand associates to coarse silts or clays, sometimes also with fine silts. Coarse sands are represented very little on the level of the profiles. In a general way, texture is sandy to sandy-muddy.

2.3 Living resources

Flora

The El Mellah lagoon is characterized by the existence of extremely reduced banks including one of the most diversified terrestrial vegetations. Indeed, the general configuration of banks makes it possible for the woody vegetation made up of maquis to settle meadows at the limit of the water of the lake.

On the level of the western bank rise solid masses of cork oak with a procession of vegetation going up to 2 or 3 meters from the water surface. The northwestern part was the subject of a reforestation of eucalyptus that leaves the place towards the north to a vast alder plantation. On the floristic level, a grouping of Pines of Alep stands at the northwest of Mellah.

Fauna

The gradient of space and temporal variation in the salinity of water is the cause of the biological richness and the great production of invertebrates and fish of the site.

Birds

Ecological diversity is largely determined by the influences of freshwater, of rain origin and the brackish water of marine origin, in various points of the site. The El Mellah lagoon is characterized by a significant ornithological diversity. The brackish character of the water and the diversity of the additional mediums are at the origin of the presence of abundant and specific resources (benthic fauna, fish, vertebrates and invertebrates of the marshy zones, various vegetable resources, etc.). These trophic resources condition the presence of a particular avifauna where piscivorous and limicolous species dominate.

Currently, 61 species constitute the settlement of the site, with a presence reinforced with Phalacrocoracids, Larids and the Limicolous (32 species of Charadriiformes, seven species of Ciconiiformes, three species of Coraciiformes, eight species of Passeriformes, six species of Anseriformes, two species of Gruiformes, one species of Podicipediformes, one species of Pelecaniformes and one species of Falconiformes) (MADR 2004; 2005).

Aquatic species

The gradient of space and temporal variation in the salinity of water determine biological richness and great levels of production. The groups of species of interest for exploitation purposes are hereunder reported.

Shellfish: Nine species of autochthonous shells are listed: five bivalves and four gastropods. The maximum richness (nine species) is recorded in the North of the lagoon, and two allochthonous species (mussels and oysters) were voluntarily introduced for culture purposes.

The local species are as follows:

Loripes lacteus, Brachydontes marioni, Ruditapes decussatus, Cerastoderma glaucum, Abra ovate, Cerithium vulgatum, Nassa reticulate, Cyclonassa neritea, Haminoea navicula,

The introduced species are: *Mytilus galloprovincialis* and *Crassostrea gigas.*

Fish: *Anguilla anguilla, Conger conger, Dicentrarchus labrax, Chelon labrosus, Liza aurata, Mugil cephalus, Liza ramada, Liza saliens, Muraena helena, Solea senegalensis, Sparus aurata, Diplodus sargus, Diplodus vulgaris*

Crustaceans*:* The only exploited shrimp species in the Mellah lagoon is *Penaeus kerathurus.*

2.4 Lagoon exploitation

2.4.1 Aquaculture and capture fisheries

Fishing gear

The activity of fishing of fish and shellfish in lake Mellah is practised by means of various fishing gear: fish wiers (*bordigue*), gillnets and bow nets for fish, rakes for the digger shells (clams).

Fish wiers: *The bordigue* is an installation that allows the capture of the euryhaline species in their migratory phase. This system of trapping does not represent only one capture device, but also a tool to prevent fish from migrating back to sea. The bordigue in Mellah was built around 1920 and has been used ever since.

Algerian bordigues

Mono-twine nets: The mono-twine net consists of only one cloth, maintained on the surface by a rope of floats and ballasted by lead to its lower part. It is composed of several pieces 50 m long attached one to the another, forming a net of 200 (four pieces) to 350 m (seven pieces) long. With a mesh size from 3.2 to 4 cm.

Trammel nets: Trammel nets are made of three juxtaposed nappes; the two external ones have large mesh size (10 cm), the intermediate nappes have small mesh size (2.5 m). It is 300 m long on average (six pieces of 50 m) and from 3 to 5 m high, and it is placed in the coastal belt (in particular near the nappes) because of the lack of oxygen in the central zone (especially in summer). Once fixed, this net forms a vertically maintained wall.

Fyke nets (or *verveux*): This capture gear, of artisanal manufacture (circles made of wood, plastic, metal or net), is generally intended for fishing of the sedentary and benthic species. In lake Mellah, it is composed of three capture chambers in the form of large conical pockets. Each pocket is divided into compartments communicating between themselves by a small opening. Fixed firmly to the bottom, the water current cross-piece from the beginning to the end.

Clam harvest is related to primarily clam and constitutes an artisanal activity, as in the majority of the areas where it is the subject of an exploitation. The exploitation is centered on two principal zones, Is and the south of the lake. Two fishing techniques are used:

- Manual harvest: it is the most currently used but also the most selective; the fishers wear a waterproof waterleg and the clams are collected by hand and at very low depths not exceeding 1m. They are located at sight at naked eye thanks to the small holes which appear on the surface of the sediment and which correspond to the inhale and exhale siphons of the individuals.
- Fishing with the *clovissière*: it is a rake with teeth, provided with a small net 2 cm mesh size and with a handle of approximately 2 m long (see below). It is used in the zones

where manual gathering is impossible (1 to 1.5 m depth). When the depth is more significant (2 to 3 m) this gear is used with a small boat.

Boats: There are 6–10 meters long fishing boats with 25 CV outboard engines.

Examples of fishing gear and boats

The principal species captured in the lagoon are grey mullets, European seabass, gilthead seabream, eel, white bream and shrimp.

Aquaculture facilities

There was an aquaculture farm in the El Mellah lagoon with facilities located at the northern end of the lake in the zone of the beginning of the channel. They were mainly annexes and cold rooms near a storeroom, which were built to shelter a hatchery and concrete tanks for the pre-fattening and the grow-out of the culture products. But the hatchery was never built and the facilities are not used anymore, and are currently in rather bad conditions.

In the middle of the channel and *vis-a-vis* the mouth of the Oued Bou Hadjl, there were facilities for shellfish culture similar to those found in the Thau lagoon (France). The mussels and the oysters produced in the lagoon are introduced species. They were grown on shellfish culture installations on tables, set up on the bottom 2.5 to 3 m deep in the northern zone of the lagoon. These supports are of traditional type, made of iron poles (railroad rails), inserted vertically and separated 2.5 to 3 m apart. These systems have the advantage of being very robust and require little maintenance. There has been no shellfish producion since 2004.

There is no specific management plan for the coastal lagoon of El Mellah.

Eels are exported directly to Italy. The transport of aquaculture products is ensured by isothermal trucks.

Currently eels are not exported in case of standards for export given that the European regulations require that lakes should have a management plan.

Regarding of this, The Ministry of Fishing and Fisheries Resources will soon launch a study determining the biomass of eel and development of a management plan.

Table II: Lagoon fish production (1992–2014)
(Source: Direction de la pêche et des ressources halieutiques – El Taref, 2015)

Year	Grey mullets	Seabass	Sole	Seabream	Eel	Others
Tonnes						
1992	5.717	0	0.181	0.753	1.143	3.766
1993	27.674	3.697	0.084	4.061	0	2.414
1994	15.168	8.782	0.191	2.761	2.751	2.900
1995	20.116	7.928	0.076	2.148	1.458	2.871
1996	11.805	0	0	4.646	4.678	3.458
1997	11.327	0.695	0.145	8.067	2.079	4.668
1998	19.760	2.545	0.210	6.186	0	2.806
1999	13.767	2.216	0.195	11.866	1. 380	2. 329
2000	1. 257	1 .140	1.299	3 .008	0.0 70	1. 588
2001	--	- -	--	--	--	--
2002	10. 235	--	0.0 30	0.504	--	0.815
2003	0.868	0.038	0.006	0.830	0	3.017
2004	--	--	--	--	--	--
2005	--	--	--	--	--	--
2006	5. 950	0.141	0.079	0.062	- -	--
2007	5. 285	0. 827	2.353	--	--	--
2008	42. 789	1. 336	0.810	3.488	1.594	0
2009	17. 337	1.046	0.103	0.211	5.800	0.350
2010	3.438	--	0.02	0.02	3.400	3.587
2011	4.919	--	--	0.748	--	0.77
2012	3.847	0.30	--	0.04	0.400	0.093
2013	0.350	0.20	0.065	1.087	--	0.827
2014	1.748	0.10	0.04	0.02	--	0.175

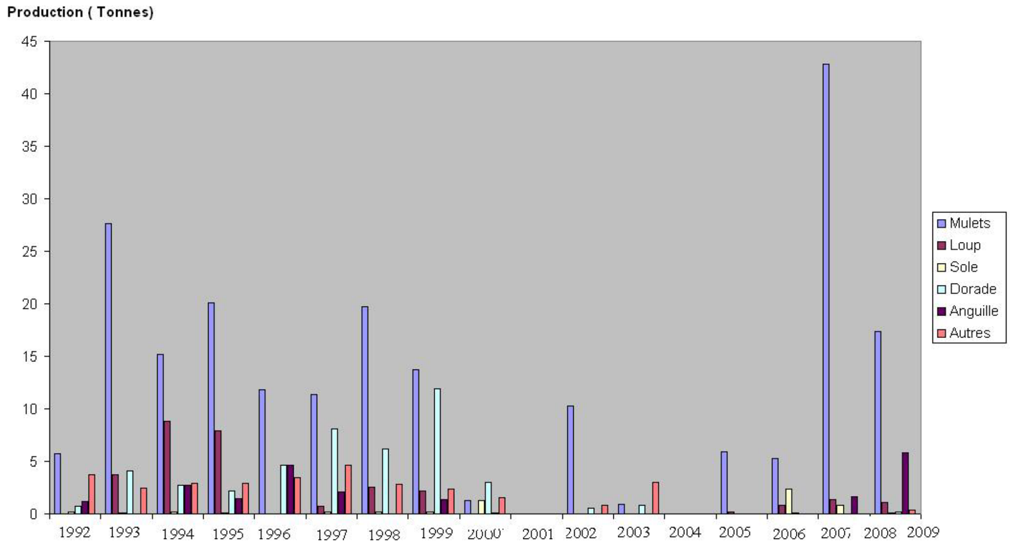

Figure 2. Fish production from El Mellah lagoon (tonnes) from 1992–2009

Table III: Production of bivalve molluscs
(Source: DPRHW –El Taref, 2010)

Year	Mussel	Oyster	Clam
Tonnes			
1992	17.67	--	2.09
1993	0.72	--	16.52
1994	4.71	--	12.52
1995	0	--	16.57
1996	0	--	19.27
1997	0	--	20.51
1998	0	--	27.62
1999	0	--	8 .65
2000	0	0.68	10.70
2001	--		--
2002	0	0.12	0
2003	--	2.99	1.58
2004	0.015	0.013	--
2005	--	--	--
2006	--	--	--
2007	--	--	--
2008	--	--	--
2009	--	--	--

Table IV: Shrimp *(Penaeus kerathurus*) production
(Source: DPRHW –El Taref, 2015)

Year	Production (tonnes)
1992	0.18
1993	0
1994	0
1995	0.03
1996	0
1997	0
1998	5
1999	0
2000	0.67
2001	--
2002	0
2003	--
2004	--
2005	--
2006	--
2007	0.44
2008	0.25
2009	0.39
2010	0.149
2011	0.077
2012	--
2013	--
2014	0.113

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3. EGYPT

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3.1 Introduction

Egypt has an area of 1 000 250 km² and a population of about 81 000 000 inhabitants (CAPMAS, 2011). Egypt is bound by Libya in the west, Sudan in the south and Israel and the Gaza strip in the east. The Egyptian Mediterranean coast is almost 1 100 km long (Fig. 1). The Nile divides the plateau across which it flows from south to north into two regions: the Western Desert and the Eastern Desert. The lower Nile Valley is a green strip across the desert, demarked by steep valley sides. North of Cairo, the valley flattens out and the river enters the delta (300 km wide, 175 km deep and about 26 000 km² wide). The delta contains a network of irrigation canals and drainage systems. Drainage waters finally flow into several wetlands and lagoons that face the Mediterranean Sea. These lagoons contribute significantly to the economics, environmental aspects and fishery production of the country. Fish production in Egypt totaled 1 092 888 tonnes in 2009, of which 387 389 tonnes were coming from capture fisheries and 705 490 tonnes from aquaculture (GAFRD, 2009). Moreover, fish imports into Egypt totaled 230 000 tonnes in the same year, increasing fish consumption for humans to almost 1.3 million tonnes (CAPMAS, 2009). Fish consumption in Egypt increased from 6.4 kg per capita in 1992 to about 16 kg per capita in 2009.

Figure 1. Map of Egypt

3.2 Generalities on the coastal lagoons of Egypt

The Mediterranean coastal area of Egypt may be divided into three sectors, according to the coastal lagoons presence and typology. The western sector (west of Alexandria to Sallum) is an arid area with many tourist villages and resorts along the shore that occupy almost all the coast without any important lagoons, except for Mersa Matrouh, which is really part of the sea. The central area, from Alexandria to Port Said (Nile delta), extends for about 260 km, and contains the most important lagoons and wetlands: from west to east Edku, Burullus and Manzala. East of Edku, there is Maryout, which has originated as a coastal lagoon, but at present can be considered as a freshwater basin as it has no connection to the sea. It is about 4 meters under sea level and receives drainage freshwater from agriculture and sewage treatment plants, which are pumped to sea by a huge pumping station. The third sector extends from Port Said to Rafah (North Sinai) and encompasses two hypersaline lagoons (Port Fouad and Bardawil) as shown in Fig. 2.

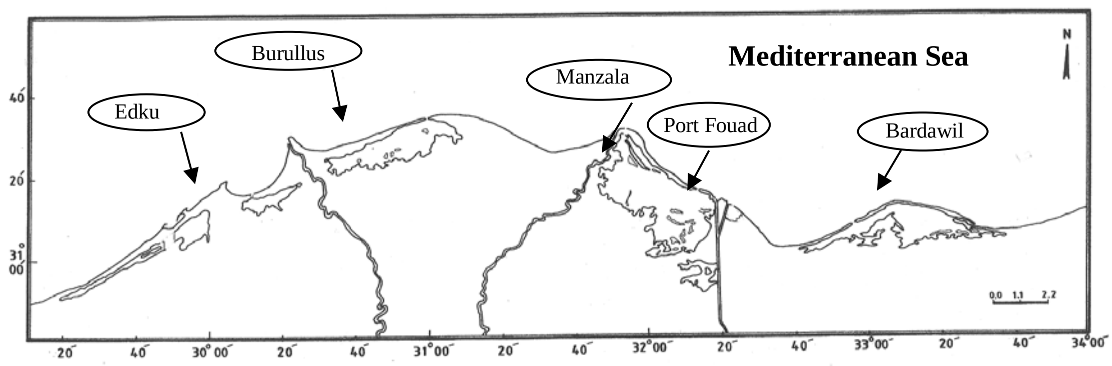


Figure 2. The Mediterranean coastal lagoons of Egypt

At present, Egyptian coastal lagoons cover a total area of about 200 000 ha. It is reported that some coastal lagoons of Egypt have lost about 70 percent of their total areas during the last 60 years (El Mezayn, 2010). Table I illustrates the present state and main characteristics of all Egyptian coastal lagoons.

Table I: Present state and water characteristics of Egyptian coastal lagoons
(Source: Abdel Rahman, 2008)

Lagoon	Area (ha)	Water sources	Water characteristics
Edku	8 000	drainage + sea	freshwater - brackish
Burullus	41 000	drainage + sea	freshwater – brackish
Manzala	78 000	drainage + sea	freshwater – brackish
Port Fouad	6 000	sea	saline - hypersaline
Bardawil	66 000	sea	saline - hypersaline
Total	**199 000**		

Main characteristics of coastal lagoons

The three delta lagoons (Edku, Burullus and Manzala) have almost the same pattern of water salinity. Each of them receives large volumes of drainage water from the south (Table II) and has one or more narrow connections to the sea from the north. Freshwater enters the lagoons all year round, keeping the water level in the lagoons higher than the sea level and preventing the intrusion of seawater, except in the winter season. In winter, the freshwater flow into the lagoons is greatly reduced for the maintenance of drainage canals. All lagoons are shallow water bodies with average depth ranging between 0.8–1.0 meters.

Table II: Drainage water input and maximum depth in coastal lagoons of Egypt
(Source: Abdel Rahman, 2008)

	Edku	Burullus	Manzala	Port Fouad	Bardawil
Drainage water input (m3 x 109)	1.4	4.0	3.7	-	-
Maximum depth (m)	2.0	2.4	3.0	2.0	2.2

Generally, each lagoon can be divided into three salinity zones; the southern part, with about 50-60 percent of surface area, has a salinity range between 1–3 gl^{-1}, the middle part (about 20–30 percent of surface) has a salinity range between 3–6 gl^{-1} and the north part (10–20 percent of surface) has a salinity range from 6–12 gl^{-1} (Shaltout and Khalil, 2005). Most fish farms are located in the southern part of the lagoons. On the other hand, no freshwater flows into the

Bardawil and Port Fouad lagoons; consequently the salinity in both lagoons ranges from 36 to 120 gl^{-1} depending on the distance from the sea inlet. The main site for mariculture in Egypt is located in the north-west part of the Manzala lagoon and is known as "*Diba Triangular*", as ithas a triangular shape of low-lying reclaimed land. This area is known in Arabic as "*Mosallath El Diba*". Its total area is about 14 000 ha and its widest part is near Damietta (to the west), whereas the narrowest part is to the east (near Port Said), and bordered from the south by the Manzala lagoon and from the north by the Mediterranean Sea. Almost all farms in this area are extensive polyculture ponds using marine fish fry from the wild. Fish farmers in this area dug several canals connecting their farms with the sea allowing them to culture marine fishes such as gilthead seabream, European seabass, meagre and marine shrimp (Sadek, 2001).

Legal framework and constraints

Capture fishery and aquaculture activities in Egypt are regulated by Law 124/1983 authorizing the GAFRD to implement the acts and decrees of fish production activities. The Law 4/1994 on the protection of the environment constitutes the main legislative act in the field of environmental protection and promotion. Two coastal lagoons in Egypt were designated as Ramsar Sites.

The first lagoon is the Burullus wetland, which was declared as a natural protectorate in 1998. The protectorate includes the lake, its islets, as well as the sand bar between the Mediterranean and the lake. The lake reed beds represent one of the most important habitats in the Mediterranean,and are becoming rare and threatened. This habitat is very important for migrant birds for foraging, refuge and breeding.

The second lagoon is the Bardawil lagoon, also designated as a Ramsar Site in 1988. It is one of the least polluted lagoons in the whole Mediterranean. Very limited eco-friendly human activities are allowed in the surroundings of the lagoon. At the eastern part of the lagoon lies the Zaranik Natural Protectorate established in 1996, covering an area of 250 km^2. All development activities are forbidden inside the protectorate except salt production.

Other coastal lagoons are unprotected, apart from the Ashtum El Gamil Protected Area (declared by Prime Ministerial Decree 459/1988), which encompasses a small area (c.35 km^2) located along the sandbar at Bughaz El Gamil, in the Manzala lagoon. Constrains include land reclamation, pollution and illegal fishing practices.

3.3 Living resources

Flora

The coastal lagoons flora is dependent on water salinity characteristics. Southern parts of delta lagoons that have low salinities are characterized by the presence of freshwater aquatic weeds and vascular plant species. Flora recorded in Burullus Wetland were shown to be 197 species belonging to 44 families and 139 genera (Shaltout and Khalil, 2005). Twelve of these species are floated and submerged hydrophytes contributing about 6 percent of the total species. Woody plants contribute to about 17.3 percent of the total species. delta lagoons (Burullus, Manzala and Edku) are considered rich in phytoplankton communities, both in density and richness. Recorded species indicate the presence of many algal species such as Bacillariophyta (diatoms), Chlorophyta and Cyanophyta. The delta lagoons ecosystem is considered mesotrophic with eutrophic tendencies, due to the increased density of submerged hydrophytes, mainly *Potamogeton pectinatus* (it constitutes 85 percent of submerged plants). Water hyacinth is widely distributed on the water surface of these lakes. On the other hand, in the Bardawil lagoon that is characterized by high water salinity, diatoms are dominant and were represented by 159 species, followed by dinoflagellates with 53 species (Shaltout, 2010). About 54 species were recorded recently and considered as alien species. Epiphytic algal species comprise 121 species belonging to 42 genera. Diatoms were the most important group. According to the International Union for Conservation of Nature (IUCN) Red List categories, six threatened species are recorded in Bardawil; four of which are categorized as endangered species (*Astragalus camelorum*, *Bellevalia salah-eidii, Biarum olivieri* and *Salsola tetragona*). One species is indeterminate (*Lobularia arabica*), while another one is rare (*Iris mariae*).

Aquatic fauna

The zooplankton community in delta lagoons is represented by various species belonging mainly to 3 groups (Rotifera, Copepoda and Cladocera). Rotifera is the most abundant group in all seasons and areas of these lakes (66–77 percent of the total zooplankton density in 2004), whereas it constituted only 17 percent of the density in 1978. Macrobenthos were represented by three groups with complete vanishing of marine species (Dumont and El-Shabrawy, 2008). Commercial fish species are mullets, tilapias, catfish, *Bagrus bajad*, *Dicentrarchus labrax, Anguilla anguilla* and penaeid shrimps. In the Bardawil lagoon, the zooplankton community is represented mainly by the holoplankton groups (Protozoa, Copepoda, Cladocera, Coelentrata, Chaetognatha and Rotifera). Copepod was the most abundant group (69 percent of total zooplankton community). The dominant species in 1985 (*Tintinnopsis labiancoi* and *Acartia clausii*) were replaced in 2003 by *T. tocantinensis* and *Oithona nana*. Meiobenthic and Macrobenthic communities comprise Foraminifera, Ostracoda, Copepod, Coelentrata, Annelida, Arthropoda, Mollusca and Echinodermata. Standing crop of total benthos decreased considerably during the last 20 years. Commercial fish species are *Sparus aurata*, *Dicentrarchus labrax, Solea solea, Argyrosomus regius*, *Umbrina cirrosa*, *Epinephelus aeneus* and mullets. Shrimp species include *Metapenaeus stebbingi, Penaeus japonicus and P. semisulcatus* and crab, *Portunus pelagicus*.

Wildlife

Egyptian coastal lagoons are an important wintering and staging area for birds. However, in Bardawil, the great cormorant, *Phalacrocorax carbo* causes substantial damage to fisheries as it devours more than 6 percent of Bardawil's fish production (Khalil and Shaltout, 2006). Four mammals (fennic fox, wild cat, sand cat and *Jaculus orientalis*) are recorded as threatened species in the Bardawil lagoon.

3.4 Land and water management

The openings or sea inlets of the coastal lagoons are essential for flooding and ensuring a vigorous exchange of seawater between each lagoon and the Mediterranean Sea and to allow the flow of freshwater from delta lagoons to the sea. This type of management based on hydraulic engineering is a very important means for developing fisheries in the lagoons. Movements of sediments by currents and wave action along the coast cause silting of the sea openings. It was estimated that the yearly accumulation of sand in these openings in the Bardawil lagoon only amounted to about 700 cubic meters (Pisanty, 1981). Restrictions in water exchange between the lagoon and the sea resulted in an increase of salinity, inhibition of spawning migration of commercial fish species, and reduction in the available area for fish feeding and growth, thus having an adverse effect on commercial fish stocks in this lagoon.

Dredging of the openings is the most expensive part of the maintenance of the lagoon, amounting to 80 percent of the total cost of the up-keep. Therefore, it is important to keep the amount of dredging at a minimum, whilst maintaining favorable physical and biological conditions for a prosperous fishery. In general terms, it was agreed by experts that protective walls at the entrance of the openings should be helpful. During the last twenty years, GAFRD carried out several engineering works to improve the entry, exchange and circulation of water inside the lagoon. These works included: dredging of the channels of the *Boughazes*, digging of radial channels eastward and westward from each *Boughaz* to allow water circulation and cladding of *Boughaz* channel banks with stones to reduce sand accumulation and silting.

During the last ten years, coastal lakes lost about 25 percent of their surface area due to seizure of land in parts of the lagoons and transferring it to fish farms, silting and spreading of aquatic weeds (El-Mezyn, 2010).

3.5 Lagoon exploitation

The main activities carried out in Egyptian coastal lagoons are illustrated in Table III. The most important activities in these lagoons are capture fisheries and aquaculture. The three main delta lagoons (Edku, Burullus and Manzala) yield over 60 percent of Egypt's annual fish catch. Moreover, aquaculture is the largest single source of fish supply in Egypt, accounting for more than 51 percent of the total fish production of the country. Most aquaculture activities are located along the shores of the north delta lagoons, with hatcheries generally located in the vicinity of the fish farms. The second important activity is agriculture. After the construction of the Aswan High Dam and the decrease in water volume flow to northern lagoons, large areas around the delta lakes were subjected to drought. These land areas had been reclaimed for agriculture and aquaculture.

Table III: Main activities in Egyptian coastal lagoons

Lagoon	Ownership	Capture fisheries	Aquaculture	Agriculture	Tourism	Bird hunting
Edku	Government	+++	+++	++	–	+
Burullus	Government	+++	+++	++	+	++
Manzala	Government	+++	+++	++	–	+++
Port Fouad	Public sector company	+++	+	–	–	–
Bardawil	Government	+++	–	+	+	++

+++ high activity, ++ moderate activity, + low activity and – no activity

3.5.1 Aquaculture and capture fisheries

Fishing gear

As described by El-Maghraby et al. (1977), the most common fishing gear in coastal delta lagoons are:

Entangling gear

Gillnet: It is is used to catch the Nile perch, *Lates niloticus*, sometimes grey mullets or tilapias. The length of a gillnet section varies between 10–20 meters.

Trammel net (*Nasha* and *Takem*): It is used to catch various fish species including tilapias, grey mullets and others. It consists of three layered walls of webbing.

Stationary trammel net (*Saksook)*: *Saksook* is a modified type of trammel net used in the Burullus lagoon.

Encircling gear

El-Gafsha: El-Gafsha (Shebak El-Habl): El-Gafsha is the largest of all nets, it is about 500 to 1 000 meters long, 4 meters high, without floats nor weights. Designed to catch grey mullets.

El-Ganeb: Is made up of sections, each of about 15 meters long and 1.5 meters wide attached together.

Trawl gear (dragged gear):

Lokkafa: is a sac-like funnel shaped net, fastened to a wooden frame shaped like a reversed "V". *Lokkafa* is not selective.

Kerba : Similar to *Lokkafa*, but smaller in size, with a modified wooden frame. The wooden frame is triangular in shape

Seine nets*: Eshalta:* is a common type of seine nets used in lagoons, having 10 m total length.

Set nets

Shrimp set net: Consists of two parts, a weir (fence) and a catching box.

Mullet set net: is used mainly at the time of mullet's migration.

Traps

Wire basket trap

Clarias trap: The whole net consists of three traps joined together and the net is set between two banks of a freshwater stream; traversing the water flow.

Hook and line gear

Cast nets (*Torraha* or *Shabka*)

Hosha: It is an enclosure located mostly at the southern shores of the lake, as well as around some islands. It is a pond having shallow water basin built by erecting low dykes made of mud and straws. It has one or more narrow openings connecting it with the lake: *Hosha* are periodically closed, water is pumped out and the fish are harvested.

In addition, fishing is performed by simple methods such as catch by hand or catching fish concealed under aquatic weeds using surrounding nets.

Work force, establishments and institutions

The number of cooperative societies in Egypt was recorded to be 93 in 2007 (Barrania, 2007). The largest and the most active society is the "Co-operative union of aquatic resources" in addition to other 82 local societies and ten aquaculture societies. The activities of these societies are not limited to coastal lagoons, but they extend to all other fishery and aquaculture activities in the country. It is very difficult to estimate the actual number of fishers in the coastal lagoons of Egypt, because the number of unlicensed workers may exceed those licensed. In the Bardawil lagoon, the number of licensed fishers in 2009 was 3 460, engaged in five cooperatives. The number of licensed boats in the lagoon was 1 159, mostly motorized. In Burullus, 30 000 fishers are working in the lagoon but only 10 300 of them are licensed. Licensed boats in the lake in 2003 reached 10 000 (GAFRD, 2009), only 160 of these are motor boats and the rest are "sambouk" (small rowing boat), "felouka" (medium size rowing boat) and sailing boats (large boats). In the Manzala lagoon, the number of fishers working in the lagoon is estimated at 22 000, but only 13 000 are licensed (GAFRD, 2009). The number of licensed boats is recorded as 6 781 in 2009. In the Edku lagoon, the number of licensed fishers is recorded as 6 000 working on 3 000 licensed boats, mostly non-motorized.

Aquaculture and capture fishery management

From 2004 to 2007 there was a stock enhancement programme to supply Burullus and Edku lagoons with fish seed from governmental hatcheries. During these years 3 million grass carp and 8 million Nile tilapia fry were released in the Burullus lagoon and about 4 million Nile tilapia fry were released in the Edku lagoon (GAFRD, 2009)**.** There iso available data on the stocking programme's progress. Regarding aquaculture, it is estimated that about 100 000 ha of reclaimed land were converted to aquaculture ponds in the last 30 years. Most of these aquaculture facilities are located at the southern parts of coastal lagoons to receive drainage freshwater.

Fish production

Fish production from northern lagoons varies over time, even though it significantly contributes to national fish production. Total fish production in Egypt amounted to more than one million tonnes in 2009, of which 387 398 tonnes (35.4 percent) from capture fisheries. Thirty percent of the total capture fish production comes from Northern lagoons (113 225 tonnes) (Table IV). Fish and crustacean production of main species are illustrated in Figures 3 and 4 and Table V.

Table IV: Capture fishery production from different environments (GAFRD, 2009)

Lagoons name	Production from capture fisheries (tonnes)*	Percentage of total production
Coastal lagoons		
Edku	6 206	
Burullus	53 401	
Manzala	48 023	
Port Fouad	185	
Bardawil	5 410	
Total from coastal lagoons	113 225**	29.2%
Inland lakes	59 017	15.2%
River Nile and its tributaries	87 335	22.5%
Mediterranean Sea	78 790	20.4%
Red Sea	49 031	12.7%
Total fish catch (tonnes)	387 398	

*Data calculated from GAFRD Year Book Statistics
**Including 7 525 tonnes of crustaceans (crabs and shrimps)

Species composition of the catch of northern delta lagoons showed relatively high diversity in the Manzala and Burullus lagoons but very low diversity in the Edku lagoon (Table V). This phenomenon needs more investigations as these lagoons have almost the same water characteristics.

Table V: Species composition (%) of fish catch from northern delta lagoons in 2009 (Source: GAFRD, 2009)

Fish species	Manzala lagoon	Burullus lagoon	Edku lagoon
tilapias	39.18	38.81	98.37
catfish	18.00	21.74	0.72
grey mullets	9.81	14.44	0.85
Bagrus bayad	8.36	0.55	-
grass carp	7.02	5.47	-
shrimp	5.75	1.85	-
spotted seabass	0.64	4.53	-
crabs	0.59	-	-
soles	0.43	1.40	-
European seabass	0.33	2.17	-
gilthead seabream	0.33	1.52	-
silver side	0.31	1.83	-
European eels	0.04	1.43	-
Total (%)	100	100	100
Total fish production (tonnes)	48 023	5 401	6 206

In the Bardawil lagoon, the total fish catch increased from 2 227 tonnes in 2004 to 5 410 tonnes in 2009. However, there was a drastic decrease in catch of highly valued fish (gilthead seabream and flathead grey mullet) and an increase in low value small shrimp and crabs (Table VI). The phenomenon was studied by Abdel Razek *et al.* (2008) and concluded that it is due to illegal fishing methods.

Table VI: Fish catch and percentage species composition from Bardawil lagoon (2004 and 2009) (Source: GAFRD Year Book Statistics)

Fish species	2004	2009
grey mullets	31.6	20.4
gilthead seabream	15.2	5.8
European seabass	1.2	1.5
Soles	5.7	4.3
shrimp	14.8	25.3
crabs	25.6	38.3
others	5.9	4.4
Total	100	100
Total fish catch (tonnes)	2 227	5 410

Aquaculture production amounted to about 705 490 tonnes in 2009, representing about 64.6 percent of total fish production in Egypt. The aquaculture production sector is clustered around the shores of coastal lagoons benefitting from the reclaimed cheap land and water availability from drains. The contribution to fish production of aquaculture around the northern lakes is very great. In 2009, fish production from aquaculture activities in the coastal lakes and their surroundings amounted to about 496 805 tonnes, representing ~70.4 percent of total aquaculture production in the country (Table VII). The share of aquaculture in Egyptian fish production increased from 17 percent in 1991 to 65 percent in 2009 (Fig. 5).

Table VII: Aquaculture production from coastal lakes and their surroundings (2009) (Data calculated from GAFRD Year Book Statistics)

Lagoon	Aquaculture area (ha)	Fish production (tonnes)	Percentage of total aquaculture production in Egypt*
Edku	11 250	29 741	4.2
Burullus	56 430	324 479	46.0
Manzala	46 095	142 585	20.2
Total		496 805	70.4

*Total aquaculture production in Egypt = 705 490 tonnes

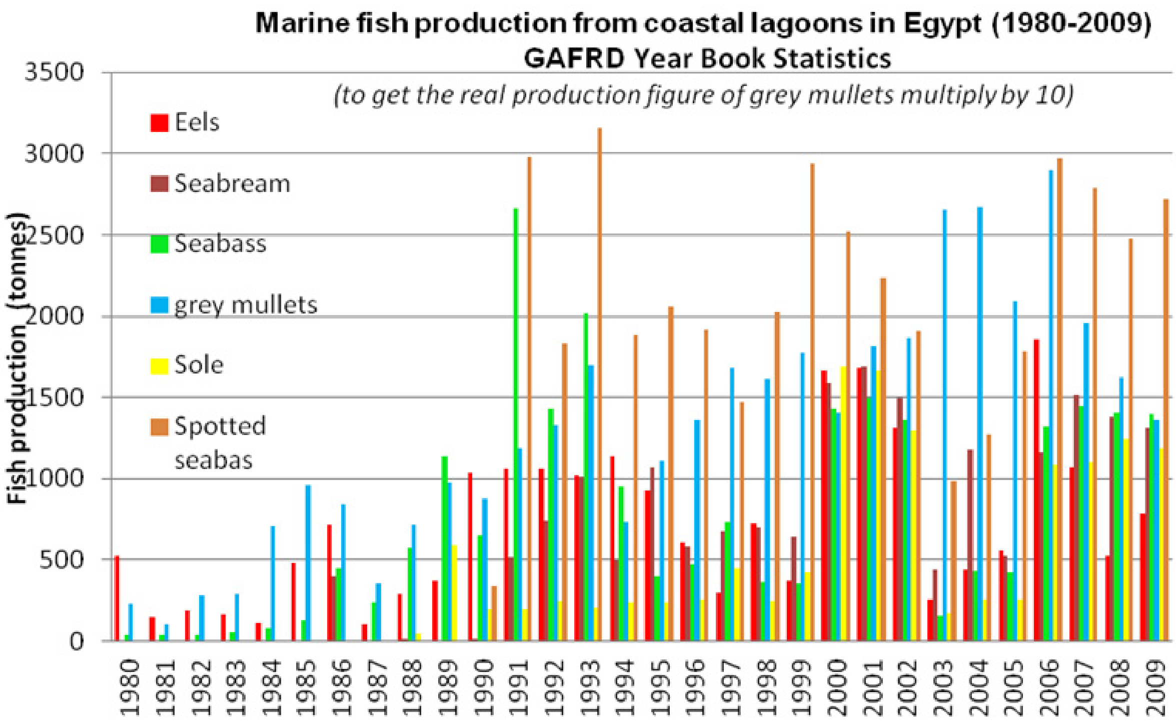


Figure 3. Marine fish production from coastal lagoons in Egypt (1980–2009)

Table VIII: Fish production of main species from coastal lagoons of Egypt (1980–2009, GAFRD Year Book Statistics)

Year	Eur. eel	Seabream	Seabass	Grey mullets	Sole	Spotted seabass	Tilapias	Catfish	Carps
1980	523	0	35	2 317	0	0	19 848	1 136	0
1981	151	0	35	1 092	0	0	13 507	1 220	0
1982	189	0	41	2 808	0	0	24 721	1 463	0
1983	166	0	53	2 915	0	0	26 506	1 734	0
1984	118	0	81	7 085	0	0	28 565	1 806	0
1985	484	0	131	9 593	0	0	44 333	2 467	0
1986	718	400	452	8 402	0	0	51 429	3 198	0
1987	104	0	236	3 608	0	0	52 015	3 413	0
1988	286	16	577	7 158	47	0	38 543	4 217	0
1989	370	0	1 137	9 762	593	0	35 515	3 990	0
1990	1 040	13	654	8810	194	342	43 546	3 558	0
1991	1 064	515	2 661	11 907	197	2 984	49 244	8 495	170
1992	1 062	739	1 430	13 314	244	1 830	68 020	8 211	148
1993	1 019	1 013	2 014	17 016	202	3 159	65 893	11 676	291
1994	1 136	501	956	73 39	239	1 881	67 643	8 844	640
1995	924	1 067	396	11 100	240	2 058	78 414	7 093	197

Year	Eur. eel	Seabream	Seabass	Grey mullets	Sole	Spotted seabass	Tilapias	Catfish	Carps
1996	607	587	474	13 620	256	1 918	81 845	8 148	356
1997	300	672	734	16 825	450	1 470	78 030	9 003	312
1998	730	704	363	16 160	246	2 026	83 915	8 845	291
1999	370	641	359	17 719	420	2 939	74 760	8 860	258
2000	1 662	1 592	1 428	14 058	1 688	2 523	78 483	14 545	1 375
2001	1 683	1 690	1 496	18 178	1 668	2 233	81 815	13 901	2 511
2002	1 309	1 495	1 366	18 676	1 297	1 907	77 601	11 789	2 193
2003	260	443	159	26 536	171	985	76 882	15 997	2 275
2004	438	1 182	429	26 676	257	1 270	70 421	11 874	2 720
2005	562	525	422	20 947	254	1 782	54 145	10 250	2 560
2006	1 862	1 165	1 318	29 013	1086	2 976	42 096	19 043	3 211
2007	1 067	1 517	1 447	19 600	1103	2 786	48 300	13 922	1 748
2008	521	1 378	1 402	16 212	1249	2 478	50 425	15 753	1 892
2009	786	1 315	1 401	13 628	1190	2 724	45 650	20 298	2 919

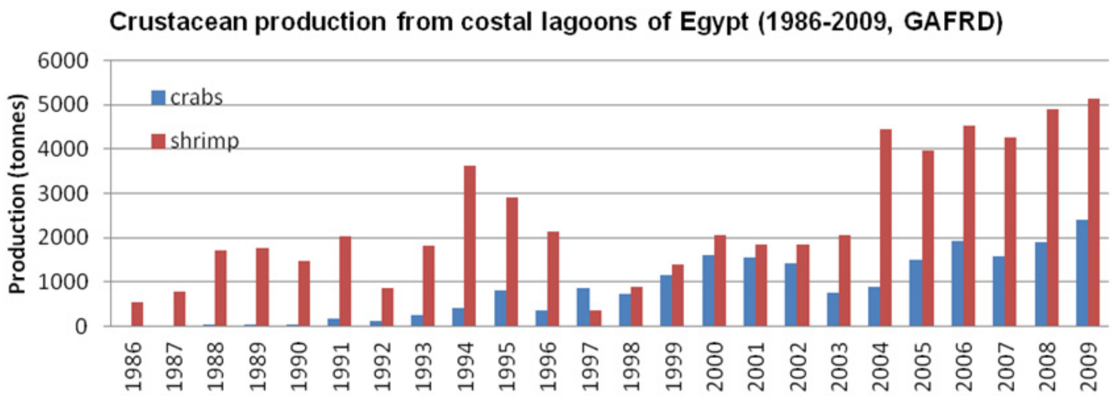


Figure 4. Crustacean production from coastal lagoons of Egypt (1986–2009), GAFRD Year Book Statistics)

Table IX: Crustacean production from coastal lagoons of Egypt (1986–2009, GAFRD, Year Book Statistics)

Year	Crabs	Shrimps
1986	0	550
1987	0	770
1988	26	1 697
1989	31	1 762
1990	26	1 474
1991	172	2 033
1992	111	869
1993	250	1 821
1994	420	3 609
1995	815	2 914
1996	349	2 136
1997	853	345
1998	714	876
1999	1 139	1 402
2000	1 616	2 054
2001	1 546	1 843
2002	1 412	1 843
2003	744	2 058
2004	879	4 455
2005	1 492	3 966
2006	1 918	4 517
2007	1 569	4 259
2008	1 892	4 906
2009	2 393	5 132

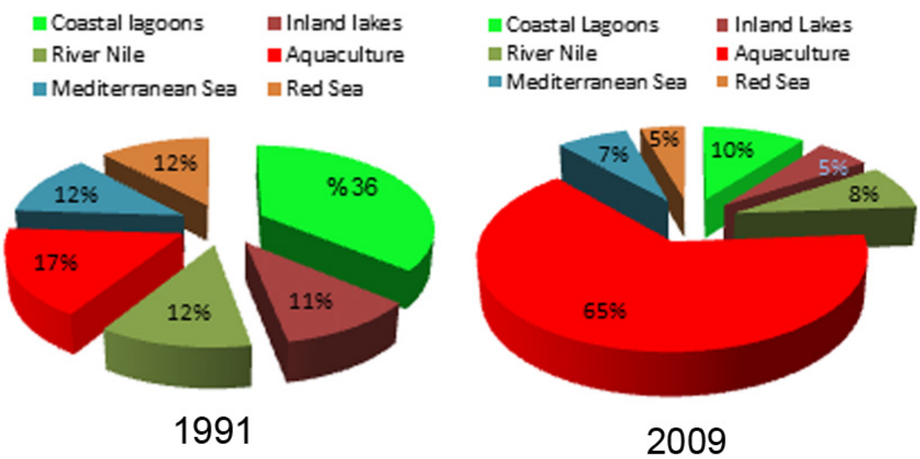


Figure 5. Fish production in Egypt by sector in 1991 and 2009
Source: GAFRD Year Book Statistics (1991–2009)

In conclusion, fish production (capture and culture) from northern coastal lakes added up to about 610 030 tonnes in 2009, representing about 55.8 percent of total Egyptian fish production. Regarding cultured fish species in all Egypt (including North lagoons), tilapias showed the highest production (~360 000 tonnes) in 2009 ranking second in world tilapia production, and grey mullets production reached 209 421 tonnes (30 percent) ranking first in the world (Table X). Cultured mullet species in Egypt include mainly the thinlip grey mullet (*Liza ramada)*, flathead grey mullet (*Mugil cephalus)* and bluespot mullet (*Valamugil seheli)*. Data on aquaculture production of each species of grey mullets is not available, but fry species composition data showed that the collected seeds in 2005 are composed of 80 percent *Liza ramada*, 11.5 percent *Mugil cephalus* and 9 percent *Valamugil seheli* (Saleh, 2008). Cultured tilapia species include mainly *Oreochromis niloticus* with other minor species as *Oreochromis aureus*, *Sarotherodon galilaeus* and *Tilapia zillii* (El-Sayed, 2006).

Table X: Egyptian aquaculture production according to species
(Source: GAFRD Year Book Statistics)

Species	Production (tonnes)	%
Tilapias	359.76	51
Grey mullets	209.42	30
others*	136.31	19
Total	705.49	

*mainly carps

3.5.2 Other uses

Recreational activities

In the Burullus, Manzala and Edku lagoons, tourism activities are mainly concentrated in the north along the Mediterranean coast, on the sand bars of these lagoons. It is visited by Egyptian tourists coming from Cairo and Nile delta cities in summer months. There are three famous towns in these lagoons (Maadia, Baltim and Gamasa).

In the Bardawil lagoon, tourism resorts are spreading west of Arish town up to the borders of the Zaranik protected area. The Mediterranean coast in this area has a good climate all throughout the year with many palm-fringed beaches. This tourist potential attracts both Egyptian and Arab tourists. In addition, there are a number of archeological sites near the lagoon dating to Roman and Islamic periods. Bird watchers and ornithologists visit the lagoon occasionally in very few numbers. However, there are only few visitors to the area due to the lack of facilities and restricted access to the shore, sandbar and the lagoon placed by military authorities.

Others

Other activities in the coastal lagoons of Egypt include: 1) bird hunting; in delta lakes, where most people who work in fisheries also practice bird hunting. The main markets for these wild birds are Alexandria, Damietta and Rosetta. This activity may pose threats to the lakes' value as a wetland area and breeding area for a lot of water bird species, 2) grazing of sheep and cattle, 3) salt production, 4) reed harvesting and 5) some other small industries (fish salting, *Batarekh* production, shipyards, etc.).

3.6 Interactions among aquaculture, capture fisheries and the environment in coastal lagoon management

3.6.1 Interactions between commercial and recreational fisheries

There are only a few individuals engaging in recreational fishing near *Boughazes* and a licence is required.

3.6.2 Interactions among different fishers groups and conflicts between fishers/fish-farmers and public or private stakeholders

There have always been complaints from fishers that fish farms pollute water, reduce the free fishing areas and the productivity in the lake by reclamation and collection of fish fry to stock their farms. Land reclamation for either agriculture or aquaculture is in conflict with fish production development from the lake. Aquaculture activities reduced the water volume of the lake andled to illegal fry collection for stocking fish farms. Also, fish farms discharge huge amounts of nutrients that cause eutrophication and excessive plant growing in the lake.

Land reclamation along the shores of the delta coastal lagoons is causing serious conflicts between poor fishers and wealthy aquaculture investors. Those investors employ armored guardsmen to protect their "*hoshas*" (aquaculture ponds inside the lagoon) and other illegal fry collecting devices used to stock their farms. The Manzala lagoon for example lost about 23 percent of its area in the last 15 years as a result of land reclamation.

It is estimated that 22 000 fishers work in the lagoon using 7 000 boats, and employing an additional 12 000 people. Lagoon Burullus, the second largest of delta lagoons, sustains the livelihoods of about 20 000 fishers and their families (GAFRD, 2009), though Shaltout and Khalil (2005) estimated that the population dependent solely on the Burullus lagoon for their livelihoods is closer to 50 000 fishers. The Edku lagoon supports the living of about 150 000 people as their primary source of livelihood. These fishers suffer from decreased fish catch, low income and unemployment. The catch from these lakes is steadily increasing annually, but this is due mainly to increased fishing efforts (number of fishers and boats), not to increased productivity.

On the other hand, supporters of aquaculture say that this sector provides jobs and experience for thousands of young graduates, who have the ability to deal with technology used in fish farms and hatcheries. GAFRD (2009) reported the presence of about 114 000 ha of aquaculture areas and about 500 freshwater fish hatcheries in Egypt. Each large farm and each hatchery employs at least one university graduate to deal with technical issues of fish culture (fertilization, hormone treatment, feeding schedule, disease control and treatment, water quality monitoring, harvesting and marketing). Other young graduates prefer to begin with their own aquaculture business encouraged by loans from Social Fund Banks at low interest rates. Aquaculture also increased fish production, which is a cheap protein source for the poor people. In addition, aquaculture services (equipment sale and maintenance, feed manufacturing, consultancy and drug trade) gained a lot of investments and afforded jobs for large cross-sections of people.

3.6.3 Competition for space

Most aquaculture facilities are located at the southern parts of the lagoons near drainage freshwater sources. Fish farmers try all the time to expand their farm areas by filling new areas inside the lagoons. Government authorities took many measures to stop infringement on lagoon shores and to control "*hoshas*". The implementation of the rules is slow and response is weak.

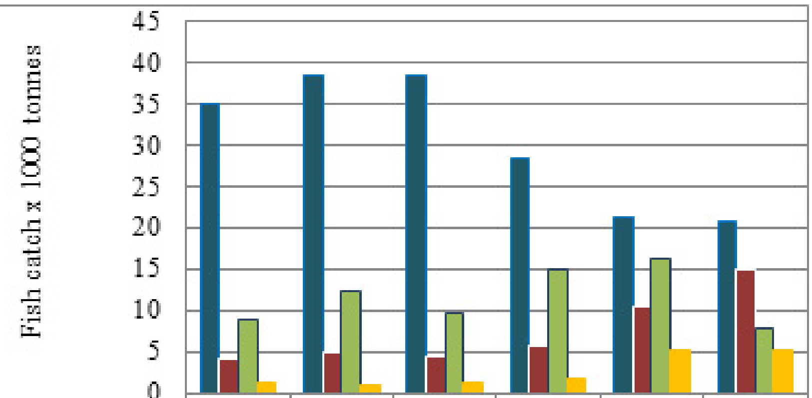
3.6.4 Product interaction on the market

Few years ago, consumers preferred fresh products from capture fishery (with relatively higher prices in the market), but recently they cannot differentiate between products from different sources. As aquaculture products are sold fresh and sometimes alive they are now mostly preferred by consumers. Fish are sold in fish markets without label or processing. Some large supermarkets sell fresh fish, also without any packing nor labels.

3.6.5 Environmental effects of aquaculture and capture fisheries on biodiversity conservation

Information about the impact of aquaculture on the lagoon environment in Egypt is scarce and scattered. Almost all drain water from fish farms and hatcheries is released into the environment without any treatment. It is estimated that there are about 400 tilapia hatcheries close to the Burullus and Manzala lagoons, which mainly produce monosex tilapias using hormonized feed (17-α-testosterone). Water from these hatcheries carries uneaten hormone-added feed and metabolites to the environment. Though the exact impact of this hormone on wild fish population is not clearly acknowledged yet, there is evidence that tilapia production in the Burullus lagoon has significantly decreased during the last six years (GAFRD Yearbook 2) in spite of the noticed increase in other freshwater fish species (Fig. 6). Whether this observation is related to hormone release or not needs detailed and intense studies. This point needs a special programme to monitor, detect and propose solutions.

Drain water from fish farms and hatcheries carries considerable amounts of nitrogen, phosphorous and other organic compounds. The release of these nutrients into the lagoon environment causes eutrophication leading to hypoxia, the spread of aquatic plants resulting in decrease of free fishing areas, and severe problems in drinking water treatment plants. However, the input of these nutrients into the lagoons increases productivity and helps the flourishing of phytoplankton and zooplankton, the primary food for most fish fry and juveniles. Aquatic plants act as refuge for migrating birds, nursery for young fish and clarify the water from heavy metals and pesticides. Management and control of the flow and release of these nutrients into lagoons is necessary and needs further detailed studies.



	1999	2001	2003	2005	2007	2009
tilapias	35	38,5	38,4	28,3	21,35	20,7
other freshwater fishes	4,1	4,9	4,3	5,8	10,5	14,8
grey mullets	8,9	12,3	9,7	14,9	16,3	7,7
marine Fishes	1,2	1	1,1	1,8	5,2	5,1

Figure 6. Fish catch from Burullus lagoon (1999–2009)
Source: GAFRD Year Book Statistics (1999–2009)

Since Egypt has diverse aquatic systems with various species, few trials were carried out to introduce new species into Egypt. The first trial was performed fifty years ago, with the introduction of several carp species (grass carp *Ctenopharyngodon idella*, silver carp *Hypophthalmichthys molitrix*, bighead carp *Hypophthalmichthys nobilis* and common carp, *Cyprinus carpio*) from Hungary, China and other countries. The purpose was to provide fast growing cheap fish to the people, control aquatic weeds that gather around dams, bridges and barrages and help rice growers to increase their income. So far, only poor people in rural areas accept the taste of these fish. There was a stock enhancement programme in Egyptian fishery resources from 2004 to 2007, in which about 6 million grass carp fry were released to freshwater parts of Burullus, Edku and Maryout lagoons (Abdel Rahman, 2009). The production of carps reached about 130 000 tonnes in 2009 (80 percent of it from freshwater aquaculture and the rest from Nile river and freshwater lakes, GAFRD, 2009). There are no indications at present that these fish caused any environmental problems in Egyptian waters (Abdel Rahman, 2008).

On the contrary, ten years ago, a private aquaculture company introduced the freshwater crayfish, *Procamparus clarkia,* to Egypt from abroad. After the investors recognized that this crustacean was not accepted by Egyptians, they just released it into the wild. This species was able to grow and reproduce in the River Nile and its tributaries and invaded all the freshwater bodies from Qena (south) to the northern coastal lakes. It caused serious environmental problems such as weakening of river and canals banks by its burrowing behaviour, which includes voracious feeding on tilapia nests, but it can be used to exterminate belharzia. Now scientists and authorities are trying to find methods to eradicate it (Khalil and Selim, 2011). The last trial started in 2011 with the import of the shrimp *Penaeus indicus* from Thailand. Strict measures were taken to prevent introducing any viral or bacterial disease. The experimental trial just started in *Deeba Triangular* (see section 2), inside Manzala lagoon, which is the only site for mariculture in Egypt. The trial cannot be yet evaluated (author, personal communication).

3.6.6 Juveniles/spat collection in the wild for culture and/or restocking purposes

The production of large quantities of fish from aquaculture mainly depends on the availability of fry and feed ingredients. The grey mullet aquaculture industry in Egypt totally relies on fry collection from the wild. In 2007, GAFRD reported that about 75 million of mullet fry were (officially) collected from the wild, representing about 99 percent of total marine fish fry collected at sea. This number is greatly underestimated, especially when these data are compared with the production biomass. If the smuggling business of mullet fry, loss during transportation in unequipped trucks and mortality due to acclimatization to brackish water and freshwater are considered, the number may be expected to reach around 400 million fry annually or even higher.

In addition, there is an old traditional practice to collect ripe mullet females during their spawning migration from lagoons to the sea to collect the egg roe (*Batarekh*) which is salted, dried and sold as high priced delicatessen in local and European markets. In the Bardawil lagoon, ripe mullet females (mainly *M. cephalus*) caught for *Batarekh* (processed egg roe) production is recorded at an average of 60 tonnes per year from a total production of 1 000 tonnes (author, personal communication). Egg roe from this lagoon has the highest quality and is sold at high prices. *Batarekh* is produced also from cultured *Liza ramada* in large quantities in winter and sold in the local market.

Marine fish fry for aquaculture are collected by licensed fishers under the supervision of GAFRD. GAFRD will only supply fry to properly licensed fish farms. The quantity of fry supplied through this channel has been relatively consistent over the last 15 years ranging from 90 to 120 million fry per year without a clear trend. Flathead grey mullet *Mugil cephalus* constitutes about 12–15 percent of the fry catch, whereas *Liza ramada* constitutes about 70–80 percent of the catch with a few hundred thousand of other marine fish as the seheli mullet, meagre, gilthead seabream and seabass. With the increasing demand for marine fish fry and restrictions on official supply, the black market of fry smuggling has flourished. It is very difficult to estimate the real number of fry caught and marketed illegally. Sadek (2001) estimated that the number of mullet fry needed for the production of 120 000 tonnes of market size fish is in the range of 500 million fry. This figure is almost five times greater than the recorded official trade.

As far as fish feed is concerned, most ingredients used in fish feed manufacturing in Egypt are agricultural wastes. These include cottonseed, rice bran, wheat bran, chicken industry wastes and macaroni industry wastes. Fish meal and fish oil are used in limited quantities in fish feeds due to their high prices and to the low nutritional requirements of tilapias, but still constituting a great obstacle for the development of this sector. Recent trends toward intensification of fish culture in Egypt increased the demand for formulated diets and consequently the pressure on global demand for fishmeal and fish oil.

3.6.7 Impact of Ichthyophagous birds

Many migratory birds visit Egypt from late autumn up to the end of winter seasons. This kind of migration cannot be controlled, as it is difficult to put these birds in quarantine or take any hygienic measures on their arrival to the country. There is great evidence that transmission of diseases from wild birds to domestic ones may occur. In Egypt, it was reported that cloacal swabs of quail and king fisher contained different pathogenic microorganisms (*Salmonella* sp., *Escherichia coli and Staphylococcus* sp.). Ectoparasitic infestation is one of the most important parasitic diseases of birds. In a study on ectoparasites from migratory birds, it was found that quails are infected with six species of acarina (*Megninia* sp. *Pterophagus* sp., *Cheyletiella* sp., *Falcutifer rostratus, Dermanyssus gallinaae* and *Dermoglyphus* sp.). These parasites may cause losses for the poultry industry, house dust allergy, topic dermatitis and human scabies. In Egypt, during 2005, there was proof that the spread of avian influenza was promoted by migratory birds. It caused a huge loss for the poultry industry in Egypt.

The great cormorant, *Phalacrocorax carbo*, causes substantial damage to fisheries in Bardawil – one estimate suggested that 6 percent of Bardawil's fish production was lost to the species in the winter of 1989-90. Up to 30 000 individuals of the former species were estimated to be present at Bardawil in winter and it appears that the numbers of this bird wintering at the Bardawil lagoon are growing.

3.6.8 Elements for green accounting

Electricity can be found in almost all inhabited villages of Egypt (80 percent) but not along the shores of the lagoon. The main source of energy for household uses is LP gas. For fishing boats, the main source of energy is diesel fuel. The cost of both sources is subsidized by the government. They are sold at very low prices (US$ 1 for 5 liters of diesel fuel and US$ 0.5 for 12 kg of LP gas). These low prices encouraged some people to smuggle and resell it to other international fishing boats in the open sea. In rural areas around the lagoons, some poor fish farmers and fishers still use agriculture by-products as fuel (corn, cotton, rice, or wheat straws).

Most of the cultured fish in the delta lagoons is composed of tilapias and mullets. Tilapia is usually transferred alive in tanks by trucks, after harvesting to special cages arranged in water bodies near the market site. This process is usually conducted at night and the fish arrive at market in the early morning alive. Mullets are transferred in Styrofoam containers with crushed ice to the market. There is no control over this process. Fishers have to pay taxes at landing sites to compensate for administration work and pay their subscription and share for fishery cooperatives.

3.7 Environmental considerations

Coastal lagoons face the following problems with respect to ecosystem productivity and capacity to sustain fishers' livelihoods. Each problem represents a serious constraint to the development of captured fish production from these lagoons.

- Degradation, habitat loss, filling up and drought; which lead to a decrease in size of all delta lagoons by over 70 percent of their original areas.
- Pollution: delta lagoons are the most polluted areas in Egypt. They receive great amounts of industrial, municipal and agricultural wastewaters without treatment.
- Spread of aquatic plants that cover large areas of these lagoons.

- Overfishing, illegal fishing practices and illegal harvesting of fish fry.
- The silting of Boughazes (the connections with the open sea).
- High levels of eutrophication resulting from the increased nutrient inputs from agricultural activities and fish farm drains carrying large amounts of washed and leached fertilizers, chemicals and pesticides.The low awareness of fishers and aquaculture investors about environmental issues and the importance of fisheries and aquaculture regulation measures.

Development perspectives in fish production

- Selective breeding programmes for the production of fast growing tilapia, to replace the present technique of using hormones to produce all male tilapia.
- Monitoring, detecting and proposing solutions for the problem of releasing hormonized fish feed into the environment.
- Research on the biological treatment of excess nutrients flowing from fish farms into lagoons through simple and profitable technologies (integration, aquaponics, etc.).
- Training programmes and technology transfer of marine fish hatcheries to produce considerable numbers of grey mullets and other marine fish fry, meagre, groupers).
- Evaluation of conflicting fish culture practices inside the delta lakes (e.g. hoshas) and proposing development solutions.
- Stocking freshwater areas of lagoons with hatchery-produced tilapia fry.

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4. FRANCE

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4.1 Introduction

The 20 French lagoons are located along the continental Mediterranean coastline (Languedoc-Roussillon and Provence-Alpes-Côte d'Azur regions) and along the eastern coastline of the Corsica island (Figure 1) and cover a total surface of 52 164 ha.Their general characteristics have been described in several reports and publications from which the information in the present country report is extracted (Quignard *et al.*, 1980; Reynal, 1980, Cepralmar, 1984; 2003, Farrugio and Le Corre, 1985; Quignard, 1989; Le Corre, 1990; Arfi, 1991; DIREN, 2007; Barral *et al.*, 2007; Pôle Relais Lagunes, 2008; Ifremer, 2010; Charret and Passerieux, 2011; Gervasoni *et al.*, 2011).

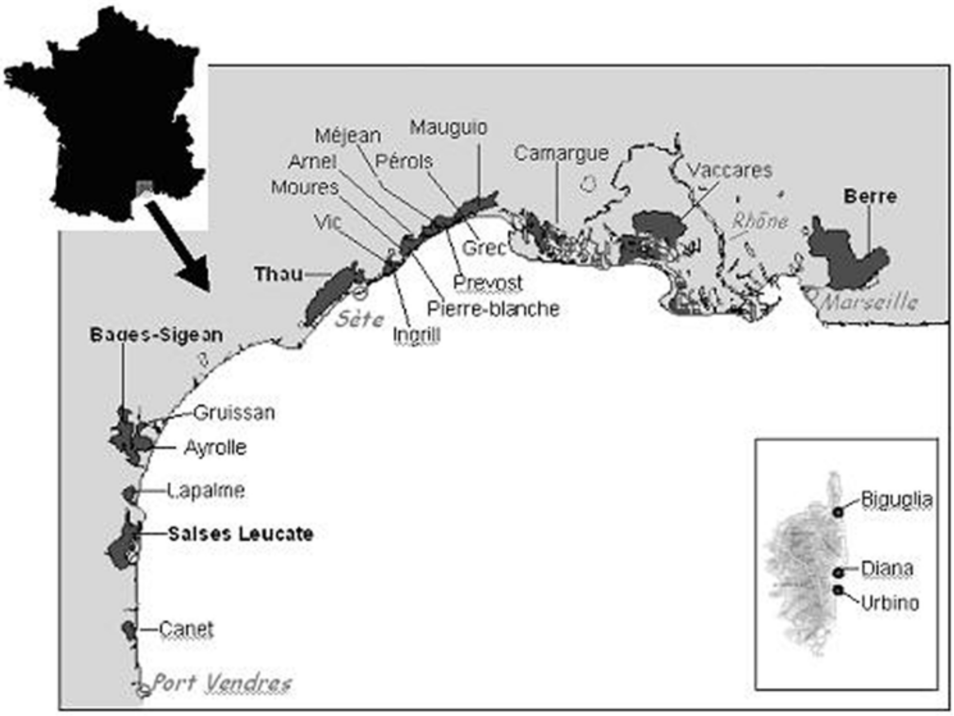

Figure 1. Geographical situation of the French Mediterranean lagoons

4.2 Generalities on coastal lagoons of France

The surfaces of the French lagoons vary from 15 000 ha (Berre lagoon) to 86 ha (Perols lagoon) and except in some cases (Berre, Thau) their average and maximum depths are generally very low (most of them less than 1 meter, Table I). Their water salinity is very different from one lagoon to another. It varies according to the seasons and depends mainly on the rain regime. The water temperature and the dissolved oxygen ratio are also very variable: due to the low depth of these lagoons, they follow the trends of the air temperature; in winter the surface water layer can freeze, while in summer it can reach up to 30°C. The oxygen concentration is very often near to the maximum except in summertime; during this season annual dystrophic crises caused by the biodegradation of opportunistic macroalgae resulting from anoxic conditions can be observed regularly. The main temperature variations are caused by the wind regime which can generate daily variations of 10° C.

Table I: Characteristics of French lagoons

Lagoon name	Surface (ha)	Average depth (m)	Maximum depth (m)	Fisheries	Aquaculture
Canet	480	0.4	1	yes	no
Salses-Leucate	5 400	1.8	3.7	yes	yes
Bages-Sigean	5 240	2	3.6	yes	no
Ayrolle	1 800	0.5	1.5	yes	no
Gruissan	136	0.4	1.1	yes	no
Thau	7 500	4.5	10	yes	yes
Ingrill	550	0.7	1.3	yes	no
Pierre Blanche	368	0.4	0.8	yes	no
Vic	1 370	1.2	1.6	yes	no
Prévost	380	0.5	1	yes	no
Arnel	469	0.3	0.6	yes	no
Pérols	86	0.5	0.8	yes	no
Méjean	380	0.5	1	yes	no
Mauguio	3 167	0.8	1.3	yes	no
Ponant	280	2.7	5.5	yes	no
Camargue	6 705	1	2	yes	no
Berre	15 000	6	9.5	yes	no
Biguglia	1 450	1.2	3	yes	no
Diana	570	4	11	yes	yes
Urbino	750		9	yes	yes

Legal framework and constraints

Fisheries and aquaculture activities in the French lagoons, as well as recreational activities, are submitted to the French national legislation.

4.3 Living resources

Flora

Except in some rare cases, few detailed information exist. In the Camargue area some 1 200 species of plants and seven natural habitats have been classified as preferential at the European scale. The Mauguio lagoon counts more than 25 species of green and red algae.

Aquatic fauna

The last census of the fauna indicates the presence of 31 different species in the Ayrolle-Campignol lagoons. A census of 58 fish species was carried out in the Bages lagoon, 34 fish species in the Diana lagoon and 24 species in the Mauguio lagoon. In the Biguglia lagoon over 120 species of sedentary and migratory birds and 41 species of marine and freshwater fishes were censed. Everywhere the most abundant species are eels, seabass, seabreams, grey mullets, soles, atherinas, green crabs and shrimps.

Wildlife

The surface of the French Mediterranean lagoons and their surrounding peripheral wetlands is around 130 000 ha. This territory represents 17 percent of the French wetlands classified as important conservation areas of Community Interest, and all the lagoons constitute hot spots of plant and animal biodiversity and are included in the European network *Natura 2000*. Many commercially important migratory fish species spend a large part of their life cycle in these lagoons, which are also used by more than 200 species of sedentary or migrating birds among which 45 percent of the overall Mediterranean number of adult couples of flamingos. They also provide shelter for 40 percent of the French amphibian species.

The animal biodiversity of the Thau lagoon is high: 85 species of sedentary or migrating fish species and 60 species of sedentary or migrating bird species were censed. The invertebrates are also well represented, as shown in the Table II

Table II: Number of species present in Thau lagoon

Group	Number of species
Protozoa	several hundreds
Sponges	7
Coelenterata	28
Bryozoa	20
Worms	more than 50
Echinodermata	12
Molluscs	70
Crustaceans	110
Arachnids	2
Tunicata	8
Fishes	85
Birds	60

4.4 Land and water management

The French lagoons communicate with the sea through permanent or temporary openings, most of which have been artificialized to avoid their natural tendency of silting up. They receive freshwater inputs from permanent or temporary small rivers and from draining channels of their catchment basins, from temporary springs and from karstic resurgences.
The Mediterranean is connected to the Atlantic Ocean by the canal du Midi crossing the Palavasian lagoons between the Rhône River and the Thau lagoon. This canal is part of the world human patrimony (United Nations Educational, Scientific and Cultural Organization [Unesco]).

Furthermore, more than 10 percent of the surface of the French Mediterranean lagoons and their peripheral wetlands have been bought by an institution aimed at the protection of the coastal zone, the Conservatoire du Littoral; two regional natural parks (Camargue, 84 360 ha and Narbonnaise, 81 170 ha) include large lagoons systems in the heart of their areas; their main objectives are the protection of the natural environment, the maintaining of the artisanal fishery and the equilibrium between the various activities (professional and recreational fisheries, sailing and other touristic activities).

4.5 Lagoon exploitation

4.5.1 Aquaculture and capture fisheries

There is a very old tradition of fishing and collecting shellfish in the French Mediterranean lagoons. Only some partial historical series of catches in some of the French lagoons can be found in the official statistical reports or in the published or "grey" literature. From these data, it appears that these activities have been decreasing from the early eighties, due to the unequilibrium between the retiring of aged persons versus the arrival of young people and an increasing sharing of the effort between lagoon and sea, probably linked to a stock size diminution of some target species. The fishing activity in the French lagoons is based on eels, seabass, seabreams, grey mullets and atherinas.

Fishing gear

Different types of gear, essentially set nets, traps and lines, are used seasonally with varying frequencies in different areas. There are no more fixed fishing gear at lagoon openings to the sea and the main type of gear currently used to catch fish is the classical fyke net *(capéchade).* Other gear categories, gillnets, trammel nets, trolling lines and a few longlines are also used, but they are less important.

Work force, establishments and institutions

The professional people exploiting the lagoons are officially registered at the maritime Administration. In 2010 there were 526 aquaculturists and around 600 fishers. They are members of different socio-professional organizations, the "Prud'homies" that manage the organization of fishing by enforcing the general rules but also by developing their own internal rules. They own a Court, elected for three years, which can impose fines on violators. Every year they also distribute the fishing posts for the fyke nets by drawing lots between their members.

Aquaculture and capture fishery management

The management regulations include several types of measures: a part of them concern the regulation of the access to the resource by limiting the number of fishers and aquaculturists by means of licences and by the conditions of obtaining of the professional status. The number of aquaculture plants is regulated. The allocation of the fishing places to install the fyke nets is made at random and there are calendars of opening/closing of fishing zones. The number of nets is also regulated, as well as the mesh sizes. Other measures concern the technical characteristics as the dimensions and the spacing between nets and size of the net dams, which do not have to exceed two thirds maximum of the width of the passages between sea and lagoons to favour the escape of the spawning migration to sea.

Fish production

There is a general lack of statistical series on fish production. More than 30 species of fishes are captured in the French lagoons, from which the main commercial ones are the eels, grey mullets, seabasses, seabreams, soles and atherinas. For these species some indication on the production by unit of surface can be found in the literature: according to the lagoon this production varies between 20 kg/ha and 90 kg/ha, the eel being the main bulk of the catch (up to 75 percent but very variable from one year to another.).

More than 20 species of fishes and crustaceans are commonly caught in the fyke nets, among these the European eel, *Anguilla anguilla*, is the most important target species, representing 70 to 80 percent of the total catches and the most important commercial revenue of the overall lagoon fishery. Glass eels fishing is prohibited on the French Mediterranean coast and the adults (yellow or silver eels) are fished all along the year, and in autumn large quantities of adults eels migrate to the sea; during this season in some lagoons several hundreds of fyke nets are installed along long net barriers to close the passage at sea (national regulation prohibits the installation of barriers of more than two thirds of the opening wide in all the French Mediterranean lagoons, however this rule is not completely implemented).

Eel production in the French lagoons has always been irregular, however in the last 20 years this production has shown a regular decreasing trend. On some lagoons like the Etang de Thau, clams are the most commercially important target species of the fishery; traditionally they are caught using rakes but they are also intensively exploited by scuba divers. Poaching is very common for the catching of clams and glass eels.

Regarding aquaculture production, according to the official data the French lagoons have produced 8 825 tonnes of oysters and 4 180 tonnes of mussels in 2010.

4.5.2 Recreational activities

The touristic pressure on the French lagoons is very variable from one lagoon to another. Nevertheless, in general the cities surrounding the lagoons receive in summer a quite important number of tourists attracted by the long sandy beaches on the seaside and their population can be ten times more important in summer than in winter. In several cases there is also an important industrial activity around some lagoons.

4.6 Interactions among aquaculture, capture fisheries and the environment in coastal lagoon management

4.6.1 Competition for space (location of aquaculture facilities in fishing grounds, existence of "planning management" for lagoon areas, etc.)

Some conflicts between the professional fishers and farmers against the non-registered ones or against the tourists, or against the people coming from different regions can exist. In the past, they have been sometime very important, mainly in the Thau lagoon, but nowadays it can be said that the situation is calm.

4.6.2 Organic input from aquaculture activities

The main interaction between fishery and aquaculture is due to the presence of large amounts of shellfish allowing for the development of a massive benthos, while organic enrichment from biodeposition changes the specific composition of soft-bottom benthos. In the deeper areas where summer thermoclines limit oxygen transfer from surface water, the organically enriched substrate induces oxygen depletion and ammonium and nitrogen sulfide accumulation in the water column. This ecosystem dysfunction kills benthic populations, and sometimes reaches pelagic populations and affects at the same times the shellfish farming and the fisheries economy.

4.7 Environmental considerations

Coastal lagoons face the following problems with respect to ecosystem productivity and capacity to sustain fishers' livelihoods.

Most of the French lagoons have to face increasing anthropogenic pressures as they are the final receivers of pollution, in particular the incoming quantities of nutrients coming from the water treatment plants of the surrounding cities or drained together with pesticides from the agricultural activities in their catchment basins are high (for example those coming from rice culture in the Camargue area, from vineyards in the Thau lagoon, from maintenance of urban gardens or from chemical treatments against mosquitoes in the Palavasian area). Detergents are particularly concentrated during the summer touristic season, while pesticides are more abundant in winter during the periods of rain.

Some lagoons like Berre are subject to pollution coming from the oil industry, while others like Bages-Sigean are threatened by the proximity of chemical plants.

In the Berre lagoon from 1966 to 1993, the diversion of the Durance River to feed a hydroelectric power plant has induced an inflow of freshwater of almost four times the volume of the lagoon water, at least doubling the annual natural discharge of suspended matter and nutrients. The current global discharges are now lower due to the restrictions applied to the power plant and also to dryer conditions and better treatment of sewage waters along the catchment basin. Until 1966 the Berre lagoon was a salty lagoon with a highly diversified marine fauna and flora. The decrease in biodiversity, the eutrophication processes and the chemical pollution of water and sediments have deeply altered that natural environment. Almost all the vegetal species have disappeared, including the eelgrass *Zostera marina*, a keystone species that previously constituted extensive meadows in the lagoon; while the marine animal populations have declined or have disappeared and they have been substituted by a euryhaline macrofauna. Due to the anoxic conditions existing in the deeper parts of the lagoon, the benthic life has disappeared.

The faecal germs have an impact on filter-feeders (shellfish), which can become contaminated and unfit for consumption (risk of typhoid, hepatitis). The fecal bacteria (*Escherichia coli* and *Streptococcus*) show periods of particular abundance after heavy rainfall and in the lagoon where shellfish aquaculture is developed, consumption of shellfish is regularly prohibited for some time.

The phenomenon of "malaïgue", an eutrophication due to the excess of nutrients combined with the high summer temperatures, is regularly observed in most of the French Mediterranean lagoons; they have biological (mortalities of shellfishes and fishes, development of unwanted plants or animals), economic (benefit loss resulting from oysters and mussels mortalities) and touristic (bad water quality, bad smells due to the production of hydrogen sulphide). Another recurring problem for the French lagoons is the sporadic development of toxic microalgae and especially those of the genus *Alexandrium* and *Dinophysis,* the toxins of which are dangerous for humans and are concentrated by the oysters and the mussels.

Since 2009, there is a high mortality of young oysters, the origin of which has not yet been completely determined. This crisis led 20 percent of the producers to change their strategy, some of them increasing their mussel production, others beginning to produce mussels for the first time.

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5. GREECE

This country report was written by Sofia Reizopolou, Hellenic Centre for Marine Research, Anavyssos, Greece.

5.1 Introduction

Coastal lagoons in Greece are defined as enclosed water bodies situated in coastal locations, with a wide range of temperatures and salinities, separated from the sea by narrow barriers with openings allowing limited water exchange.

Almost all lagoons in Greece operate as extensive fish farms and, except for a few cases, they belong to the state and are leased to local fishing cooperatives. Fisheries exploitation is implemented through the use of nets and barrier fish traps. The number of lagoons and total surface for each periphery[1] in Greece is shown in Table I. It is estimated that in a total area of about 34 00 ha, including more than 76 lagoons (30 in the Aegean and 46 in the Ionian coast), about 700–1 600 tonnes of fish from fishing and extensive aquaculture activities are landed annually (Dimitriou *et al.,* 2001; Tsihrintzis *et al.*, 2007). The mean annual production varies significantly depending on the size of the lagoon, where differences in fish catch composition are also observed.

Most lagoons in Greece are managed by regional authorities; they are mostly leased to fishing cooperatives and in a few cases to private companies, however the priority is given to local fishers.

Table I: Number of lagoons and total surface for each periphery in Greece (Source: Dimitriou *et al.*, 2001)

Periphery	Lagoons (no)	Surface area (ha)	Lagoons (%)	Surface (%)
Eastern Macedonia & Thrace	22	8 256	28.9	23.9
Central Macedonia	1	30	1.3	0.1
Thessaly	1	36	1.3	0.1
Sterea Hellas	2	120	2.6	0.3
Attiki	4	176	5.3	0.5
Peloponnese	7	606	9.2	1.8
Western Greece	16	14 946	21.1	43.3
Ionian Islands	5	1 550	6.6	4.5
Epirus	18	8 792	23.7	25.5
Total	76	34 511	100	100

5.2 Generalities on coastal lagoons

Divergent views about the number of lagoons in Greece exist. Heliotis (1984) identifies 37 lagoons, whereas a major wetland inventory lists 60 lagoons, covering an area of about 288 km^2 (approximately 14 percent of all Greek wetlands) (Zalidis and Mantzavelas, 1994). An unpublished inventory records 76 lagoons covering 34 500 ha without comprising the lagoons located in the Aegean islands (Dimitriou *et al.*, 2001).

The most extensive lagoon systems are located in western and northern Greece (Fig. 1). The largest lagoon is the Messolonghi complex located in western Greece, comprising six lagoons. The Messolonghi lagoon system covers about 15 000 ha. The most important systems are protected under the Ramsar Convention or are part of the *Natura 2000* network and almost all are used for extensive fish culture.

[1] Administrative division of Greece

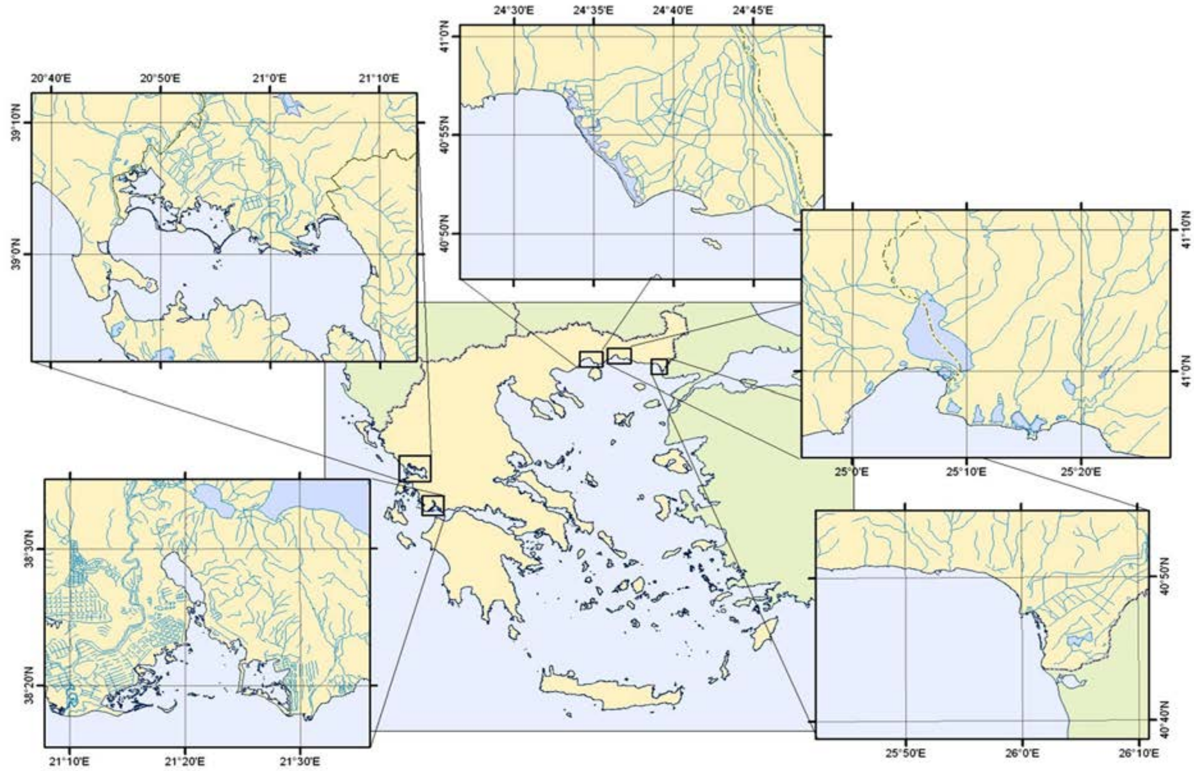


Figure 1. The main lagoon systems in Greece

Table II shows the total number of lagoons and their mean size for each periphery in Greece. It should be noted that the number of the lagoons and their size reported at the various inventories listing the lagoons in Greece is not exhaustive and some size data may be an approximate estimation. Moreover, many small lagoons are not inventoried and some are not included in the protected areas.

Table II: Lagoons and their mean size (ha) for each periphery in Greece (Source: Dimitriou et al., 2001)

EASTERN MACEDONIA AND THRACE

Lagoon	Prefecture	Mean size (ha)
Agiasma	Kavala	4 300
Eratino	Kavala	3 500
Keramoti	Kavala	1 500
Vassova	Kavala	2 700
Palea Kiti Strymona	Kavala	700
Chaidefto	Kavala	530
Gefyrakia	Kavala	350
Palea Kiti Nestou	Xanthi	280
Vistonida	Xanthi	45 000
Lagos	Xanthi	3 250
Lafri	Xanthi	1 500
Lafrouda	Xanthi	750
Divari	Xanthi	150
Ptelea	Rodopi	2 000
Elos	Rodopi	2 000
Limni	Rodopi	500
Mavrolimni	Rodopi	1 500
Ksirolimni	Rodopi	2 500
Alyki	Rodopi	3 000
Drana	Evros	4.800
Monolimni	Evros	1.650
Akrotiriou Samothrakis	Evros	100

CENTRAL MACEDONIA

Lagoon	Prefecture	Mean size (ha)
Avlakas Papapouliou	Pieria	300

THESSALY

Lagoon	Prefecture	Mean size (ha)
Avlakas Paleopotamou	Larisa	360

STEREA HELLAS

Lagoon	Prefecture	Mean size (ha)
Megalo Divari	Evvoia	1.000
Mikro Divari	Evvoia	200

ATTIKI

Lagoon	Prefecture	Mean size (ha)
Artemis	Attiki	30
Valario	Attiki	350
Vourkari	Attiki	1.300
Agkistri	Attiki	80

PELOPONNESE

Lagoon	Prefecture	Mean size (ha)
Ververonta	Argolida	1 300
Vivari	Argolida	550
Thermisia	Argolida	500
Koumpourna	Argolida	106
Potokia	Argolida	50
Solinari	Argolida	300
Gialova	Messinia	3 250

WESTERN GREECE

Lagoon	Prefecture	Mean size (ha)
Aetoliko	Aitoloakarnania	21 000
Voriou Diavlou Klissovas	Aitoloakarnania	4 500
Tholi	Aitoloakarnania	10 000
Katafourko	Aitoloakarnania	500
Messolonghi	Aitoloakarnania	68 500
Klissova	Aitoloakarnania	18 000
Kokkala	Aitoloakarnania	700
Bouka	Aitoloakarnania	656
Myrtari	Aitoloakarnania	900
Paleopotamos	Aitoloakarnania	4 500
Petalas	Aitoloakarnania	2 500
Rouga	Aitoloakarnania	700
Saltini	Aitoloakarnania	2 500
Papas	Achaia	4 500
Prokopos	Achaia	2 000
Kotychi	Ilia	8 000

EPIRUS

Lagoon	Prefecture	Mean size (ha)
Agios Georgios	Arta	160
Agrilos	Arta	2 500
Koftra-Paliobouka	Arta	2 100
Konstantia	Arta	1 200
Tsoukalio-Rodia	Arta	28 300
Tsoukalou	Arta	2 000
Sakoletsi	Arta	400
Logarou	Arta	35 000
Mazoma	Preveza	1 800
Tsopeli	Preveza	1 200
Pogonitsa	Preveza	450
Vathy	Preveza	450
Alykes	Thesprotia	3 000
Vatatsa	Thesprotia	750
Vonta	Thesprotia	3 840
Loutsa-Papadia	Thesprotia	3 500
Kalaga	Thesprotia	520
Richo	Thesprotia	750

IONIAN ISLANDS

Lagoon	Prefecture	Mean size (ha)
Antnioti	Kerkyra	5
Korission	Kerkyra	5
Chalikiopoulou	Kerkyra	2
Alyki Alexandrou	Lefkada	
Avlemonas-Paleo	Lefkada	4

In general, most lagoons in Greece are smaller than one hectare and have a mean depth smaller than 1 meter; only about 15 percent of the lagoons have a mean depth over one meter. All biological components show great variability both in space and time, which is attributed to environmental variability. The most important variable influencing species distribution and diversity is the degree of communication with the sea and the nutrient load introduced through freshwater inputs.

Coastal lagoon typologies

Based on the geo-morphological features and the degree of communication with the sea, the lagoons in Greece can be divided in two types: open and closed. Most lagoons (about 70 percent) are classified as closed ecosystems (Dimitriou *et al.*, 2001), and are those separated from the sea by narrow barriers and communicating with the marine environment by artificial openings, allowing a limited water exchange. Moreover, almost 50 percent of them do not receive a direct freshwater input.

The lagoons are mainly used as extensive fish farms; they belong to the state and are managed by local regional authorities. Most of them are leased to local fishers' cooperatives, and in a few cases also to private companies. The management activities for fish production improvement inside the lagoons have been so far empirical, and were mostly based on traditional principles similar to the Italian *vallicoltura* (Tsihrintzis *et al.*, 2007). Some interventions involve restocking with fry and constructions such as wintering channels or new openings for the improvement of water exchange. Wintering ditches are covered with nets in order to protect fish from cormorant attacks. Other activities in order to increase production in some lagoons of northern Greece and Amvrakikos Gulf led to the introduction of juveniles from commercial fisheries (i.e. seabream) (Koutrakis *et al.*, 2007).

In many cases, the lagoons which are exploited by fishers can be in a better environmental state than those leased to the private companies (Koutrakis, 2005). However, in other cases (e.g. Papas lagoon), overexploitation and mismanagement of the system enhance eutrophication phenomena and may lead to dystrophic crises (Reizopoulou and Nicolaidou, 2007).

Legal framework and constraints

The most important systems are protected under the Ramsar Convention and/or are part of the *Natura 2000* network. The large part of the ecosystems is considered as an Important Bird Areas (IBA) covered by Wildlife Refuge, other systems are included in Special Protection Areas and/or Sites of Community Importance (e.g. Amvrakikos), whereas the Messolonghi lagoon complex is part of a Marine Protected Area (MPA), which is the most recent MPA in Greece, established in 2006, as National Park of Messolonghi–Aetoliko Lagoons, Estuaries of Acheloos and Evinos and Echinades Islands.

5.3 Living resources

The lagoons in Greece are not all equally explored scientifically. More attention has been paid to the lagoons of Amvrakikos Bay (Nicolaidou and Karlou, 1983; Nicolaidou *et al.*, 1985; Nicolaidou and Karakiri, 1989; Reizopoulou *et al.*, 1998; Christaki and Gotsis-Skretas, 1990; Reizopoulou *et al.*, 1996; Kormas *et al.* 2001; Lazaridou *et al.*, 2002; Reizopoulou and Nicolaidou, 2004, 2007, 2008; Nicolaidou *et al.,* 2006; Christia *et al.*, 2011), Papas (NCMR, 2000; Reizopoulou and Nicolaidou, 2007) and the Gialova lagoon in the Peloponnese (Arvanitidis *et al.,* 1999; Petihakis *et al.* 1999; Koutsoubas *et al.,* 2000a,b; McArthur *et al.,* 2000; Triantafyllou et al., 2000).

Different biological components of the Eastern Macedonian and Thrace lagoons, such as phytobenthos (Orfanidis *et al.*, 2000, 2001a,b; Malea *et al.*, 2003, 2004), zoobenthos (Kevrekidis *et al.,* 1990; Gouvis and Koukouras, 1993, Gouvis *et al.*, 1997; Kevrekidis, 1997; 2004;) and fishes (Koutrakis and Tsikliras, 2003) were also explored. An account of the available information on the main biological components of the Greek lagoons is presented in the review by Nicolaidou *et al.* (2005), while the available information on lagoon fisheries resources is summarized in the review by Koutrakis *et al.* (2007).

5.3.1 Flora

In the most confined lagoons, the most abundant phytoplankton genera are *Rhodomonas* sp. and *Cryptomonas sp*, whereas in lagoons with better communication with the sea, dominant species can be diatoms (e.g. *Rhizosolenia fragilissima* and *Nitzchia closterium*) and dinoflagellates (*Scrippsiella trochoidea, Procentrum scutellum*) (Christaki and Gotsis-Skretas, 1990; Nicolaidou *et al.,* 2005). In semi-enclosed lagoons (e.g. Gialova in Peloponnese), dinoflagellates dominate and diatoms are restricted to marine channels (Dounas and Koutsoubas, 1996).

Benthic vegetation consists of a small number of species and associations. Characteristic are species of the genera *Gracilaria*, *Ulva, Chaetomorpha* and *Cladophora*, whereas the most characteristic of Phaeophyceae is the species *Cystoseira barbata*. Their diversity varies seasonally and is higher during summer and autumn (Orfanidis *et al.,* 2001b). The angiosperms recorded mainly belong to the genera *Ruppia*, *Zostera*, *Cymodocea* and *Zanichellia* (Orfanidis *et al.*, 2001b; Nicolaidou *et al.*, 2005; Christia *et al.*, 2011).

5.3.2 Aquatic fauna

In zooplankton, copepods are the dominant group (Siokou-Frangou,1986), whereas in the inner parts of lagoons the zooplankton consists of brackish water species, such as *Calanipeda aquaedulcis*, *Acartia latisetosa, A. clausi and Centropages kroyeri* and invertebrate larvae of barnacles, molluscs, decapods and polychaetes (Nicolaidou *et al.*, 2005).

Macrozoobenthos is the most studied ecosystem component in Greek lagoons (Nicolaidou *et al.*, 1983; 1985; 2006; Reizopoulou *et al.*, 1996; Dounas *et al.,* 1998; Arvanitidis *et al.,* 1999; Koutsoubas *et al.*, 2000; Kevrekidis 1997; 2004; Kevrekidis *et al.*, 2000; Reizopoulou and Nicolaidou, 2004; 2007).

The most abundant species are typical of euryhaline and eurythermic lagoons such as the molluscs *Cyclope neritea, Abra segmantum, Mytilaster minimus, Cerastoderma glaucum,* the polychaete *Hediste diversicolor,* amphipods of the genera *Gammarus, Corophium* and *Microdeutopus,* chironomid larvae and oligochaetes. The most important variable shaping species composition and benthic diversity is the degree of communication with the sea (Reizopoulou and Nicolaidou, 2004; Nicolaidou *et al.*, 2005).

Concerning fish, more than 30 species were recorded from the Greek lagoon systems (Nicolaidou *et al.*, 2005). These are typical lagoon species, which complete their whole life-cycle in lagoons such as *Aphanius fasciatus* and *Atherina boyery;* migratory marine/estuarine species such as *Sparus aurata, Dicentrarchus labrax, Anguilla anguilla, Mugil cephalus, Chelon labrosus, Liza saliens, L. aurata, L. ramada, Diplodus sargus* and *Solea solea;* and marine species that are normally distributed in the sea and are occasionally or accidentally found in the lagoons: e.g. *Gobius* spp., *Blennius* spp., *Diplodus annularis, D. puntazzo, Lithognathus mormyrus* and *Salpa salpa* (Nicolaidou *et al.*, 2005). Most lagoons in Greece are used for the extensive culture of various fish, most of which are migratory marine/estuarine species.

5.3.3 Wildlife

The habitat types such as riparian floodplains, wet meadows and surrounding wetlands present a unique diversity of invertebrates, reptiles and amphibians. Thousands of migrating birds congregate in these freshwater marshes, which are a source of food and place of rest during spring migration. Many priority bird species such as Dalmatian pelicans, pygmy cormorant, ferruginous duck, bittern and lesser spotted and greater spotted eagles can be found in these ecosystems.

5.4 Land and water management

The biodiversity and productivity of the lagoons in Greece is threatened by severe anthropogenic pressures such as damming, pollution, water flow modifications, overfishing, alien species and so forth. The increased damming of rivers led to reduced river flow and terrestrial sediment input. An increased nutrient and pollutant influx is associated with agriculture and urban development.

A considerable loss of the wetlands surrounding the coastal lagoons due to the increase of agricultural activities led to a decline of water retention and purification capacity of these ecosystems. Figures 2a and 2b show the decline of Amvrakikos wetlands from 1945 to 1999, due to the increase of artificial and cultivated areas.

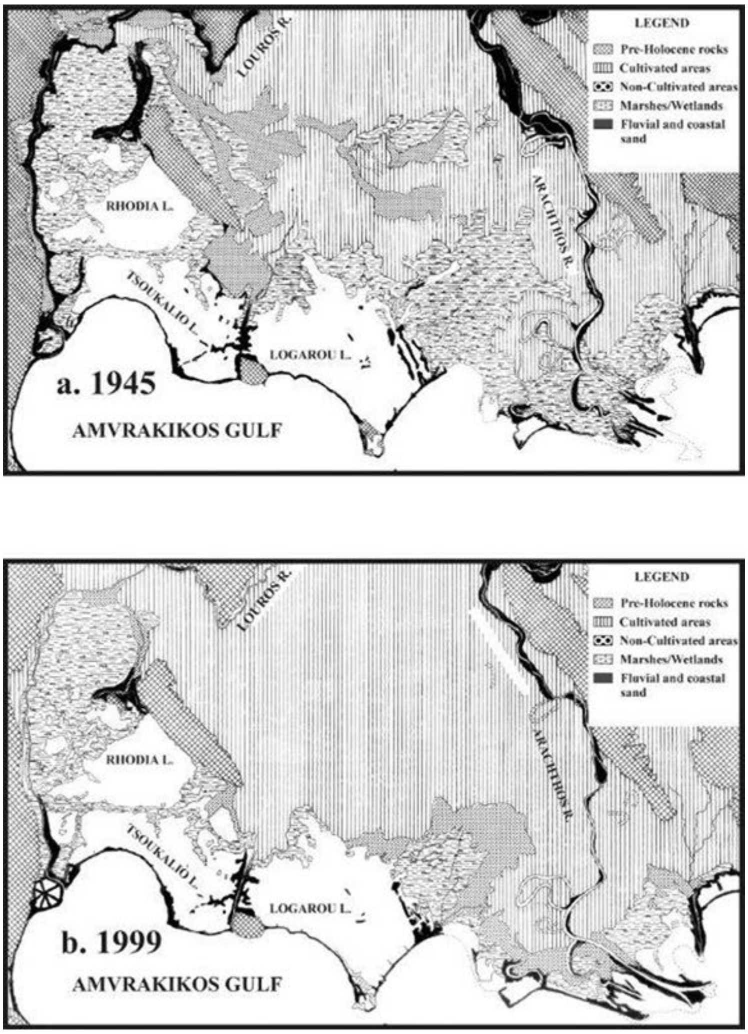
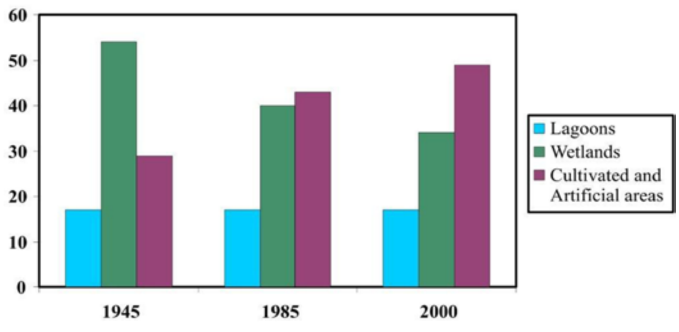


Figure 2a. Loss of wetlands in Amvrakikos Gulf
(Source: Kapsimalis, HCMR)



Land use (%)	1945	1985	2000
Lagoons	17	17	17
Wetlands	54	40	34
Cultivated and artificial areas	29	43	49

Figure 2b. Land use changes in Amvrakikos from
1945 to 2000 (Source: Kapsimalis, HCMR)

The aforementioned changes have a direct effect on lagoon biodiversity and on the quality of goods and services, and consequently affect society welfare. The responses of ecological communities to increased environmental changes led to a variation in the diversity of community composition in many lagoons in Greece. The nutrient enrichment led to a replacement of sea-grasses by opportunistic green macroalgae, while the loss of sea-grass beds and the degradation of the water quality caused a decrease in species diversity and a decline in fish abundance. In some cases such as Papas lagoon in the Ionian Sea, anoxic conditions and release of hydrogen sulphide caused massive mortality of fish and shellfish communities. Some areas of Papas, Aetoliko and Gialova become completely defaunated, especially during summer or early autumn (Reizopoulou & Nicolaidou, 2004; Koutsoubas *et al.*, 2000b).

Another problem is the decrease of lagoon productivity. Data analysis on fish landings from the last decades (20–30 years), indicate a clear trend of decrease in fish production in Greek lagoons (Koutsikopoulos *et al.*, 2007; Koutrakis *et al.*, 2004). This is attributed to the increase of the fishing effort, but also to the environmental alteration of the lagoons due to anthropogenic stressors (pollution, damming, urbanization) and to the processes affecting the coastal areas.

5.5 Lagoon exploitation

The main activities carried out in the lagoons in Greece are fisheries, aquaculture, tourism/recreation, water management, nature conservation and research. Coastal lagoons also provide essential goods and services making with many conflicting interests, from fisheries to tourism and from aquaculture to urban development.

The fishery exploitation in the lagoons in the past was mostly based on traditional fish barriers consisting of wooden poles sustaining a net of reeds (Fig. 3), however, after the 1980s most of these installations were replaced with cement installations that copied the Italian *vallicoltura* capture systems (Fig. 4) (Koutrakis *et al.*, 2007; Tsihrintzis *et al.*, 2007).

Traditional fish barriers made out of reeds, photo ©ETANAM: Development Agency for South Epirus – Amvrakikos SA

Fish barriers in Papas lagoon, photo ©Zoulias, HCMR

In some lagoons nets (mainly trammel nets) are also used. During spring fish enter the lagoons and the commercial species are caught by entrapment devices during their reproductive migration to the sea. Immature fish spend the cold season in dredged deep channels, the wintering channels (Koutrakis *et al.*, 2007). A restocking with fry can also be carried out. Most lagoons are leased to local fisher cooperatives and several commercial species (various species of grey mullets such as *Liza saliens*, *L. aurata*, *L. ramada*, *Chelon labrosus* and *Mugil cephalus*, gilthead seabream *Sparus aurata*, European seabass *Dicentrarchus labrax* and eel *Anguilla anguilla*. are traditionally exploited, entering seasonally through the openings to the sea (Zoulias, 2003; Nicolaidou *et al.*, 2005; Koutrakis *et al.*, 2007).

Another traditional product of considerable commercial value is the fish roe made from the female ovaries of the flathead grey mullet (*Mugil cephalus*). The highest production of fish roe is attributed to Messolonghi lagoon and it is called "Avgotaracho Messolonghiou". Other lagoon products are Caramote prawns *Penaeus kerathurus*, Mediterranean mussels *Mytilus galloprovincialis* and grooved carpet shell, *Ruditapes decussatus*.

5.5.1 Aquaculture and capture fisheries

Facilities

Fishing gear

The fishery exploitation is mostly based on fish barriers however also nets such as trammel nets and fyke nets are used.

Boats

Small motor boats are used in the lagoons.

Buildings and infrastructures

Fish landing sites are present, and in some lagoon there are offices and cold storage; packing rooms can be constructed.

Work force, establishments and institutions

The lagoons belong to the state and are managed by local regional authorities, where the major part is leased to local fisher cooperatives, and in few cases also to private companies. All the lagoons in north Greece and in the Amvrakikos Gulf are leased to fisher cooperatives supporting about 300 and 450 fishers respectively, whereas in Messolonghi part of the lagoons is leased to local cooperatives and part of them can be also exploited by individual fishers. Messolonghi lagoons support about 60 fishers belonging to fishing cooperatives and 600 individual fishers (Koutrakis *et al.*, 2007)**.**

Aquaculture and capture fisheries management

Restocking

In many lagoons, restocking with M. cephalus, D. labrax and S. aurata fry is carried out. Immature fish spend the cold season in the wintering channels, which are dredged deeper channels. In some lagoons (e.g. Papas lagoon in Peloponnese), semi-intensive fish aquaculture of S. aurata with food additions is carried out.

Selective fishery

The fishery exploitation in the lagoons is mainly based on fish barriers consisting of cement installations. Fish enter the lagoons during spring and the commercial sizes are caught by entrapment devices.

Overwintering strategies

Construction of wintering channels for the development of immature fish during the cold season.

Productions

Table III shows the fish production of the lagoons for each periphery in Greece. The highest abundance in catches is observed in September and October. Production rates during this time period may almost reach 90 percent of total production (Koutrakis *et al.,* 2007). The most productive lagoons in Greece are located in Eastern Macedonia and Thrace, western Greece and Epirus (Table IV).

Table III: Lagoon production (tonnes) for each periphery in Greece
(Source: Dimitriou *et al.,* 2001)

Periphery	Size of the periphery (hectares)	Production	Min production	Max production
Eastern Macedonia and Thrace	86 550	616.2	380.2	985.8
Western Greece	172 806	300.0	226.5	392.4
Central Macedonia	300	0.3	0.3	0.4
Epirus	96 972	137.9	107.1	166.4
Thessaly	370	0.7	0.3	1.1
Ionian Islands	18 350	26.8	21.9	31.8
Peloponnese	4 500	5.7	0.5	12.5
Sterea Hellas	1 000			
Total	**380 912**	**1 087.7**	**736.8**	**1 590.5**

Table IV: Greek coastal lagoons – Production (tonnes)
(Source: Dimitriou *et al.*, 2001)

Periphery	Lagoon	Production	Min	Max
Eastern Macedonia and Thrace	Agiasma	46.2	19.3	67.1
	Akrotiri Samothrakis			
	Alyki	7.0	2.8	12.7
	Vassova	33.1	22.7	39.7
	Vistonida	355.3	220.5	575.8
	Gefyrakia	0.2	0.2	0.2
	Divari Xanthis	20.0	20.0	20.0
	Drana			
	Elos	4.6	1.7	9.2
	Eratino	31.7	25.1	36.9
	Karamoti	27.4	16.9	35.3
	Lagos	17.5	14.0	21.0
	Lafrouda	27.4	5.5	107.1
	Limni	3.8	2.3	6.6
	Mavrolimni	3.5	0.7	7.3
	Monolimni	11.5	9.1	14.2
	Ksirolimni	15.6	11.4	18.2
	Paea Kiti Nestou	0.3	0.1	0.8
	Ptelea	4.0	2.7	5.1
	Haidefto	7.0	5.3	8.6
Central Macedonia	Avlakas Papapouliou	0.3	0.3	0.4
Epirus	Agios Georgios	2.0	1.5	2.5
	Agrilos	3.2	2.6	3.8
	Vathy	4.4	1.0	7.0
	Vatatsa	1.0	0.7	1.2
	Vonta	0.9	0.5	1.4
	Kalaga	0.6	0.5	0.8
	Koftra-Paliompouka	10.2	9.2	11.2
	Konstantio	2.3	2.0	2.5
	Logarou	26.6	25.6	27.6
	Loutsa-Papadia	3.6	3.6	3.6
	Mazoma	12.6	5.7	17.6
	Mpastia-Alykes			
	Pogonitsa			
	Riho	0.7	0.5	0.9
	Sakoletsi			
	Tsopeli	2.8	1.5	4.3
	Tsoukalio-Rodia	63.9	49.2	78.5
	Tsoukalos	3.3	3.0	3.5
Thessaly	Avlakas Paleopotamou	0.7	0.3	1.1
Ionian Islands	Alyki Alexandrou			
	Antinioti	2.6	1.2	4.2
	Avlemonas	14.9	12.9	16.9
	Korission			
	Paleo	9.3	7.8	10.7
	Chalikiopoulou			
Western Greece	Aetoliko	10.4	8.6	12.5
	Voriou Diavlou Klissovas	18.2	12.4	25.5

Periphery	Lagoon	Production	Min	Max
	Tholi	22.3	19.2	27.8
	Katafourko			
	Messolonghi	95.1	78.2	133.3
	Klissova	22.1	18.2	25.8
	Kokkala	6.9	3.4	10.5
	Kotychi	63.5	56.4	71.4
	Mpouka	2.8	1.0	4.7
	Myrtari	4.0	3.1	5.9
	Paleopotamos	19.3	12.4	23.9
	Papas	18.9	4.3	29.2
	Petalas-Soupi	7.5	4.4	9.4
	Prokopos	8.5	4.6	11.4
	Rouga	0.6	0.2	1.3
	Saltini			
Sterea Hellas	Megalo Livari			
Peloponnese	Gialova	5.7	0.5	12.5
	TOTAL	1 087.7	736.8	1 590.5

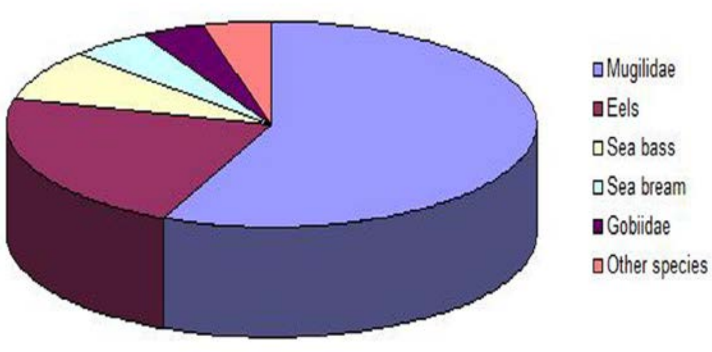


Figure 3. Mean composition (%) of lagoon production in Greece

Mugilidae are the major part of the total production of the lagoons in Greece, whereas the mean composition of the fishery production is approximately formed by 56 percent Mugilidae, 22 percent eels, 8 percent seabass, 5 percent seabream, 4 percent gobiidae and 4 percent other species (Dimitriou *et al.*, 2001) (Fig. 3).

5.5.2 *Other uses*

Recreational activities such as fishing and wildlife observation are carried out in some coastal lagoons.

5.6 Interactions among aquaculture, capture fisheries and the environment in coastal lagoon management

The main anthropogenic pressures to which coastal lagoons are subjected in Greece are agriculture, animal husbandry, dam constructions, water level alterations and overfishing (Fig. 4). In the lagoons' catchment area ground waters can also be polluted in terms of total nitrogen, phosphorus and organic pollutants. The above pressures have also substantial impact on the lagoon ecological quality.

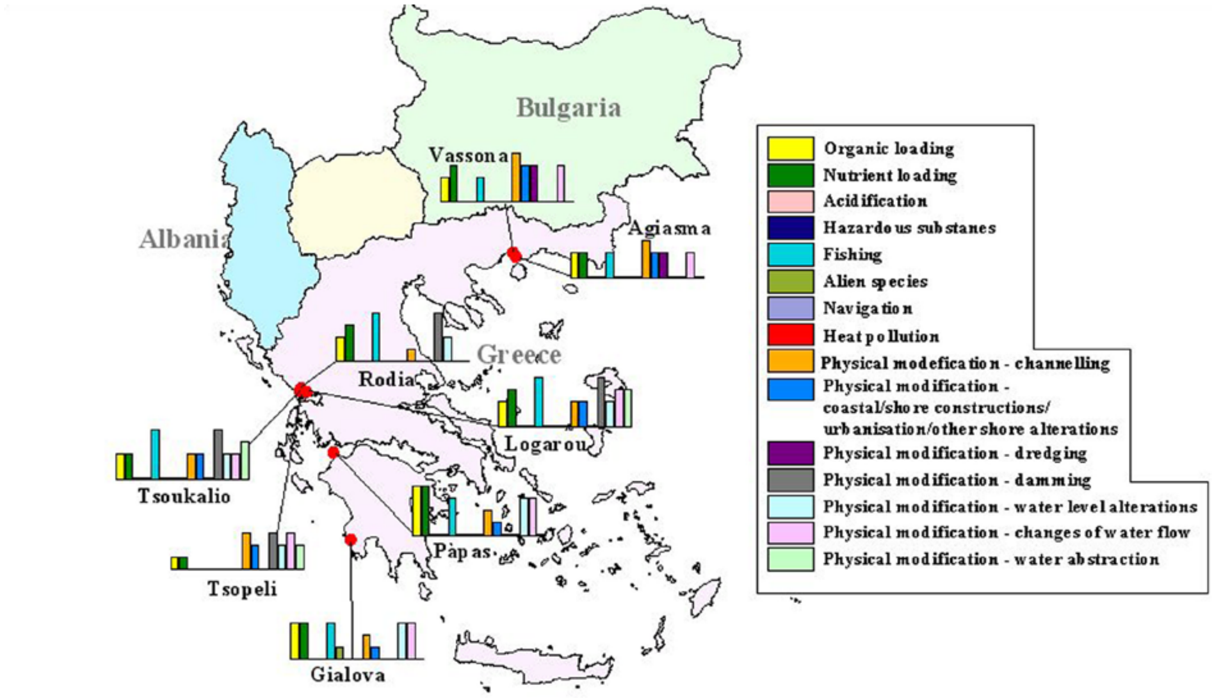


Figure 4. Main anthropogenic pressures in Greek lagoons

There was a considerable loss of the wetlands of the coastal lagoons in the last century, due to the increase of artificial and cultivated areas.

Many of the lagoons' catchments waters can be organically polluted due to anthropogenic stressors such as agriculture, aquaculture, animal husbandry, etc.

Environmental effects of aquaculture and capture fisheries on biodiversity conservation

In some lagoons (e.g. Papas in Peloponnese), overexploitation of the system due to semi-intensive aquaculture activities may lead to dystrophic crises and massive fish kills. Moreover, the loss of surrounding wetlands/habitats due to land use changes led to biodiversity loss.

Juveniles/spat collection in the wild for culture and/or restocking purposes

In many lagoon systems, restocking with *Mugil cephalus*, *Sparus aurata* and *Dicentrarchus labrax* fry is carried out, and in some cases can be supported by food additions.

Elements for green accounting and ecological services

Electricity can be found in almost all the areas and along the shores of the lagoons. For the fishing boats, the main source of energy is diesel fuel. After harvesting, fish are usually transferred in containers by trucks with crushed ice to the local markets.

Due to the loss of wetland habitats, there is a decline of water retention, purification capacity and capacity to regulate peak flows during floods, whereas the river damming affected freshwater and sediment input altering the environmental conditions of the lagoons. In some cases a dramatic decline and/or total loss of fish stocks in the lagoon and adjacent marine environment has been recorded. Organic pollution affected water quality leading to biodiversity changes (e.g. replacement of sea-grasses by opportunistic green macroalgae).

5.7 Environmental considerations

Local regional authorities, management bodies and conservation measures in Greece have often been proved insufficient due to the lack of funding, coordination and integrated coastal zone management policy.

There is lack of scientific information on the environmental state and hydrological regime for many lagoon systems in Greece. Consequently, the practices for the improvement of productivity may often lead to further deterioration of the lagoon environment, resulting in anoxic crises and massive fish mortality. It is important to involve hydrological and ecological monitoring, in order to establish the baselines for a sustainable management and conservation of these particularly sensitive ecosystems.

Lately the Water Framework Directive 2000/60/EE (EC, 2000), which is the basic legislative management tool of water resources within the EU, promoted the implementation of the ecosystem approach in order to prevent negative impacts on coastal ecosystems and sectors of activity depending upon them.

Monitoring of coastal lagoons is a crosscutting activity within the Directive in Greece. The design of the monitoring network for Greek transitional waters was based on the results of the implementation of the WFD 2000/60/EE article 5 in Greek coastal waters where 28 transitional water bodies of sufficient size were defined. All these water bodies were considered as "at risk" of succeeding good ecological status up to the year 2015, due to the increased susceptibility of these sensitive ecosystems to anthropogenic pressures; and are thus subject to operational monitoring. For each waterbody, one site within the known or predicted zone of impact was selected, with the exception for some lagoon complexes where more than one site was selected (Fig.5). Phytoplankton, macroinvertebrates, phytobenthos and fish fauna will be monitored twice a year, whereas the hydro-morphological elements every three years and the physico-chemical elements seasonally.

Figure 5. Monitoring network for transitional waters in Greece

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6. ITALY

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6.1 Introduction

Italy has an extensive coastline (8 353 km), extremely diverse in morphology and pattern. The present outline of the coast has been shaped over time by geological processes combining marine and continental dynamics, such as transport of materials, erosion and sedimentation. Among these, downstream transport by rivers has been the main process responsible for the extraordinary richness of lagoons, coastal lakes and ponds in Italy. The present surface of lagoon areas amounts to about 167 000 ha.

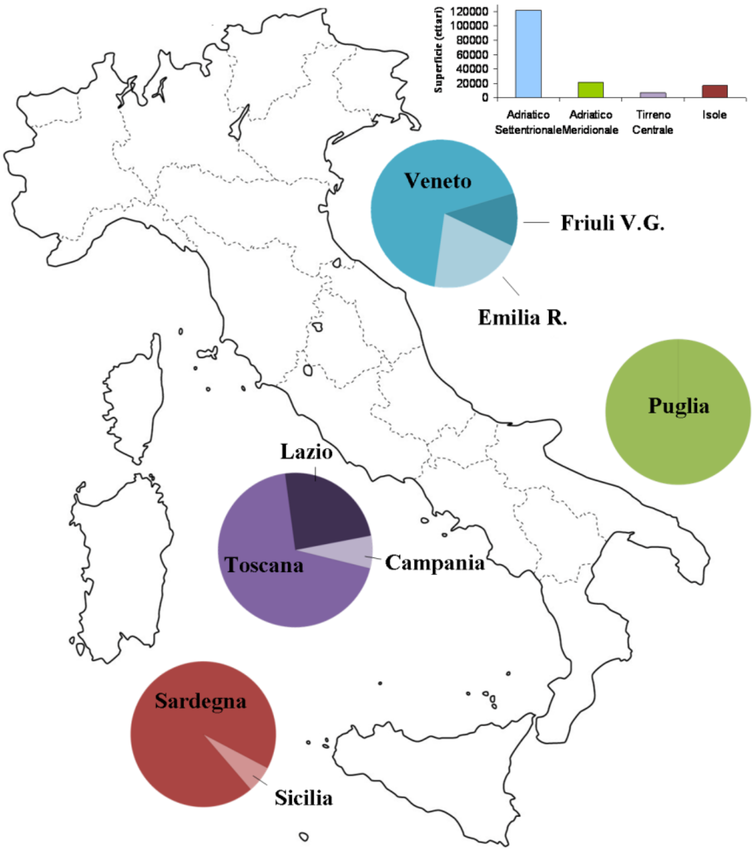

Figure 1. Coastal lagoons in Italy: surface in the four geographic areas (histogram) and relative distribution of in the nine regions (circles).

This area is a remnant of a larger extent: in pre-Roman times wetlands in Italy amounted to over three million ha (Rossi Doria and Bevilacqua, 1984). The first land and water management interventions date back to the Romans, who carried out the first reclamation interventions in the Pontine Plain (Latium) and in Tuscany (Val di Chiana, Ansedonia). In later centuries, in different moments there were other important interventions: in the twelfth and thirteenth centuries, many Benedictine monasteries were built in areas that necessitated the implementation of hydraulic works of drainage, sewerage and irrigation. Around mid-1500, the Venetian Republic reclaimed over 40 000 ha. In 1865, the Italian wetlands were reduced to 1 300 000 ha, which, however, still accounted for 4.6 percent of the total area of Italy. In the late nineteenth and early twentieth century, Italian wetlands suffered the most radical contraction, with the loss of over 1 100 000 ha. The demographic increase, the need for large areas for agriculture, but also the urgency to address malaria, which affected populations in many rural areas of the country, led to massive land reclamation, most of which was implemented in the two decades of the Fascist period. With the reclamation of the lagoon areas between Modena and Ferrara, the landscape of the lower Po valley radically changed, and most wetlands of the Maremma and the Pontine plains disappeared. Even on the coasts of southern Italy and on the islands, first of all Sardinia, large areas of coastal marshes and ponds were eradicated. In the Republican period, however, and in some cases up to the 1950s, reclamation continued through various forms of intervention on the territory.

In Italy, 198 lagoons and coastal basins are present, for a total surface of 167 575 ha. This figure arises from an inventory made for the purpose of the present project, and includes all types of coastal water bodies, such as delta branches and *sacche*. Ardizzone *et al.* (1988) reported 150 000 ha of coastal lagoon environments used for fisheries and aquaculture, 61 000 of which are effectively exploited. Lagoons are present only in nine Regions, and are concentrated in four geographic areas of the country: the northern Adriatic on the northeastern side of the country, the south Adriatic on the southeastern side, the central Thyrrhenian on the western side and in the main islands, Sardinia and Sicilia (Fig. 1).

In the northern Adriatic, the greatest extent is present, 120 000 ha, which includes the large micro-tidal (tidal range > 0.5 m) lagoons of Venice, Caorle, Grado and Marano, along with the 45 000 ha of wetlands and *valli* of the Po delta. In the southern Adriatic, the lagoons of Lesina and Varano are the most important, while in the central Tyrrhenian coast there are several coastal lakes in Lazio, as well as the Orbetello lagoon in Tuscany, the largest in central Italy. In the main islands, Sicily and Sardinia, over 15 000 ha of lagoons are present, mostly located in Sardinia. These environments of central Italy are "non-tidal", as the tidal range is less than 0.5 m.

6.2 Generalities on coastal lagoons

Overall, Italian coastal lagoons add up to more than 190 coastal lagoons, including all typologies, i.e. lagoons, coastal lakes and ponds, *sacche*, delta areas and *valli*. The complete list of the coastal lagoons is reported in Table I; the revision was made for the present project by consulting the most recent literature and the official websites (Ispra, Ministero dell'Ambiente) for the complete list and then verifyied, for presence and surface, by the geographic information system (GIS). Inconsistencies in numbers or surfaces among different sources usually are due to the fact that some coastal lagoons, specifically the *valli* in the northern Adriatic area, often undergo maintainance works or reorganizations due to change in ownership. In Table II, coastal lagoons are listed by geographic area and by Region, and within each group they are listed by surface area. Lagoon surfaces range from the over 57 000 ha of the lagoon of Venice, the largest of the Mediterranean, to the few hectares of some *valli* of the northern Adriatic area and of many Sardinian ponds.

"Lagoon" is a term used in Italy only for large lagoons, 5 000–50 000 ha, such as the microtidal lagoons of the northern Adriatic (Venice, Grado, Caorle, Marano), for the non tidal large lagoons of the southern Adriatic (Varano and Lesina) and for the lagoon of Orbetello (Tuscany). They vary in depth between 2 and 5.5 m, salinity ranges between 7–47 ‰ and productivity between 70 and 150 kg/ha.

In the northern Adriatic area (in the Friuli Venezia Giulia, Veneto and Emilia Romagna regions), the *valli*, lagoon sectors enclosed for fish culture by means of earthen embankments, are present. Main features of a *valle* include, besides embankments, sluice gates, internal canalization, basins for fish collection and wintering and fish barriers (*lavorieri)*. *Vallicultura* is a term that indicates the traditional management model carried out in the northern Adriatic *valli*, based on hydraulic management, dredging, enhancing of fisheries by stocking and fish capture at the *lavoriero*. Their surface varies from very small (1–2 ha) to more than 10 000 ha (usually a complex of *valli*, such as the famous *valli* of Comacchio). Depth is 0.6 m average, max 2 m; salinity ranges between 10–40 ‰ and productivity: 20–150 kg/ha. Other tipologies typical of the northern Adriatic are the *sacche*, brackish water areas typical of the Po delta: these are wide bays communicating with the sea and only partially enclosed by sand banks. Fishing activities are carried out in the *sacche*, and shellfish culture in most of them. Their surfaces are about 2 600–3 200 ha, usually shallow, depth 0.5–2 m, their salinity ranges between 18 and 35 ‰. Productivity for shellfish culture can reach 15 000 kg/ha (Sacca di Goro).

In Italy, the term "coastal lake" refers to the medium-size lagoons and to the coastal basins in communication with the sea by one or more channels. The term is often used for the lagoons of the central Thyrrhenian area. Usually, only artisanal fisheries are carried out within coastal lakes. This typology overlaps with the *stagni*, ponds that also indicate medium-sized basins.

The term *stagno* (pond) is almost exclusively used for the lagoons of Sardinia. Artisanal fisheries is performed in these *stagni*, and shellfish as well in some of them. Over 60 *stagni* are present in Italy, mostly concentrated in Sardinia.

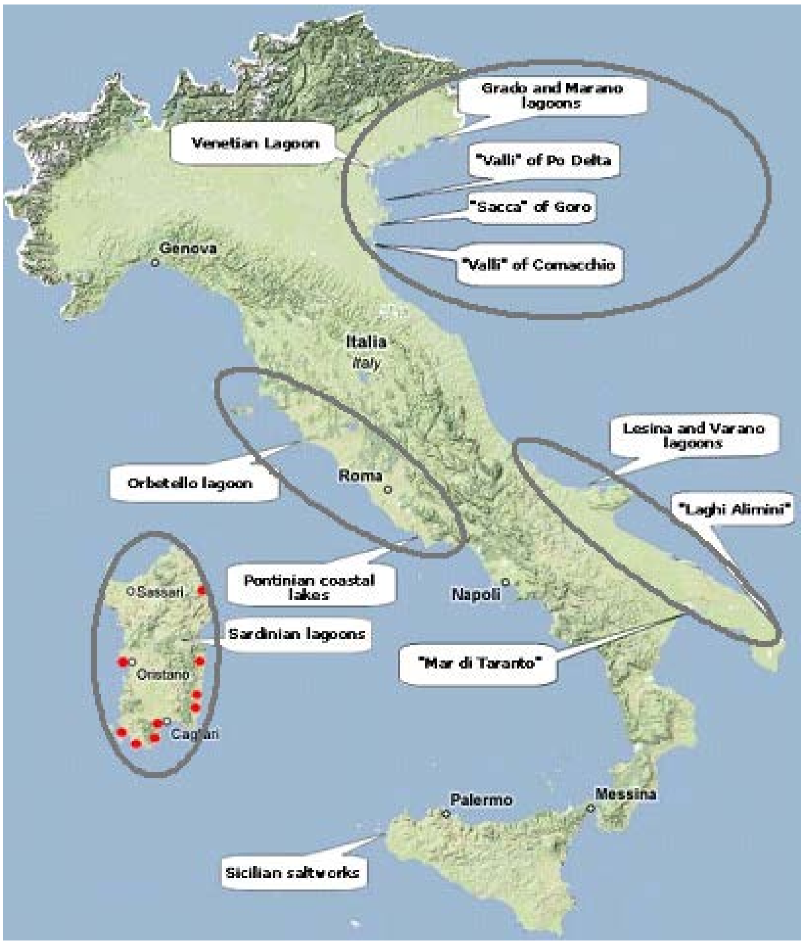

Figure 2. Location of the main coastal lagoons in Italy (from Marino *et al.*, 2009)

This simple classification probably gives rise to a certain improper use of the terms, a confusion that stems in part from local names of commonly used terms, in Italy as elsewhere in the Mediterranean. According to the classification proposed by Brambati (1988), the key parameter that allows to distinguish between coastal lagoons and ponds is the presence of tidal range, absent in the lagoons and coastal ponds. Recently, the problem of classification of the types defined in the Mediterranean lagoons has become particularly topical in relation to some criteria introduced by the WFD, 60/2000/CE. The Directive introduced a new terminology for aquatic systems. In particular, transitional waters are defined as "surface water bodies near the mouth of a river, the saline because of their proximity to coastal waters but substantially influenced by freshwater flows." According to the definition given by the WFD for the transitional waters, and to the interpretation given to it (De Wit *et al.*, 2007), most Mediterranean lagoons, and all the Italian ones, fall within the category of coastal lagoons. At the national level, as a part of the lentic transitional waters, Italian lagoons can be classified according to the influence of the tide (micro-tidal lagoons, with a range exceeding 50 cm, and non-tidal or nano-tidal (Tagliapietra and Volpi Ghiradini, 2006) lagoons, with a range of less than 50 cm), while a second level of subdivision is based on size, discriminating between lagoons with a surface area greater or less than 300 ha (Basset *et al.*, 2004).

Thus, within the typologies sensu WFD, ponds (*stagni*) and coastal lakes comprise small and large non tidal basins, and the *valli* are considered modified water bodies. With specific regard to the typing of the Italian coastal water bodies, a characterization based on geological features (Cataudella and Tancioni, 2007), also adopted for the realization of a "geographic information system of the Italian coastal ponds", can also be the following (Valloni *et al.*, 2006):

- Pond (*stagno*): marine-adjacent basin without natural channels for communication with the sea (this definition is also valid for coastal lakes, *laghi costieri*)
- Pond system: pond integrated with wetlands in the shoreline and/or with swamps;

- Lagoon: marine-adjacent basin separated from the sea by a sand barrier stable and well defined, interrupted by one or more channels;
- Lagoon system: lagoon integrated with wetlands in the shoreline and/or with swamps;
- Bay: marine basin with a single, wide mouth opening towards the sea (includes the delta water bodies called *sacche*).

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Table I: Complete list of the coastal lagoons in Italy, by region, province and geographic area: surface, typology and use (presence/absence of fish barriers, activities in the lagoon)

Region	Province	Geographic area	Site	Total surface (ha)	Typology (according to Brambati *et al.*, 1988, modified)	Tipology sensu WFD (Tidal influence, size)	Fish barrier (Not all fish barriers are at present active)	Activities: Fisheries (F). Aquaculture (A). Other (O)
Friuli Venezia Giulia	GO	North Adriatic	Laguna di Grado e Marano (total)	12 700	Lagoon and valli	Microtidal Large	N/Y	F A O
	GO	North Adriatic	Laguna di Marano (3 basins)	ca 8 000	Lagoon		N	
	GO	North Adriatic	Laguna di Grado (2 basins)	ca 3 000	Lagoon		N	
	GO	North Adriatic	Valle 09	248	Valle	Modified Small (Limit S-L)	Y	F A
	GO	North Adriatic	Valle 32	148	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 26	123	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 31	101	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 12	100	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 33	96	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 06	67	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 15	63	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 16	51	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 01	43	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 07	34	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 35	33	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 34	32	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 17	31	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 04	31	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 37	30	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 14	29	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 08	27	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 30	26	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 25	26	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 23	26	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 27	25	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 40	24	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 24	23	Valle	Modified Small	Y	F A

Region	Province	Geographic area	Site	Total surface (ha)	Typology (according to Brambati *et al.*, 1988, modified)	Tipology sensu WFD (Tidal influence, size)	Fish barrier (Not all fish barriers are at present active)	Activities: Fisheries (F). Aquaculture (A). Other (O)
	GO	North Adriatic	Valle 02	22	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 39	21	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 42	20	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 05	20	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 03	20	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 28	19	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 22	16	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 41	13	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 29	12	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 18	9	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 10	9	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 38	8	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 19	7	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 36	7	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 21	6	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 13	6	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 20	4	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 11	3	Valle	Modified Small	Y	F A
	GO	North Adriatic	Valle 43	2	Valle	Modified Small	Y	F A
			Total area for 43 valli	**1 660**				
Veneto	VE	North Adriatic	Laguna Venezia	57 770	Lagoon and valli	Microtidal Large	Y/N	O A F
	VE	North Adriatic	Treporti basin	ca 15 000	Lagoon and valli	Microtidal Large	N	
	VE	North Adriatic	Lido basin	ca 10 000	Lagoon and valli	Microtidal Large	N	
	VE	North Adriatic	Malamocco basin	ca 17 000	Lagoon and valli	Microtidal Large	N	
	VE	North Adriatic	Chioggia basin	ca 13 000	Lagoon and valli	Microtidal Large	N	
	VE	North Adriatic	Valle Dogà	1 687	Valle	Modified Large	Y	F A O
	VE	North Adriatic	Valle Dragojesolo	1 056	Valle	Modified Large	Y	F A O
	VE	North Adriatic	Valle Grassabò	893	Valle	Modified Large	Y	F A O
	VE	North Adriatic	Valle Morosina	538	Valle	Modified Large	Y	F A O
	PD	North Adriatic	Valle Averto	484	Valle	Modified Large	Y	F A O
	VE	North Adriatic	Valle Pirimpiè	468	Valle	Modified Large	Y	F A O

Region	Province	Geographic area	Site	Total surface (ha)	Typology (according to Brambati *et al.*, 1988, modified)	Tipology sensu WFD (Tidal influence, size)	Fish barrier (Not all fish barriers are at present active)	Activities: Fisheries (F). Aquaculture (A). Other (O)
Veneto	PD	North Adriatic	Valle Figheri	411	Valle	Modified Large	Y	F A O
	PD	North Adriatic	Valle Serraglia	397	Valle	Modified Large	Y	F A O
	VE	North Adriatic	Valle Galeassa	388	Valle	Modified Large	Y	F A O
	VE	North Adriatic	Valle Zappa	361	Valle	Modified Large	Y	F A O
	VE	North Adriatic	Valle Contarina	328	Valle	Modified Large	Y	F A O
	PD	North Adriatic	Valle Cavallino	307	Valle	Modified Large	Y	F A O
	VE	North Adriatic	Valle Perini	302	Valle	Modified Large	Y	F A O
	VE	North Adriatic	Valle Cornio	186	Valle	Modified Small	Y	F A O
	VE	North Adriatic	Valle Lio Maggiore	177	Valle	Modified Small	Y	F A O
	VE	North Adriatic	Valle Fosse	175	Valle	Modified Small	Y	F A O
	VE	North Adriatic	Valle Ghebo Storto	169	Valle	Modified Small	Y	F A O
	VE	North Adriatic	Valle Liona	137	Valle	Modified Small	Y	F A O
	VE	North Adriatic	Valle	116	Valle	Modified Small	Y	F A O
	VE	North Adriatic	Valle Sacheta	108	Valle	Modified Small	Y	F A O
	VE	North Adriatic	Valle Olivera	93	Valle	Modified Small	Y	F A O
	VE	North Adriatic	Valle Falconeria	41	Valle	Modified Small	Y	F A O
	VE	North Adriatic	Valle S. Cristina	30	Valle	Modified Small	Y	F A O
	VE	North Adriatic	Valle Lagonovo	27	Valle	Modified Small	Y	F A O
	VE	North Adriatic	Valle La Cura	17	Valle	Modified Small	Y	F A O
	VE	North Adriatic	Valle Sacognana	9	Valle	Modified Small	Y	F A O
			Total area for 26 valli	**8 904**				
	VE	North Adriatic	Bibione		Complex of valli			
	VE	North Adriatic	Vallesina di Bibione	350	Valle	Modified Large	Y	F A O
	VE	North Adriatic	valgrande di Bibione	250	Valle	Modified Large	Y	F A O
			Total lagoon of Bibione	**600**				
	VE	North Adriatic	Caorle		Complex of valli			
	VE	North Adriatic	Valle Grande	531	Valle	Modified Large	Y	F A O
	VE	North Adriatic	Valle Nuova	500	Valle	Modified Large	Y	F A O
	VE	North Adriatic	Valle Zignago	282	Valle	Modified Large	Y	F A O
	VE	North Adriatic	Valle Perera	176	Valle	Modified Small	Y	F A O
			Total lagoon of Caorle	**1 488**				

Region	Province	Geographic area	Site	Total surface (ha)	Typology (according to Brambati *et al.*, 1988, modified)	Tipology sensu WFD (Tidal influence, size)	Fish barrier (Not all fish barriers are at present active)	Activities: Fisheries (F). Aquaculture (A). Other (O)
Veneto								
	RO	North Adriatic/Po delta	Sacca di Scardovari	3 200	Sacca	Microtidal Large	N	F A O
	RO	North Adriatic/Po delta	Canarin		Sacca	Microtidal Large	N	F A O
	RO	North Adriatic/Po delta	Basson		Lagoon	Microtidal Large	N	F A O
	RO	North Adriatic/Po delta	Burcio		Lagoon	Microtidal Large	N	F A O
	RO	North Adriatic/Po delta	Barmarco		Lagoon	Microtidal Large	N	F A O
	RO	North Adriatic/Po delta	Vallona	1 150	Lagoon	Microtidal Large	N	F A O
	RO	North Adriatic/Po delta	Caleri	1 000	Lagoon	Microtidal Large	N	F A O
			Total area sacche & lagoons	**8 150**				
	RO	North Adriatic/Po delta	Valle Ca' Pisani	700	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle Bagliona	647	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle Sacchetta	600	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle S. Carlo	576	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle Ca' Zuliani	560	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle Segà	472	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle Sagreda	418	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle S. Leonardo	411	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle Ripiego	387	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valla Spolverina	340	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle del Moraro	320	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle Boccavecchia	310	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle Morosina	310	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle Pozzatini vecchi	285	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle Cannelle	279	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valla Veniera	270	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle Chiusa	270	Valle	Modified Large	Y	F A O
	RO	North Adriatic/Po delta	Valle Capitania	233	Valle	Modified Small	Y	F A O
	RO	North Adriatic/Po delta	Valle Passarella	216	Valle	Modified Small	Y	F A O
			Total area Valli	**7 604**				
	RO	North Adriatic/Po delta	Batteria		Wetland		N	O
			Bonelli levante		Wetland		N	O

Region	Province	Geographic area	Site	Total surface (ha)	Typology (according to Brambati *et al.*, 1988, modified)	Tipology sensu WFD (Tidal influence, size)	Fish barrier (Not all fish barriers are at present active)	Activities: Fisheries (F). Aquaculture (A). Other (O)
Veneto			**Total area wetlands**	**1 250**				
	RO	North Adriatic/Po delta	Po di Venezia		Delta branches		N	F O
	RO	North Adriatic/Po delta	Po di Goro		Delta branches		N	F O
	RO	North Adriatic/Po delta	Po di Gnocca		Delta branches		N	F O
	RO	North Adriatic/Po delta	Po di Maistra		Delta branches		N	F O
	RO	North Adriatic/Po delta	Po si Tolle		Delta branches		N	F O
	RO	North Adriatic/Po delta	Po di Pila		Delta branches		N	F O
			Total area delta branches	**4 000**				
Emilia Romagna	FE	North Adriatic/Po delta	Comacchio	12 263	Valli	Modified Large	Y	F A O
	FE	North Adriatic/Po delta	Goro	2 150	Sacca	Microtidal Large	N	F A O
	FE	North Adriatic/Po delta	Nuova - Bertuzzi	2 000	Valle	Modified Large	Y	F A O
	RA	North Adriatic/Po delta	Piallassa Baiona	1 800	Valle	Modified Large	Y	F A O
	RA	North Adriatic/Po delta	Porto Corsini	1 655	Coastal area (art)		N	O
	FE/RA	North Adriatic/Po delta	Orsi Mangelli	1 100	Valle	Modified Large	Y	F A O
	RA	North Adriatic/Po delta	Ortazzo e Ortazzino	1 050	Valli	Modified Large	Y	F A O
	FE	North Adriatic/Po delta	Fattibello - Spavola - Comacchio	950	Valle	Modified Large	Y	F A O
	FE	North Adriatic/Po delta	Campotto	850	Wetland (oasi)		N	O
	RA	North Adriatic/Po delta	Canna Mandriole	570	Wetland (oasi)		N	O
	FE	North Adriatic/Po delta	Ostellato	250	Wetland (oasi)		N	O
	FE	North Adriatic/Po delta	delle Nazioni	90	Coastal lake (art)		N	O
	FE	North Adriatic/Po delta	Cannevie - Porticino	64	Valle	Modified Small	Y	F A O
	FE	North Adriatic/Po delta	Dindona - Po di goro	54	Valle	Modified Small	Y	F A O
Puglia	FG	South Adriatic	Varano	6 050	Lagoon	Non tidal Large	N	F
	FG	South Adriatic	Lesina	5 136	Lagoon	Non tidal Large	Y (Disc)	F
	FG	South Adriatic	Margherita di Savoia	4 500	Saltworks		N	O
	TA	South Adriatic	Mar Grande	3 600	Semi-enclosed coastal area		N	A
	TA	South Adriatic	Mar Piccolo	2 070	Semi-enclosed coastal area		N	A
	LE	South Adriatic	Alimini	256	Coastal lake	Non tidal Large (Limit S-L)	Y	O

Region	Province	Geographic area	Site	Total surface (ha)	Typology (according to Brambati *et al.*, 1988, modified)	Tipology sensu WFD (Tidal influence, size)	Fish barrier (Not all fish barriers are at present active)	Activities: Fisheries (F). Aquaculture (A). Other (O)
	LE	South Adriatic	Cesine	51	Coastal lake	Non tidal Small	N	F O
	LE	South Adriatic	Aquatina	40	Coastal lake	Non tidal Small	N	F O
Toscana	GR	Central Thyrr	Orbetello	2 700	Lagoon	Non tidal Large	Y	F
	GR	Central Thyrr	Padule di Botrona	1 100	Wetland	Non tidal Large	N	O
	LU	Central Thyrr	Massacciuccoli	700	Coastal lake	Non tidal Large	N	O
	GR	Central Thyrr	Burano	410	Coastal lake	Non tidal Large	N	O
Lazio	LT	Central Thyrr	Circeo - Fogliano	404	Coastal lake	Non tidal Large	Y	(F) O
	LT	Central Thyrr	Circeo - Sabaudia	390	Coastal lake	Non tidal Large	Y	F O
	LT	Central Thyrr	Fondi	381	Coastal lake	Non tidal Large	?	F
	LT	Central Thyrr	Circeo - Caprolace	226	Coastal lake	Non tidal Large	Y	(F) O
	VT	Central Thyrr	Saline di Tarquinia	170	Saltmarsh		N	O
	LT	Central Thyrr	Circeo - Monaci	95	Coastal lake	Non tidal Small	N	(F) O
	LT	Central Thyrr	Lago Lungo	47	Coastal lake	Non tidal Small	Y	F
Campania	NA	Central Thyrr	Patria	200	Coastal lake	Non tidal Small	Y ?	F
	NA	Central Thyrr	Fusaro	97	Coastal lake	Non tidal Small	N	F
	NA	Central Thyrr	Lucrino	95	Coastal lake	Non tidal Small	N	F
	NA	Central Thyrr	Averno	55	Coastal lake	Non tidal Small	N	F
	NA	Central Thyrr	Miseno	40	Coastal lake	Non tidal Small	Y ?	F
Sardegna	CA	Islands	Stagno di S. Gilla	5 180	Pond	Non tidal Large	Y	F A
	CA	Islands	Stagno di Cabras	2 412	Pond	Non tidal Large	N	F
	CA	Islands	Stagno di S. Giusta	1 421	Pond	Non tidal Large	N	F
	CA	Islands	Stagno S. Caterina	811	Pond	Non tidal Large	N	F
	CA	Islands	Stagno di Mistras	691	Pond	Non tidal Large	Y	F
	CA	Islands	Stagno Porto Pino	560	Pond	Non tidal Large	Y	F
	CA	Islands	Stagno Curcurrica	551	Pond	Non tidal Large	Y	F
	CA	Islands	Stagno di Quartu	500	Pond	Non tidal Large	N	F
	CA	Islands	Stagno Corru de S'Ittiri	420	Pond	Non tidal Large	Y	F
	CA	Islands	Stagno Sale Porcus	318	Pond	Non tidal Large	N	F
	CA	Islands	Stagno di Porto Botte	276	Pond	Non tidal Large	N	F
	CA	Islands	Stagno S'Ena Arrubia	269	Pond	Non tidal Large	Y	F
	CA	Islands	Stagno di San Teodoro	258	Pond	Non tidal Large	Y	F A

Region	Province	Geographic area	Site	Total surface (ha)	Typology (according to Brambati *et al.*, 1988, modified)	Tipology sensu WFD (Tidal influence, size)	Fish barrier (Not all fish barriers are at present active)	Activities: Fisheries (F). Aquaculture (A). Other (O)
	CI	Islands	Stagno di Tortolì	247	Pond	Non tidal Large (Limit S-L)	Y	F
	CI	Islands	Stagno S'Acqua Durci	224	Pond	Non tidal Small	N	F
	CI	Islands	Stagno S. Giovanni	203	Pond	Non tidal Small	Y	F A
	CI	Islands	Stagno di Boi Cerbus	163	Pond	Non tidal Small	Y	F
	CI	Islands	Stagno di Cugnana	125	Pond	Non tidal Small	Y	F
	CI	Islands	Stagno di Pilo	124	Pond	Non tidal Small	Y	F
	NU	Islands	Stagno di Colostrai	122	Pond	Non tidal Small	Y	F
	NU	Islands	Stagno di Platamona	107	Pond	Non tidal Small	N	F
	NU	Islands	Stagno Is Benas	106	Pond	Non tidal Small	Y	F
	NU	Islands	Stagno di Feraxi	90	Pond	Non tidal Small	Y	F
	NU	Islands	Stagno di Casaraccio	90	Pond	Non tidal Small	Y	F
	NU	Islands	Stagno di Calich	90	Pond	Non tidal Small	Y	F
	OT	Islands	Stagno di Orosei	85	Pond	Non tidal Small	Y	F
	OT	Islands	Stagno Tarantelle	79	Pond	Non tidal Small	N	F
	OT	Islands	Stagno di Posada	61	Pond	Non tidal Small	N	F
	OT	Islands	Stagno di Marceddì	59	Pond	Non tidal Small	Y	F
	OT	Islands	Stagno di Mulargia	48	Pond	Non tidal Small	N	F
	OT	Islands	Stagno delle Saline	47	Pond	Non tidal Small	N	F
	OT	Islands	Stagno di Nora	45	Pond	Non tidal Small	N	F
	OT	Islands	Stagno di S. Antioco	35	Pond	Non tidal Small	Y	F
	OT	Islands	Stagno Notteri	34	Pond	Non tidal Small	N	F
	OT	Islands	Stagno di Chia	31	Pond	Non tidal Small	N	F
	OT	Islands	Stagno Salamaghe Budoni	19	Pond	Non tidal Small	N	F
	OT	Islands	Stagno di Teulada	19	Pond	Non tidal Small	Y	F
	OT	Islands	Stagno Gilgolu	18	Pond	Non tidal Small	N	F
	OR	Islands	Stagno Salina Bamba	17	Pond	Non tidal Small	N	F
	OR	Islands	Stagno di Berchida	15	Pond	Non tidal Small	N	F
	OR	Islands	Stagno S. Giusta (Castiada)	13	Pond	Non tidal Small	N	F
	OR	Islands	Stagno della Vivagna	11	Pond	Non tidal Small	N	F
	OR	Islands	Stagno di Salina Manna	10	Pond	Non tidal Small	N	F

Region	Province	Geographic area	Site	Total surface (ha)	Typology (according to Brambati *et al.*, 1988, modified)	Tipology sensu WFD (Tidal influence, size)	Fish barrier (Not all fish barriers are at present active)	Activities: Fisheries (F). Aquaculture (A). Other (O)
	OR	Islands	Stagno di Brandinchi	8	Pond	Non tidal Small	N	F
	OR	Islands	Stagno S. Anna Tanaunella	8	Pond	Non tidal Small	N	F
	OR	Islands	Stagno de li Cucutti	7	Pond	Non tidal Small	N	F
	SS	Islands	Stagno Punta Taverna	5	Pond	Non tidal Small	N	F
	SS	Islands	Stagno di Porto Ainu	4	Pond	Non tidal Small	N	F
	SS	Islands	Stagno di Tanca Manna	3	Pond	Non tidal Small	N	F
	SS	Islands	Stagno di Cannigione	3	Pond	Non tidal Small	N	F
Sicilia	TP	Islands	Saline di Trapani	480	Saltworks		N	O
	TP	Islands	Stagnone di Marsala	265	Coastal embayement	Non tidal Large (Limit S-L)	N	F
	SR	Islands	Pantano Vendicari	118	Pond	Non tidal Small	N	F
	RG	Islands	Pantano Longarini	105	Pond	Non tidal Small	N	F
	ME	Islands	Faro e Ganzirri	55	Coastal lakes	Non tidal Small	N	F

In Table II, Italian lagoons are grouped by geographical area and by region. Total number and total area are given, within each group, for the main lagoon typologies, considering the classification by Brambati (1988) and also the typologies as defined by the WFD.

Table II: Coastal lagoons in Italy grouped by geographic area and by region: total number and total surface of main lagoon typologies

Area	Region	Site	Tipology sensu WFD	Typology	N	Surface
North Adriatic	**Friuli VG**	**Grado Marano**	Microtidal Large + Modified	Lagoon and valli	3	12 700
			Modified Small	Valli	43	1 660
	Veneto	**Venezia**	Microtidal Large	Lagoon	1	50 000
			Modified Large	valle	13	7 620
			Modified Small	valle	13	1 284
		Bibione	Modified Large	complex of valli	2	600
		Caorle	Modified Large	valle	3	1 312
			Modified Small	valle	1	176
			Total North Adriatic without Po delta		**79**	**75.352**
North Adriatic/ Po delta	**Veneto**	**Po delta**	Modified Large	Sacca (bay)	7	8 150
			Modified Large	valle	17	7 155
			Modified Small	valle	2	449
				wetland	2	1 250
				delta branches	6	4 000
	Emilia	**Po delta**	Modified Large	Valli	6	21 313
	Romagna		Microtidal Large	Sacca (bay)	1	2 150
				Wetland (oasi)	3	1 670
				Coastal lake (art)	1	90
			Modified Small	Valle	2	118
			Total Po delta		**48**	**46.345**
			Total North Adriatic & Po delta		**127**	**121.697**
South Adriatic	**Puglia**		Non tidal Large	Lagoon	2	11 186
			-	Saltworks	1	4 500
			-	Enclosed coastal area (bay)	2	5 670
			Non tidal large (limit S-L)	Coastal lake	1	256
			Non tidal Small	Coastal lake	2	91
			Total South Adriatic		**8**	**21.703**
Central Thyrrenian	**Toscana**		Non tidal large	Lagoon	1	2 700
			Non tidal large	Wetland	1	1 100
			Non tidal large	Coastal lake	2	1 110
	Lazio		Non tidal large	Coastal lake	4	1 401
			-	saltmarsh	1	170
			Non tidal small	Coastal lake	2	142
	Campania		Non tidal Small	Coastal lake	5	487
			Total Central Thyrrenian		**16**	**7.110**
Islands	**Sardinia**		Non tidal Large	Pond	14	13 915
			Non tidal Small	Pond	36	2 127
			Total Sardinia		**50**	**16.042**
	Sicilia		-	Saltworks	1	480
			Non tidal large (limit S-L)	Coastal bay	1	265
			Non tidal Small	Pond	2	223
			Non tidal Small	Coastal lakes	1	55
			Total Sicilia		**5**	**1.023**
All	**All**		**Total, all typologies**		**198**	**167 575**

In Figure 3 (a-i) the location of *valli* and lagoons in the nine regions is reported.

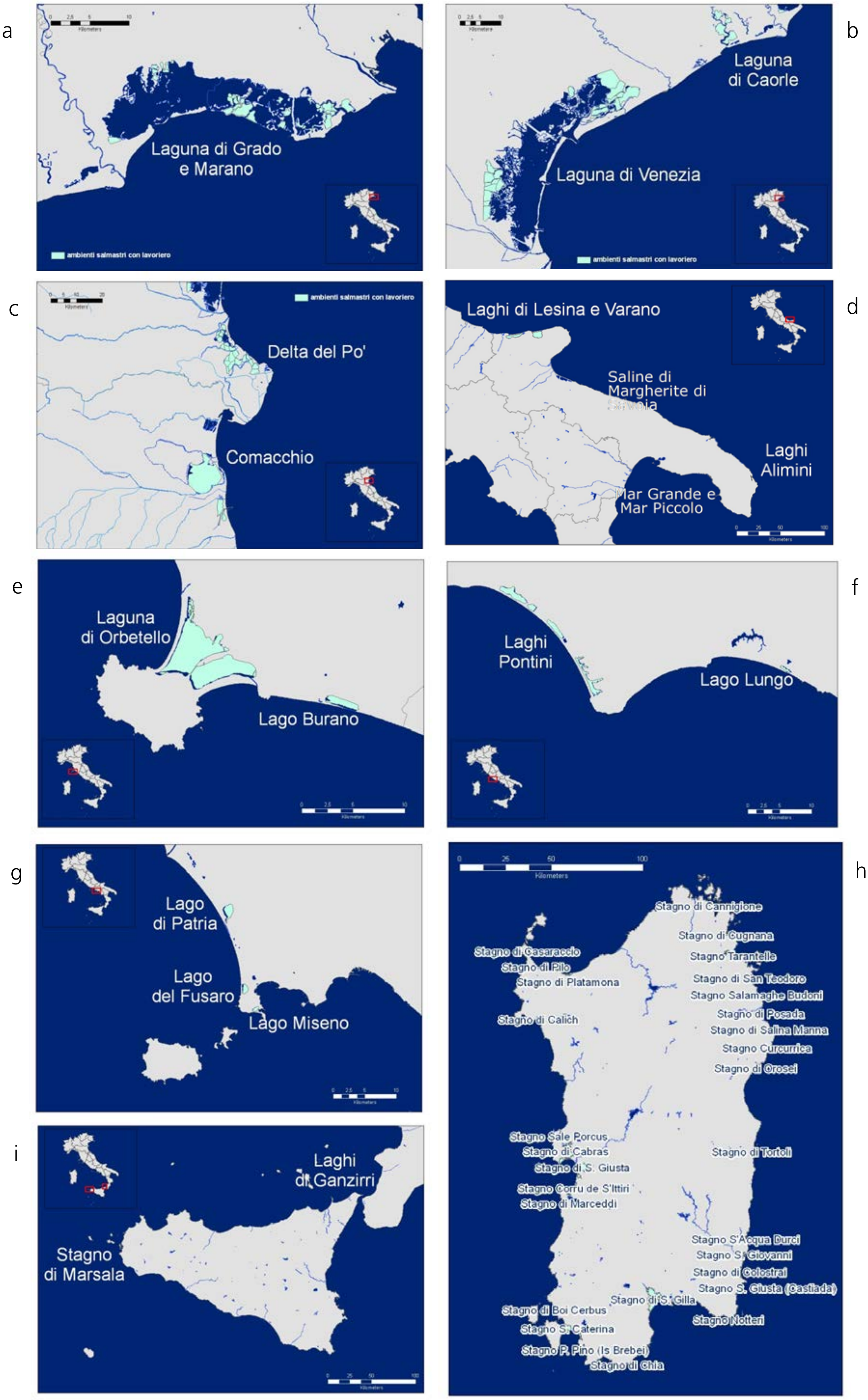


Figure 3. Location of *valli* and lagoons in the nine Regions of Italy: a) Friuli Venezia Giulia b) Veneto c) Emilia Romagna d) Puglia e) Toscana f) Lazio g) Campania h) Sicilia i) Sardinia

In almost all Italian lagoons, capture fisheries and/or aquaculture activities are carried out, with the exception of a few lagoons that are protected areas. On the whole, production from lagoon environments in Italy amounts to 2 787 tonnes of fish and 35 007 tonnes of shellfish for 2009 (Unimar, 2009).

Fisheries and extensive aquaculture carried out in coastal lagoons partially overlap with regards to culture techniques, and in statistics as well, therefore it is difficult to separate productions from the different typologies.

Extensive farming is a rearing system based on the use of the trophic resources of coastal ecosystems targeting the production of fish and shellfish and excluding human intervention in feeding. Several forms of extensive aquaculture border between fishing and culture-based fisheries techniques. Key features to discriminate between coastal lagoon fisheries and extensive aquaculture are the type of lagoon ownership, the presence of systems for hydraulic control and water management (weirs, locks) and the presence of fixed trapping systems (e.g. fish traps and barriers). A typical extensive aquaculture typology in Italy is the *vallicoltura* practised in the vally of the North Adriatica area.

In the *valli*, management for fish production is still traditional, configured as an extensive poly-culture system with relatively low productions and reduced operating costs.

In these extensive systems, the growth of fish is due only to the natural productivity of the aquatic environment. These low-energy aquaculture techniques have the side effect of contributing, through the management of the environment, to habitat conservation of sandbanks and shallow lagoon sections. Hunting is also performed in the *valli*, in relation to a high density and variety of water birds.

Shellfish farming is another aquaculture practice that occurs in coastal lagoons of Italy. Venericulture productions in coastal lagoons Italy relies mainly on the Manila clam *Ruditapes philippinarum* in the northern Adriatic, in the lagoon of Venice. Less important productions of the indigenous specie *R. decussatus* are restricted to few areas in Sardinia.

Manila clam was first introduced in Venice in 1983 using artificially reproduced seed from an English nursery. Subsequently, successful introductions were obtained in several northern Adriatic brackish environments such as Po delta lagoons of Caleri, Scardovari, Goro and in the Grado-Marano lagoon; the new species acclimatised and spread out rapidly leading to colonization of large areas and settlement of self-sustaining populations.

Manila clam farming is currently the most important activity in the fishery industry of the north-western Adriatic, and Italy has become the most important producer in Europe and in the Mediterranean.

Mussel culture is also practiced in coastal lagoons. The areas traditionally devoted to mitiliculture are the "Golfo di Taranto" (Puglia), La Spezia (Liguria), the lagoon of Venice (Veneto) and litorale Flegreo (Campania), but this activity has become an important activity in Friuli-Venezia Giulia, in Sardinia, Emilia-Romagna and on the East coast of Apulia.

In many lagoons, a multifunctional pattern of exploitation is present, in particular when towns insist on the coastal basin. In this sense, the lagoon of Venice is an extreme example, because nowadays in this large lagoon every possible use of land and water is achievable, and this has strongly influenced the lagoon ecosystem. Land based activities that deliver nutrients, heavy metals and other pollutants, fishing and aquaculture activities, in particular clam harvesting, ground-water and gas extraction, past and present interventions, combined to phenomena such as subsidence, eustatism, transportation and climatic conditions represent different stressors acting on the lagoon ecosystem.

Among the many activities carried out on coastal lagoons in Italy, tourism is one of the activities that can interest these environments, with patterns that can be also very different. In some cases, touristic activities concern sites or or near the lagoon: this is the case of lagoons such as Lesina or Orbetello or of many Sardinian ponds, where the area is frequented by many tourists in summer months, with attendance that depends on the accommodation capacity of the neighbouring towns. In other cases, there is a direct involvement of the lagoon enterprise in the touristic activity, that is the case for example of many *ittioturismi* in Sardinia and in other regions as well, where the fishers' cooperatives directly manage restaurants, fishing activities, boats tours, etc.

In some lagoons that are included within National or Regional Parks, there is a strong involvement in the conservation of wildlife and biodiversity. This is the case of the Pontinian coastal lakes (Monaci, Fogliano and Caprolace), that are included within the boundaries of the Circeo National Park, and where capture fisheries are now banned. In other Parks, some fishing activities continue to be practised, as in the Lesina lagoon, included in the Gargano National Park, or in the Valli di Comacchio, included in the Parco Regionale delta Po.

In the latter, these activities are maintained with the aim of conserving tradition and culture.

The legal framework of coastal lagoons in Italy is not unambiguous, and different frameworks exist. Ownership is in most case public, of the Italian State (*demanio*), and this concerns most lagoons, but in some cases the ownership is of the Municipality. Competent authorities are in most cases the municipalities, in some cases assisted by specific Authorities involved in lagoon management. This is the case of the Orbetello lagoon, where the Orbetello Lagoon Environmental Reclamation Authority, OLERA, was created to assist in the management of the lagoon. With regards to the legal framework, the lagoon of Venice represents an extreme situation, complicated by the lagoon extension and by the multiple uses of the lagoon, and therefore by the consequent multiple competences. The situation is further complicated by environmental issues such as the lowering of the lagoon level with respect to the sea, which has brought about the need of extraordinary interventions for the safeguarding of the town of Venice. The complexity of the lagoon governance framework can be easily understood by the high number of Institutions that have competent authority in the Venice lagoon territory.

In some cases the lagoons are private property. Such is the case of most *valli* in the Venetian area and in the other adjoining regions. This is an issue that is being addressed by an ongoing legal debate. A case for which the private ownership has been definitively established concerns the Sabaudia coastal lake in Lazio, private property of the Scalfati family since 1882.

In most cases, fishing rights are bestowed to local companies or cooperatives of professional fishers, but in some cases they can be granted by civic use to the citizens of the local Municipality (Lesina, Orbetello).

The protection of coastal wetlands, including lagoons, is a priority in the policy of conservation in the Mediterranean and in Italy as well. Given the multifunctional nature of the lagoon ecosystems, which includes among the main uses environmental conservation, lagoons have been the objective of many conventions and international directives. Among these, the first in chronological order is the Ramsar Convention (1975). More recently, the Birds Directive (79/409/EEC) and Habitats Directive (92/43/EEC) are fundamental tools for the protection of biodiversity. The implementation at the the national level of this Directive, through the *Natura 2000* network, led to the identification of numerous SCIs and SPAs that coincide with most Italian lagoon environments.

According to the national inventory of wetlands, drawn by Ispra in collaboration with the Ministry of Environment and ARPA Toscana, there are 1 511 wetland sites in Italy. The total extension amounts to 771 125 ha. 48 percent are lakes and rivers, 32 percent are marine and coastal environments and 20 percent artificial wetlands. Of these, only 6 percent is still not protected. Among these, 53 sites are recognized as internationally important under the Ramsar Convention (Table III, Fig. 4). Of the 53 Ramsar sites, 31 are coastal lagoon environments, i.e. more than 80 percent. The coastal lagoons listed as Ramsar sites amount to 60 296 ha out of the total 67 575 ha of Italian coastal lagoons, i.e. 36 percent of the total surface of lagoons in the country.

Table III: List of the sites protected under the Ramsar Convention (provided by the Italian Ministry of the Environment)

Number	Name	Surface area (ha)	Region	Coordinates
1	Isola Boscone	201	Lombardia	45°03′N 011°14′E
2	Lago di Mezzola - Pian di Spagna	1 740	Lombardia	46°13′N 009°26′E
3	Palude Brabbia	459	Lombardia	45°44′N 008°40′E
4	Paludi di Ostiglia	123	Lombardia	45°04′N 011°06′E
5	Torbiere d'Iseo	325	Lombardia	45°38′N 010°02′E
6	Valli del Mincio	1 082	Lombardia	45°10′N 010°42′E
7	Valle Averto	500	Veneto	45°21′N 012°09′E
8	Vincheto di Cellarda	99	Veneto	46°01′N 011°58′E
9	Palude del Busatello	73	Veneto	45°13′N 011°06′E
10	Palude del Brusà – Le Vallette	171	Veneto	45°10′N 011°13′E
11	Lago di Tovel	37	Trentino Alto Adige	46°16′N 010°57′E
12	Marano Lagunare - Foci dello Stella	1 400	Friuli Venezia Giulia	45°44′N 013°08′E
13	Valle Cavanata	243	Friuli Venezia Giulia	45°43′N 013°28′E
14	Ortazzo e Ortazzino	440	Emilia Romagna	44°20′N 012°19′E
15	Piallassa della Baiona	1 630	Emilia Romagna	44°30′N 012°15′E
16	Sacca di Bellocchio	223	Emilia Romagna	44°37′N 012°16′E
17	Salina di Cervia	785	Emilia Romagna	44°15′N 012°20′E
18	Valli Bertuzzi	3 100	Emilia Romagna	44°47′N 012°14′E
19	Valle di Gorino	1 330	Emilia Romagna	44°48′N 012°21′E
20	Valli residue del Comprensorio di Comacchio	13 500	Emilia Romagna	44°37′N 012°11′E
21	Valle Santa	261	Emilia Romagna	44°33′N 011°50′E
22	Punte Alberete	480	Emilia Romagna	44°31′N 012°14′E
23	Valle Campotto e Bassarone	1 363	Emilia Romagna	44°35′N 011°50′E
24	Padule Daccia Botrona	2 500	Toscana	42°48′N 010°57′E
25	Lago di Burano	410	Toscana	42°24′N 011°23′E
26	Laguna di Orbetello	887	Toscana	42°27′N 011°13′E
27	Padule di Bolgheri	518	Toscana	43°13′N 010°33′E
28	Palude di Col Fiorito	157	Umbria	43°01′N 012°53′E
29	Lago di Fogliano	395	Lazio	41°23′N 012°54′E
30	Lago di Nazzano	265	Lazio	42°12′N 012°36′E
31	Lago di Sabaudia	1 474	Lazio	41°16′N 013°01′E
32	Lago dei Monaci	94	Lazio	41°22′N 012°55′E
33	Lago di Caprolace	229	Lazio	41°20′N 012°58′E
34	Lagustelli di Percile	256	Lazio	42°06′N 012°55′E
35	Lago di Barrea	303	Abruzzo	41°46′N 013°58′E
36	Le Cesine	620	Puglia	40°20′N 018°21′E
37	Saline di Margherita di Savoia	3 871	Puglia	41°24′N 016°04′E
38	Torre Guaceto	940	Puglia	40°43′N 017°48′E
39	Bacino dell'Angitola	875	Calabria	38°44′N 016°14′E
40	Il Biviere di Gela	256	Sicilia	37°01′N 014°20′E

Number	Name	Surface area (ha)	Region	Coordinates
41	Vendicari	1 450	Sicilia	36°48’N 015°07’E
42	Stagno di S'Ena Arrubia	223	Sardegna	39°50’N 008°34’E
43	Peschiera di Corru S'Ittiri - Stagno di S. Giovanni e Marceddì	2 610	Sardegna	39°56’N 008°31’E
44	Stagno di Cabras	3 575	Sardegna	39°57’N 008°29’E
45	Stagno di Mistras	680	Sardegna	39°54’N 008°28’E
46	Stagno di Molentargius	1 401	Sardegna	39°14’N 009°10’E
47	Stagno di Pauli Maiori	287	Sardegna	39°52’N 008°37’E
48	Stagno di Sale È Porcus	330	Sardegna	40°01’N 008°21’E
49	Stagno di Cagliari	3 466	Sardegna	39°12’N 009°03’E
50	Lago di San Giuliano	2 118	Basilicata	40°38’N 016°29’E
51	Pantano di Pignola	172	Basilicata	40°36’N 015°45’E
52	Medio Corso del fiume Sele - Serre Persano	174	Campania	40°37’N 015°08’E
53	Paludi Costiere di Variconi - Oasi di Castel Volturno	195	Campania	41°02’N 015°56’E

6.3 Living resources

It is extremely difficult to describe living resources for all the Italian coastal lagoons. A comprehensive overview is given in Ardizzone *et al.* (1988), which summarizes all available information concerning planktonic as well as benthic communities and fish. In recent years, the quantity of information available concerning living resources in Italian coastal lagoons has greatly increased because of the implementing of monitoring in many coastal ecosystems. Monitoring campaigns are due to the need to document environmental quality, to follow interventions, to address requirements under the Water Framework Directive, etc. The level of scientific knowledge and of information being updated on water quality and living resources is not the same among the numerous lagoons in Italy. Some ecosystems have been extensively studied in definite moments, monitoring most components of the ecosystem. Such is the case, for example, of the lagoon of Orbetello, where a number of studies have been put in place across the end of the 1990s and 2000 because of the need to document the environmental situation and to follow the outcomes of the interventions made in the lagoon (Innamorati and Melillo, 2004).

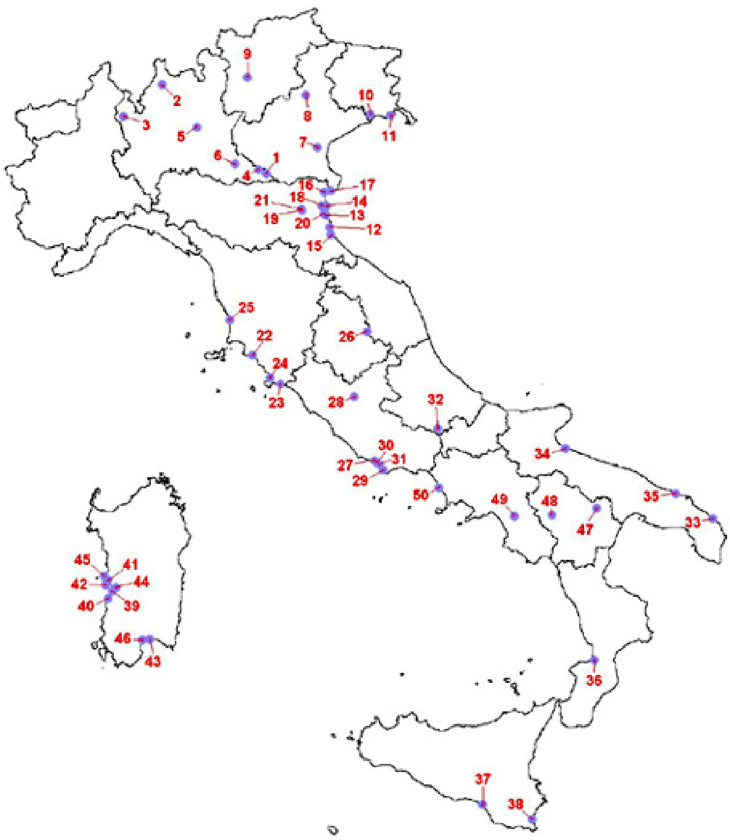


Figure 4. Location of the 53 Ramsar sites in Italy (Source: Ministero dell’Ambiente)

In other lagoons, where the main involvement is conservation of wildlife and biodiversity, as in the case of lagoons within National or Regional Parks, surveys were mainly aimed at documenting changes in biodiversity. This is the case of the Pontinian coastal lakes in central Italy, where the lakes living resources were characterized extensively in the 1980s, in the 1990s and again in 2006.

The lagoon of Venice is the lagoon where the most intense monitoring programmes are taking place. In 2000, based on the experience and knowledge gained in the previous 15 years, an integrated monitoring system (MELA, Lagoon Ecosystem Monitoring) was started by the Consorzio Venezia Nuova, concessionaire of the Magistrato alle Acque di Venezia, to provide information related to protection, control, surveillance and monitoring of the lagoon system. This system has then evolved over the years in a system of interlinked activities, often integrated with other institutional monitoring systems and with specific studies developed by Public Agencies and Public Institutions. The system represents an opportunity for comparison, sharing and diffusion of knowledge among administrators, practitioners, researchers and experts working on this complex lagoon ecosystem.

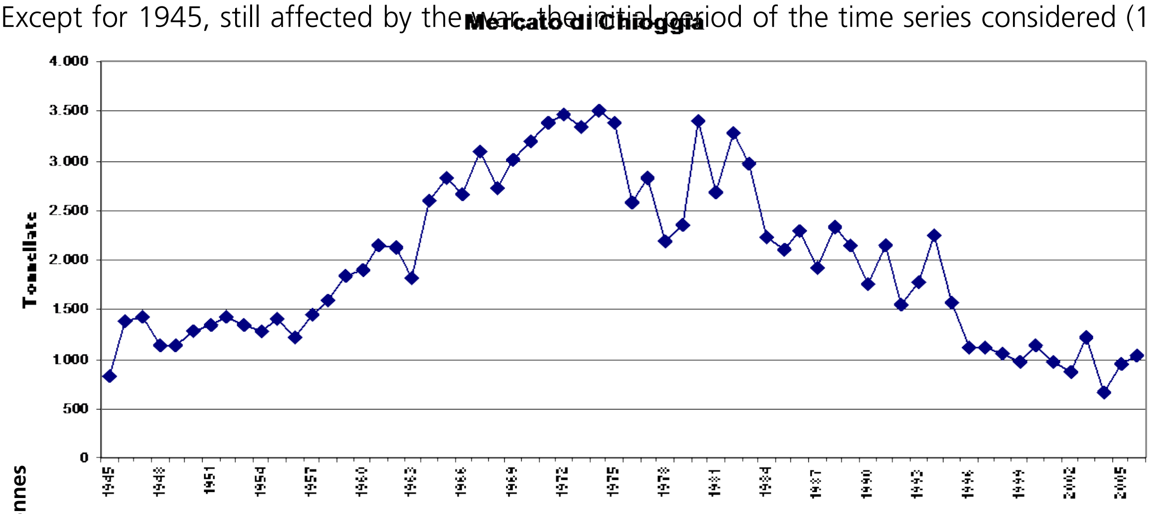
Given the importance of fisheries in all coastal lagoons in Italy, even for those lagoons where scarce or no information is available on living resources, fisheries data can somehow document, at least partially, the fish community. Fishing data are not always available in a published or documented form; nevertheless, for most lagoons some information can be obtained, if nothing else at least from a quantitative point of view.

Coastal lagoons are important sites for fish, as growing areas, wintering sites, migration routes and more generally areas that naturally support a large density of individuals (Franco *et al.*, 2006). The basic structure of fish communities of Italian lagoons is not very different from that of other Mediterranean lagoon environments, and shows a substantial stability. This is because, despite the fluctuations of abiotic and biotic parameters, factors that determine this structure can be attributed in all cases to the dominance of tolerant taxa and to the structure of food webs that are established in these systems.

The state of lagoon fish productions can be an important indicator of the ecological status of the ecosystems, and in particular historical catches may provide important clues about the status of a lagoon ecosystem. The limitations lie in the fact that fluctuations in the catches, and species composition of catches, can result from several environmental as well as socio-economic factors. Indicators of fishing effort or catch per unit effort should then be needed, to correctly interpret the observations. Despite these limitations, in many cases this approach has proved informative. An interesting example are the lagoon of Venice fisheries, illustrated by Libralato *et al.* (1994), and then again presented and updated in the "Plan for the management of the fishery resources of the lagoons of Venice and Caorle" (Province of Venice, 2009).

Time series of catches as recorded at the fish market of Chioggia for the period 1945-2006 have been used, by retaining only the catch of the artisanal fishing in the lagoon, relative to these species: plaice (*Platichtys flesus*), eel (*Anguilla anguilla*), mullets (*Chelon labrosus, Mugil cephalus, Liza ramada, L. saliens* and *L. aurata*), sand smelt (*Atherina boyeri*), the gobid *gò* (*Zosterisessor ophiocephalus*) and marsioni (*Pomatoschistus spp.*), crabs (*moleche* and *masanete*, *Carcinus mediterraneus*), shrimps (*Palaemon spp.*), grey shrimp (*Crangon crangon*), cuttlefish (*Sepia officinalis*).

Except for 1945, still affected by the war, the initial period of the time series considered (1946-



1957) shows a stable production between 1 000 and 1 500 tonnes per year. From 1958 to about 1975, lagoon catches show an increase in the quantities sold each year, to about 3 500 tonnes per year. The next period 1976–1984 is instead characterized by marked fluctuations in landings per year, from just over 2 000 to less than 3 500 tonnes per year. Finally, from 1985 to 2005 there was a decreasing trend in the quantities sold at Chioggia to values even lower than those observed at the beginning of the series (Fig. 5).

Figure 5. Fish yields in the Venice Lagoon – sale data from the fish market of Chioggia, in the period 1945–2006 (Province of Venice, 2009)

This time pattern can be explained by changes that have affected the fishing fleets of the lagoon over time. The introduction and spread of motor boats in the fleet since the 1950s, that certainly improved the efficiency of the fishery, would be primarily responsible for the increase of catches observed in the first half of the period of time considered. The competition between the small-scale fisheries in the lagoon and the emerging activities of mechanical harvesting of the Manila clam, introduced in the lagoon in the mid-1980s, would then explain the collapse of "traditional" fisheries production observed in the 1990s (Granzotto *et al.*, 2001).

The significant decrease of production in the lagoon, recorded from the mid-1980s, actually precedes the outburst of clam production, which becomes significant only in the late 1980s (Turolla *et al.*, 2008). Thus, the reverse is true, i.e. that the introduction of the Manila clam in the lagoon can be read as a response to the crisis in the traditional fishing industry. The competition between the two fisheries, artisanal fisheries and harvesting of clams, can then explain the further decline of traditional fisheries registered since the 1990s (Fig. 5), coinciding with the dramatic increase observed in production of *Ruditapes philippinarum*.

Significant differences in the time series of the lagoon catches can also be found in terms of relative composition of the species. In particular, since the late 1980s there has been a marked increase in in the catch of cuttlefish and mullets at the expense of all other species (Fig. 6). For some specific resources, the decline in annual production in the period 1945–2006 is particularly significant, as in the case of the shrimp, the green crab during molting ("*moleca*"), the gò and the plaice.

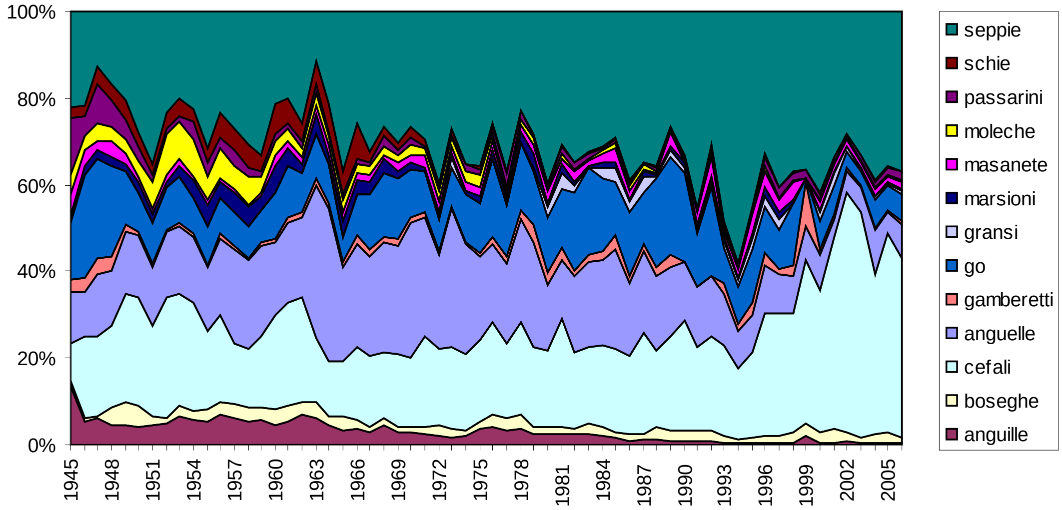


Figure 6. Relative composition of lagoon catches among species – sales data from the fish market of Chioggia, in the period 1945–2006 (Province of Venice, 2009)

A most significant reduction was observed in the eel catch of the Venice lagoon (Fig. 7), and a similar pattern is described in all Italian coastal lagoons.

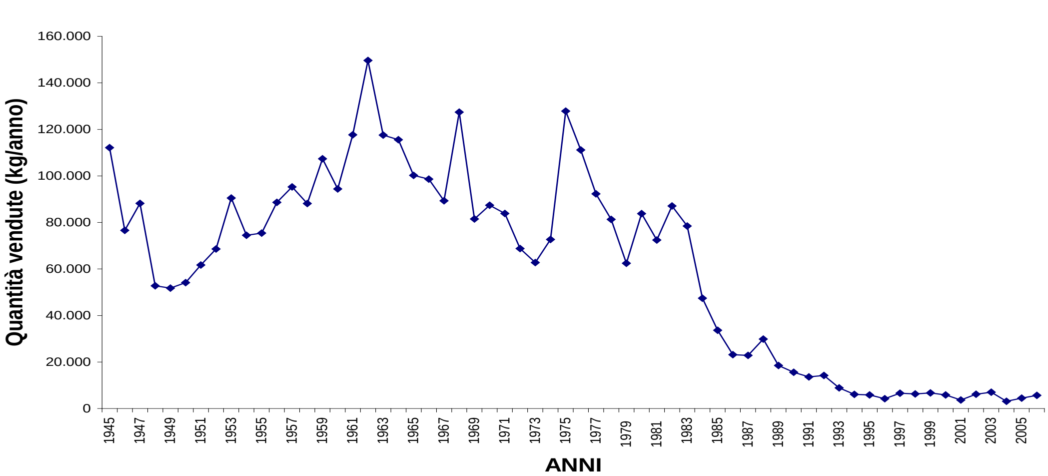


Figure 7. Eel quantities sold at the fish market of Chioggia – period 1945–2006 (Province of Venice, 2009)

In the Valli di Comacchio, the trend in the course of those two centuries has always been characterised by fluctuations ranging from 6 to > 30 kg/ha, attributable to such environmental problems as hypersalinity and freezing of the *valli*. The average annual yield of eel per hectare was 14.3 kg, about 78 percent of the total fish production. Higher yields were obtained after 1964, coinciding with restocking and seeding practices whereas, from the late 1970s, production has been considerably lower (5–7 kg/ha), attributed to falling recruitment in the Comacchio lagoons. From 1990, owing to environmental problems and to internal problems of the Consorzio Valli di Comacchio, eel production reached its historical minimum, falling to less than 5 kg/ha, stockings having been completely abandoned. Catches consist now only of large eel, the older individuals still inside the lagoon (Ciccotti, 2005).

The main limiting factor for eel production in lagoons today, apart from the habitat changes related to coastal waters eutrophication and pollution is the decline in recruitment due to the contraction of the eel global stock. National glass eel catches are used for lagoon restocking, and the fall in recruitment and the consequent decline of glass eel fisheries cannot be compensated for by imported seed, also because of rises in prices. This, together with the fact that the eel life cycle in lagoons is rather long (average seven years) and hence non-competitive with the aquaculture product, means that other species are preferred when local management strategies are formulated.

Figure 8 reports eel catches from all Italian coastal lagoons for 1969–2010, from the Italian Statistical system, that up to 2004 was responsible for the collection of fishery data for marine and coastal waters. Since eel is not present in marine waters in Italy, data can be considered relative only to Italian coastal lagoons. Catches show an evident decreasing trend, which took place during the 1980s, with yields decreasing from an average of 1 500 tonnes in the 1970s to about 500 tonnes in the 1990s to <300 tonnes in 2000. This declining trend is in accordance for the trend observed elsewhere in Europe for this species. The general picture on the status of eel stocks and fisheries throughout Europe displays in fact declining recruitment and reduced yields, apparent both for capture fisheries and for scientific indices. In relation to this situation, debate on the possible measures to protect the European eel stock is topical at the present moment, also in relation to a series of steps undertaken by the European Community, such as the issue of a specific Regulation (CE Regulation 1100/2007) outlining measures for the recovery of the eel stock (see Case Study 4, PART 3).

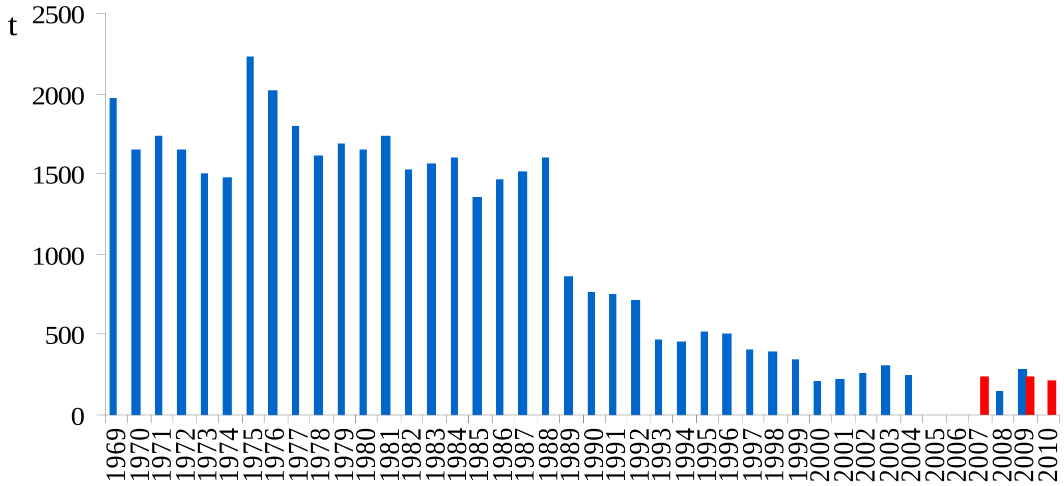


Figure 8. Eel yields from Italian coastal lagoons (Source: Istituto Nazionale di Statistica 1969–2004, blue: Mipaaf, 2007–2010, red)

6.4 Land and water management

As highlighted in the Introduction, most coastal lagoons in Italy are the remnants of reclamation carried out in swamp and marsh areas, and therefore land and water management interventions have profoundly changed the morphology of most Italian lagoons.

Such is the case of the Pontinian coastal lakes, that were once in communication with one other, and the structure of which drastically changed with the interventions carried out in the 1920s. Water level was controlled and regulated and the tidal channels were completely reorganized. Following reclamation works, the lakes were modified to allow fishery exploitation. In Fogliano, the banks were protected by concrete for about half of the perimeter of the lake and a circumdarial canal was dug, 4-5m deep, to increase circulation and thus oxygenation of the waters and to enhance the efficiency of the fish barrier (*lavoriero*). In all the lakes, over time, inputs of freshwater were reduced due to the growing water requirements of intensive agriculture practiced in the surrounding land, which lowered the water layer and depleted the springs. The Corpo Forestale that manages the coastal lakes gradually actuated a reduction and then the complete closure of all freshwater tributaries, because of the poor quality of incoming freshwater and heavy nutrient load, which certainly contributed to the lakes eutrophication.

The Orbetello lagoon also experienced changes linked to reclamation in the surrounding land, and to specific interventions on the lagoon. One of the first interventions was the enlargement of the tidal channels mouths in 1884: hydraulic and sanitary aspects in the whole lagoon improved noticeably, and lasted for about 50 years, till the mid-1900s: waters between 1930 and 1950 were for the most productive and clear. The environmental situation of the lagoon begun to worsen in 1975 due to poor water exchange with the sea, reduced depth, high temperature and salinity oscillations. Supply of nutrients from agriculture and industry resulted in a chronic hypertrophy of the Orbetello lagoon, often bringing about anoxic crises and extensive die-offs (Lenzi and Salvadori, 1986). For these reasons OLERA, the basin authority, set up specific strategies to solve the environmental crisis affecting the lagoon. OLERA action followed three main strategies: (1) macroalgal masses removal from the lagoon; (2) increase of clean seawater amount into the lagoon; (3) reduction of nutrient inputs from anthropic origin. Seawater was pumped into the lagoon at two sea-lagoon canals, and the third canal was used to make the water flow back to sea, according to the hydraulic model proposed by Bucci *et al.* (1989). In fact, the natural renewal of the lagoon water being extremely low, the pumping was boosted from 8 000 to 20 000 l/s and was concentrated in the warmer months. Between 1993 and 2000, 39 complete water lagoon changes renewal were performed. Furthermore, waste waters from domestic use and intensive land-based fish farms on the lagoons were collected and pumped into treatment plants. This articulated set of measures produced a significant reduction in algal biomass development in the lagoon in recent years.

As it can be expected, the lagoon of Venice is the lagoon that has experienced the most important land and water management interventions over time. Since the first settlements of the Venetians in the area, there was an increase of the natural tendency for sediment filling of the lagoon, due mainly to the deforestation of the mainland. To limit this phenomenon, major rivers (Brenta and Sile) were thus diverted from the lagoon between the thirteenth and seventeenth century, the number of inlets was reduced and the sand bar was reinforced. In 1604 the Po river was diverted southwards, through an artificial delta mouth, to prevent sediment infilling of some areas close to the lagoon of Venice. In the eighteenth century, the combined effects of coastal subsidence and eustatic rise in the sea level led to an increase of the flooding frequency, which obliged to protect the town of Venice: sea defences were built along the coastal strip. Under the Austrian rule and up to 1934, the Lido, Malamocco and Chioggia inlets were altered in shape and pouter dikes were built along the sea. Between the end of the nineteenth century and the beginning of the twentieth, the onset of industrialization determined further major anthropogenic changes by increased urbanization and land reclamation for agriculture, aquaculture and industry, leading to a further reduction of 3 280 ha of the lagoon surface between 1924 and 1960. Two main industrial areas were established, including oil and chemical industries, the first one in 1917 leading to dredging of new navigation channels and the second one in 1950 expanding over reclaimed areas. In 1963, a third area was foreseen, that brought about the conversion of a large area of the lagoon to solid land, but was never completed due to environmental concerns. Throughout the twentieth century, groundwater withdrawals for the industry, natural subsidence and sea level rise led to the lowering of the town of Venice and of part of the lagoon, with consequent increased frequencies of flooding. In the same period, a progressive marked decrease of the number of fishers and workers in the lagoon occurred, as well as a decline of the number of citizens of the town, up to the present 70 000 inhabitants.

The flooding in the town of Venice, due to high water (high tide), causes an increased flow of water in the lagoon of Venice that invades the town. The frequency of these exceptional high tides has increased, together with the morphological degradation, and this has led to the need to plan operations to allow the safeguarding of the town. These interventions include rising of banks and paving, qualification of the lagoon by reconstruction and re-naturalization of sandbanks, mudflats and shallow areas, rehabilitation of the smaller islands and excavation of the lagoon channels. The most ambitious intervention is the realization of the MO.S.E. (acronym for *MOdulo Sperimentale Elettromeccanico* – Experimental Electromechanical Module), a work in progress, consisting of an integrated system of defence, consisting of rows of retractable mobile gates able to isolate the lagoon of Venice from the Adriatic Sea during the events of high tide over an agreed share (110 cm) and up to a maximum of 3 meters.

An example of massive interventions is the reclamation that has interested the Valli di Comacchio, whose present surface is the remainder of a large and progressive reclamation that occurred across the twentieth century up to the 1990s. Overall surface was reduced from 73 000 ha to the present approximate 10 000 ha (13 000 ha of land area also considered).

In many cases, lagoon structure has been affected by the numerous works that have contemplated the realization of jetties, commercial ports or marinas. Such is the case of the Laguna di Grado e Marano, where the realization of the jetties of Porto Buso and Grado, the creation of the port of Porto Nogaro, with the deepening of the channel connecting the mouth to Porto Buso, the stabilization of the Island of St. Andrea and the realization of a new marina for 6 000 boats significantly affected the circulation of lagoon waters, with a gradual silting of the waterway networks in the lagoon.

The maintenance of tidal channels, dredging of the bottoms, consolidation of embankments and borders are all maintenance works needed to ensure lagoon functionality and even its persistence. Most lagoons have experienced these interventions, in all regions, as in the case of most managed Sardinian ponds.

Water management and land maintenance in the *valli* of the northern Adriatic area (see following section for a detailed description) are the clearest evidence of the role of human interventions in the maintenance of lagoon ecosystems, and represent an example of positive interaction, standing for a sustainable and compatible use of the lagoon environment.

6.5 Lagoon exploitation

6.5.1 Capture fisheries

Capture fisheries are present in all coastal lagoons in Italy. They are artisanal multi-species fisheries, practiced with traditional gear that require a good knowledge of the biology of the target species, such as reproduction timing, migration and seasonal or daily movements due to tides.

Typical instruments of lagoon artisanal fisheries are fyke nets (*bertovelli*) and pots, as well as nets and longlines the design, dimensions and materials of which vary according to the species to be caught and to local traditions. Indeed, the prevailing traditions of fishing and species are specific to regions and also to single lagoons. Fyke nets are used in series, with numbers and dispositions varying from a few nets to large systems, such as the *giostre* in Sardinia, sometimes also endowed with net walls, such as the *paranze* used in the lagoon of Lesina. The *tresse* used in the lagoon of Venice are also fixed nets, 130-140 cm tall, with a minimum mesh size of 16 mm, ending with fyke nets, locally called *cogolli* (Fig. 9).

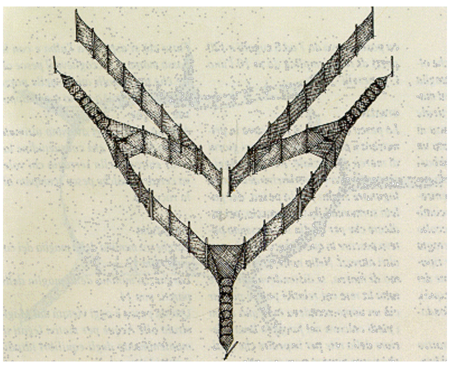


Figure 9. Tressa with fyke nets (cogolli), a fixed net used in the lagoon of Venice (from Provincia di Venezia, 2009)

In the lagoon of Venice, in the past, over 30 types of fishing gear were used, but generally with the evolution of techniques the variety of tools has decreased, coupled with a greater efficiency. Seines are used for the capture of sand smelts, while trammel nets and gillnets are generally used to catch mullets and seabass and seabream. The fyke nets, used for eel, gobids and other fish as well, consist of a series of capture chambers of decreasing mesh, and have dimensions, shapes and structures extremely variable from region to region and among different lagoons.

Fishing effort in terms of number of fyke nets or of fixed systems can vary within each lagoon with seasons. Just to give an idea, in the lagoon of Venice fishing is allowed all year round, but the total number of fyke nets vary along the year (Table IV) from a minimum of 1 283 to about 5 000 (Provincia di Venezia, 2009).

Table IV: Mean monthly number of fyke nets in the Venice lagoon (2001–2006) (Provincia di Venezia, 2009)

	Northern basin	Central basin	Southern basin	Total lagoon of Venice
January	117	258	908	1 283
February	346	374	1 546	2 265
March	1 636	736	2 678	5 049
April	1 664	603	2 681	4 948
May	1 379	582	2 466	4 427
June	634	345	1 581	2 560
July	347	222	1 527	2 095
August	240	102	1 052	1 394
September	928	447	2 234	3 608
October	1 470	693	2 824	4 986
November	985	665	2 293	3 943
December	504	302	1 277	2 083

On the other hand, in Sardinia, a mean number of 2 fyke nets/ha are reported in most managed ponds, and the allowed period of fyke-net fishing is 4 months (Cannas *et al.*, 1998).

In Sardinian ponds, fyke-net and traps catches account for 24 percent of the total catch, trammel nets for 34.8 percent, harpoons for 0.28 percent and the fish barriers for 41 percent (Cannas *et al.*, 1998). Total catch from the Sardinian ponds amounted in the 1990s to about 1 000 tonnes/year, for a mean productivity of 156 kg/ha/year (Table VI) but higher figures have been reported, up to 300 kg/ha have been estimated for these ecosystems, Marino *et al.*, 2009), up to 600 kg/ha in some ponds, a value observed for example in the pond of Tortolì up to the 1980s. Sardinian ponds are indeed the most productive lagoons in Italy. The productivity is lower today, but remains very high when compared with that of northern Adriatic *valli* or other lagoons. The production greatly differs among different ponds (Table V), as a function of salinity. In the last 30 years, important dystrophic crisis occurred in some ponds in Sardinia reducing the mean annual production.

Different causes have been considered, such as: the low recruitment of the young for the increase of fishing activities along the coasts, the reduction of seawater and freshwater flows and the effect of predators such as ichthyophagous birds.

Table V: Some production data in Sardinian ponds grouped by salinity level (Cannas *et al.*, 1998)

	Hypersaline water ponds	Marine water ponds	Brackish water ponds	Low salinity water ponds	Total or average
Surface ha	1 000	956	1.018	3.190	6 163,5
Total (kg)	25 472	163 053	236 305	538 876	963 706
kg/ha	25,47	170,45	232,13	168,93	156,36
Seabass, seabream, soles	13,06	17,19	8,92	4,06	7,71
Mullets	55,56	35,08	32,07	82,29	61,28
Eel	12,44	16,78	18,29	11,66	14,17
Carps	0,00	0,00	0,39	0,00	0,10
Crabs	12,39	11,84	17,50	0,01	6,63
Clams	0,00	0,36	0,73	0,00	0,24
Other	6,56	18,75	22,10	1,98	9,87

Table VI: Production data on Sardinian ponds (tonnes)

(Source: Idroconsult, 2006, in Marino *et al.*, 2009)

Pond name	Fish	Clam	Mussel
Cabras	130,95	0	0
S. Giovanni	43,32	0,98	17,88
Tortolì	41,44	6,02	86,95
Marceddì	33,35	52,08	67,5
S. Teodoro	20,17	0	0
Corru Mannu	15,8	0	0
Bau Cerbus	15,42	0	0
Paringianu	0	0	0
Forru su stangioni	0	0	0
Colostrai	14,02	0	0
Cirdu	11,95	0	0
Sos Tramesos	9,93	0	0
Porto Pino	9,46	0	0
Padrongianus-gravile	7,53	0	0
S'Ena Arrubia	7,15	0	0
Calich	6,93	0	0
San Giuseppe	5,3	0	0
Is Benas	4,96	0	0
Su Stangioni de Teulada	4,08	0	0
Stagno Longu (Posada)	3,02	0	0
Mistras	2,34	0	0
Flumini durci	1,59	0	0
Su Graneri	1,07	0	0
Pilo	1	0	0
Casaraccio	0,4	0	0

However, reduction in productions due to a series of environmental problems affect similarly all the Italian lagoons, with the exception of a few cases. The lagoon of Orbetello, which exceeded 80 kg/ha in the 1980s, almost 50 percent of which were eels, now shows a much lower production, and catches concerns now other species such as grey mullets and seabream. The same is observed in the lagoon of Lesina. In the forties, the average output ranged between 120 and 140 kg per hectare, to drop below 60 kg in the sixties. Today the annual production averages, which consist largely of grey mullet, do not exceed 20 kg/ha.

Capture fisheries in the lagoons can be exclusively based on small-scale fisheries, as in many ponds in Sardinia, or some of the Tyrrhenian coastal lakes. They can also include the use of fixed capture systems, the *lavorieri*. These are fixed traps, originally made of reeds and other plant materials; today most of them are made in concrete and plastic or metal grids. The design can be more or less complex, and include generally V-shaped chambers to facilitate movement of the fish towards the point of capture (Fig. 10).

Their position on the tidal channels communicating with the sea and their management allows capture of fish when they migrate from the lagoon back to the sea, during reproductive migration. In other cases, however, fish barriers can also allow the capture of fish moving from the sea towards the lagoon, as often practiced in Sardinia during summer. The dimensions of the grids of the *lavoriero* are such that the entry of young fish fry is always possible, in order to support fish recruitment to the lagoon.

Fish barriers, lavorieri in a Sardinian pond (upper left), photo ©C. Leone, and in the Caprolace lagoon, Lazio, (upper right), photo ©A. Fusari, fish capture (lower left) and fish selection (lower right), photos ©S. Cataudella

In some lagoons, peculiar fishing activities are carried out, related to local traditions and/or to local management strategies. Among these, two are carried out in the lagoon of Venice: the fishing for the *moeche* and fry fishing. The *molechicoltura*, i.e. the collection and production of *moeche*, still takes place today with the same technique unchanged from hundreds of years. The target is a stage of the crab (*Carcinus mediterraneus*) immediately after moulting, which is a gastronomical delicacy. The *molechicoltura* activity is strictly local; fishing skill has been handed down from father to son. Today it involves a limited number of employees: 60 on the island of Burano, 44 on the island of Giudecca in Venice, 108 in Chioggia.

Fry fishing is a specialist fishery that consists in collecting juvenile fish from the open lagoon at the moment of its ascent from the sea, to be used as seed for stocking in the *valli* (see below). This centuries-old tradition is closely linked to the development of *vallicoltura*. Fishers concentrate young fish, previously dispersed on the whole lagoon, in the *valli* that have a function of nursery areas; such *valli,* being distant from the sea, would not be well positioned to receive natural recruitment. Fishing for young fish is currently practiced by fishers who operate in the lagoon of Venice on a local basis, or fishers-traders moving along the Italian coasts with equipped trucks, with tanks and water oxygenation, to transport live fish. Seine nets of different lengths are used for fishing (Rossi and Franzoi, 1999).

6.5.2 Vallicoltura

The *vallicoltura* represents one of the oldest forms of fish culture, not only in Italy, but in the Mediterranean area, dating back at least to the eleventh century, when the practice of enclosing lagoon areas with wooden fences or reed trellises was first established. Thus, it was possible to exploit the seasonal movements of euryhaline fish fry, migrating from the sea to the lagoon where trophic and thermal conditions were optimal for their growth (Bullo, 1940; Fabris, 1991). It is only in the second half of the nineteenth century, however, that this practice became a true form of fish farming, thanks to technical hydraulic innovations and to fish culture practices (Bullo, 1899, 1940; Brunelli, 1933; Boatto and Signora, 1985).

The origin of *vallicoltura* can be brought about to the "nursery" role played by the lagoon for euryhaline fish species that reproduce at sea (Brunelli, 1916; Bullo, 1940; Rossi, 1986): in late winter and spring fry of seabream, seabass, plaice, sole and mullets leave the open sea to find food and protection in the lagoon shallow waters. After a period of permanence in the lagoon, young and sub-adults migrate offshore, usually during the summer and autumn months, to complete their development and reproduction. Therefore, areas of concentration of young fish were at first surrounded and enclosed with the *grisiole*, trellises made of reeds, to allow fish to grow exploiting the trophic resources of the lagoon, in order to catch it easily when migrating back to the sea. Along with the development of the *vallicoltura*, the rearing cycle was extended: fish were kept wintering in fish ponds (*bacini di sverno*) to be then released in the open *valle* in the following spring. It was thus possible to rear species that required several years to reach market sizes (Bullo, 1940; Boatto and Signora, 1985; Franzoi *et al.*, 2002).

The structure of the *valli* has evolved over time depending both on the morphological changes that affected the lagoons, first of all the lagoon of Venice but also the other lagoons of the northern Adriatic area, and on the specialization of fishing and management techniques. The following description and terminology refers to the *valli* of the lagoon of Venice, but the structure and functioning of the *valli* is similar also in the *valli* of the other regions. In the past, the *valli* were open water spaces where exclusive fishing rights were exercised (*valli aperte*). The delimitation of water spaces with the *grisiole* gave rise to the *valli a seragia*; the fragile structure of these, subject to adverse weather and sea conditions, led to the reinforcement with earthen banks, originally only on a single side, in order to maintain a good water circulation (thus giving rise to a *valle* of the type s*emiarginato*). The final evolutionary stage is the *valle arginata*, completely separated from the lagoon environment by robust long embankments, and communicating with it through sluice gates (*chiaviche*) that allow to control completely the water exchanges with the lagoon. This is the type of *valle* that currently exists in the lagoon of Venice (Fig. 10) and in the other regions as well.

Key feature of the *vallicoltura* is the hydraulic management of the basin that ensures a good water exchange in order to guarantee in all seasons the best conditions of temperature and salinity for fish growth and survival. The inner side of the *valle* is usually organized in a series of ponds or basins bordered by saltmarsh areas but communicating with each other. The *valle* is generally bounded by a circular ditch (*fossa circondariale*) following the morphology of the banks of the *valle* and of varying depth (between 2 and 4 meters), whose function is to facilitate the movement of water and the movement of the fish. There are also numerous channels, said *tagliavalle*, which are included in the main channel, which ends in the vicinity of the collection basin of the fish, called *colauro*, where the fish barrier, the *lavoriero*, is placed. Other basins are the *gorghi*, small deep (about 5-6 m) lakes, near the embankments, used to shelter fish in winter.

In late autumn, water level is lowered to ensure that fish concentrate in the channels. The main sluice gate is opened, and the incoming seawater spreads in all the channels system, from the main channel to the *tagliavalle* channels, attracting fish. Fish begin to move against the current, attracted by the warmer water at higher salinity, concentrating in the first channel, *sbregavalle*, and then in the *colauro*. Here fish are selected by the grids of the lavoriero, according to species and size, and harvested with nets if they have reached commercial size, or transferred to be wintered in the case where there are under size.

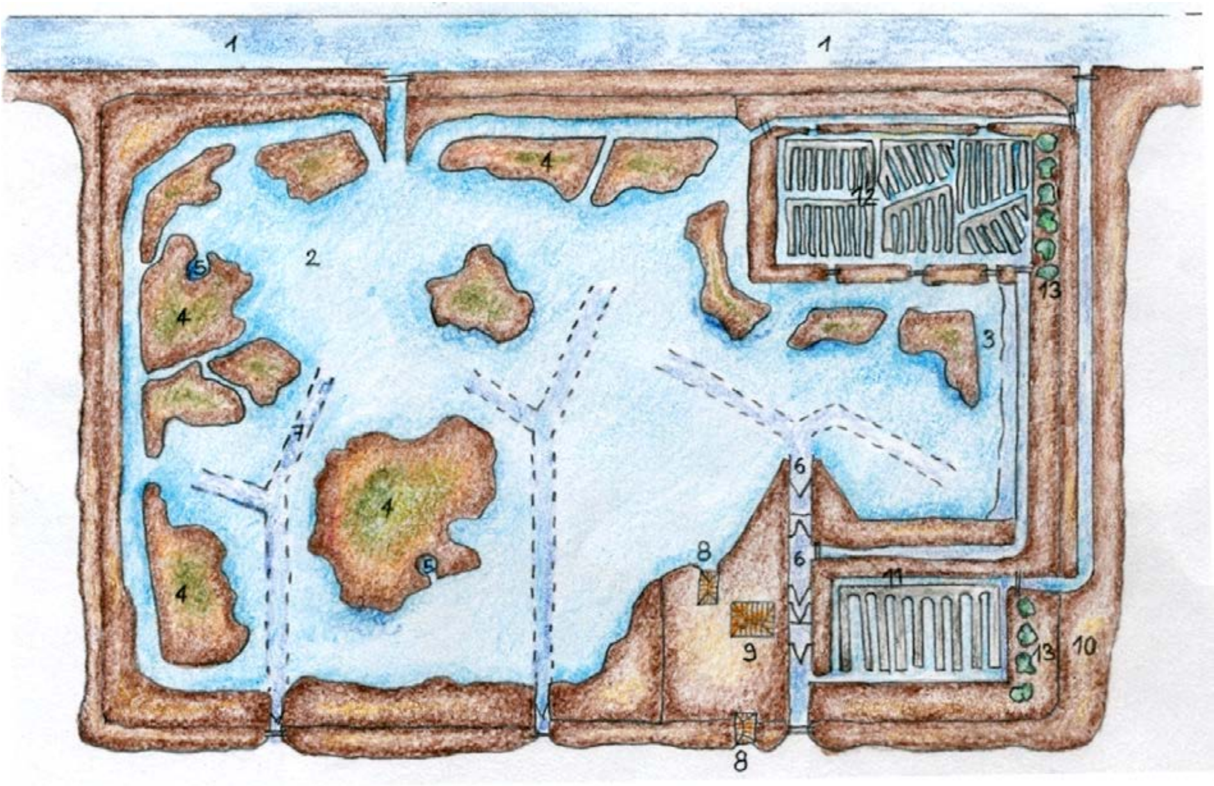


Figure 10. Schematic drawing of the organization of a valle of the type arginato (drawing by S. Silvestri, Provincia di Venezia, 2009). Legend: 1. trees acting as a wind barrier river or freshwater channel 2. valle 3. circular ditch, 4. "barena", 5. "gorgo", 6. "coluro", 7. "tagliavalle" channel, 8. "cavana", 9. "casa di pesca", 10. Embankment, 11. "peschiera" for fish fry, 12. "peschiera" for wintering**.**

The *vallicoltura* is an extensive poly-culture method, in which the fish is free in the basin and grows exploiting natural food resources. Direct interventions on the environment are limited to the control of the hydrological regime, but also foresee stocking with young fish fry in order to sustain recruitment, and capture and selection of the fish both to protect fish from adverse conditions and predation and to obtain commercial product (Boatto and Signora, 1985; Ardizzone *et al.*, 1988, Donati *et al.*, 1999).

Overview of a *valle* of the arginato type (Valle Figheri), photo ©A. Fusari.

In the lagoons of the Venice area, in a few (five percent of the total, Neotron, 2006) *valli* enterprises intensive and semi-intensive basins are also present, where fish stocked at higher densities are fed, and which often are aerated to provide for the great demand for oxygen required particularly in the summer because of the higher biomass.

The main fish species cultured in the *valli* are seabream (*Sparus aurata*), seabass (*Dicentrarchus labrax*) and the five mullet species (*Liza ramada, L. aurata, L. saliens, Chelon labrosus* and *Mugil cephalus*). To these, eel must be added (*Anguilla anguilla*), a migratory species linked to continental waters, lagoons included, in the growing phase of its biological cycle. A second group is represented by accessory fish species that include sand smelt, *Atherina boyeri*, the go, *Zosterisessor ophiocephalus*, the shrimps *Crangon crangon* and *Palaemon* spp. and the common crab, *Carcinus aestuari.*

The juveniles for restocking in the *valli* are from capture, or by artificial breeding. The capture is the main source of seed for all species, wild seed being preferred because better performing in the *valli* where conditions are similar to natural ones. Fry specialist fishery (see above) provides for this product. Stocking operations extend from March to May, but in some cases to June or, as in the case of eels, to October. The quantities per hectare are variable and amount to 150–400 fingerlings/ha for seabass, seabream, eel and *Chelon labrosus*, and around 1 000/ha for other mullet fry. Stocking quantities depend on the features of the *valle* (extension, salinity, hydraulic conditions) and also by the main use that is mad of the *valle* (if largely used in other activities besides the fish, such as hunting). The availability of seed, its costs, current prices of the *valle* fish product, ecological factors (presence of fish predators or ichthyophagous birds, fish biomass of different fish species living in the *valle* are also relevant factors in planning stockings.

The productivity of the *valli* of the northern Adriatic is extremely variable, depending on its total surface and position, on water quality and of course on the management strategy. It is estimated that the potential productivity in the lagoon of Venice area ranges between 100 and 250 kg/ha of water surface per year (Province of Venice, 2000). In 1996, the average production of the *valli* in the Veneto Region (*valli* of the Venice lagoon and those present in the area of Caorle and Bibione), was evaluated as 132 kg per hectare of water surface (Donati *et al.*, 1999). These values seem to confirm a substantial stability in yield values of these *valli* from the late nineteenth century (Bullo, 1891, 1940; Boatto and Signora, 1985, Donati *et al.*, 1999).

For the *Valli di Comacchio*, in Emilia Romagna, a long time series is available, which shows a mean production per hectare in the period 1781–1982 amounting to 16.4 + 6.5 kg, with fluctuations being due mainly to adverse climatic conditions in certain years. Eel was the main species among captures, adding up to 90 percent of catches. Mean catches in the 1980s-1990s were about 15 kg/ha/year, eels about6 kg/ha.

The decrease in total yield for this complex of *valli* arises from the drastic reduction in surface due to reclamation. The strong decrease that has interested eel catches is anyhow to be connected to the drastic decline that eel local stocks have faced since the late 1980s across its distribution area.

For the lagoon of Venice area, data are available about the productive *valli* companies that amount to 15 (Table VII). The discrepancy in number and total surface with the list reported in Table IV is due to the fact that only active enterprises are listed here, and that surface is here discriminated among water and land surface.

Table VII: Surface of the valli of the lagoon of Venice, aquaculture typologies and target species (Provincia di Venezia, 2009, from Neotron, 2006)

Name	Total surface (ha)	Water surface (ha)	Agricultur e surface (ha)	Uncultivated surface (ha)	Main typology (E=extensive; I=intensive; S=semi-intensive)	Target species			
						Sea bass	Sea bream	Eel	Mullets
Laguna nord									
Valle Cavallino	483	350	8	125	E				
Val Dogà	1 670	1 000	11	659	E				
Valle Dragoiesolo	1 000	700	285	15	E				
Valle Fosse	172	152	0	20	E				
Valle Grassabo'/ Vallesina	960	640	100	220	E				
Valle Lio Maggiore	67	50	0	17	E				
Valle Galeazza	407	287	0	120	E				
Laguna sud									
Valle Averto	300	265	0	35	E				
Valle Cà da Riva/Perini	310	150	0	160	E				
Valle Contarina	353	345	0	8	E				
Valle Figheri/Cor nio Alto/Cornio Basso	752	695	0	57	E				
Valle Pierimpiè	500	450	0	50	E + I				
Valle Sacchetta e Sacchettina	115	70	0	45	E				
Valle Serraglia	1 228	338	670	220	E				
Valle Zappa	372	350	0	20	E				
Total	**8 697**	**5 842**	**1 074**	**2 074**					

6.5.3 Shellfish culture

Shellfish harvesting is an important activity in Italian coastal lagoons that has now evolved towards a culture-based activity. The Manila clam production and harvesting is now the prevailing aquaculture activity in Italy, and the most important share is carried out in the lagoon of Venice. This activity, briefly described in the previous section, has created a peculiar situation in the lagoon management, and brings about a number of consequences at different levels, from the environmental to the socio-economic.

This species was introduced in the Venice lagoon in 1983; this allochthonous bivalve mollusc belongs to the same genus of the local clam *Ruditapes decussatus* (Linnaeus, 1758). Compared with the native species, the Manila clam proved to be more resistant to temperature changes and salinity, it can adapt to a greater variety of substrates and, most important, shows a much higher growth rate. These characteristics have led to a great success of this species, so that now

Italy, due to the almost exclusive fishing activity of the Adriatic, has the highest European production.

In the early 1990s, there were about 100 boats equipped with hydraulic dredges in the lagoon, but their use has been prohibited since 1992. The use of this tool brings about morphological changes of the bottom (Pranovi and Giovanardi, 1994), modifications of the biocenoses and short and medium-term alterations in the benthic communities. Dredges were replaced by the *rusca*, now the most common method of collection, whose spreading is due to the increase of illegal fishing and the need to have a tool easy to handle even where the water is low. Other gear used for the harvest of the Manila clam are the vibrating dredge, and hand tools such as rakes and rasca, all based on the same principle to penetrate the sediment to recover bivalves.

Since the mid 1990s, Manila clam production changed from a harvest production to a culture based fishery. The Consorzio Veneto Allevamenti Lagunari has been established, which has the concession of some portions of the lagoon of Venice for the Manila clam production and harvesting; the total area in concession at present covers about 3 000 ha. The Manila clam production is now carried out by stocking wild seed (15–20 mm in size) and only rarely hatchery produced seed. Final production can reach 2.25 kg/m^2, natural mortality being around 20 percent per year.

The autochthonous species *Rudiapes decussates* is still harvested in some ponds in Sardinia, with yields that amount to about 73 tonnes/year in Sos Tramezzos and in Marceddì (density up to 2 kg/m^2). The Manila clam has been introduced also in Sardinia in some ponds, where it has superseded the autochthonous species; the maintenance and protection of the local species is of great interest in Sardinia in relation to the maintenance of biodiversity, and lower yields can be compensated by the economic return linked to an appropriate valorisation of the product.

The collection of mussels (*Mytilus galloprovincialis*) and the practices for their cultivation have been present in many Italian lagoons for a long time. In Sardinia, in several ponds (Tortolì, San Giovanni, Feraxi, Corru St'Ittiri and Corru Mannu) floating rafts (*zattere*) are used, rare in other regions. The most common mussel culture methods are fixed systems, longlines "*monoventia"* and longlines "*triestino bi-triventia*". Approximately 2 000 000 longlines linear meters are available in Italy with an average of 10 000 m per farm. The regions with the highest longlines meters are Emilia-Romagna (631 150), Apulia (550 270), Veneto (303 240), Friuli- Venezia Giulia (186 440) and Sardinia (143 660).

The lagoon of Venice accounted, up to the early 1980s, for an important share of the national production (about 60 percent), with its 100 licences, and a total production of 30–35 000 tonnes of mussels, amounting to 6 billion lire (about 3 million euros). A progressive decline in the lagoon production of mussels followed, with annual production estimated at around 21 000 tonnes in the 1980s, 9 000 tonnes in the 1990s and 4 000 tonnes inthe early 2000 (Pellizzato and Penzo, 2002; Silvestri Pellizzato, 2005). In 2005–2007, the lagoon production has declined further, with an average of 1 500–2 500 tonnes of mussels/year over a total area of 1.5 to 3 ha. This decline can be caused by several factors (Pellizzato and Penzo, 2002), that have prompted many operators to develop "offshore" mussel farms along the Venetian coast, where there is the availability of large spaces and production of mussels with highest growth rate and better quality. A change in trophic conditions of the lagoon, with a decrease in growth rates of mussels and a consequent increase in production cycle to 18 months, has been an important factor for the decline of the mussel lagoon production, as well as the increase of the risks and constraints linked to hygiene and sanitation.

6.5.4 Other harvest activities

In addition to the main fishery resources, other species belonging to the flora and fauna of Italian coastal lagoons are being (or have been) exploited, albeit only occasionally or on a small scale, by fishers and other professionals or occasionally by other categories. Some of these species are not exploited but are used for food or as bait or for other uses. In Table VIII, a list of the target species of these minor harvest activities are listed, relative to the lagoons of the northern Adriatic area, but the same species have been or still are harvested in other regions of

Italy. These minor collection activities, practiced to supplement the family income, are currently in strong reduction. Among them is also the collection of baits, in relation to the sale for purposes of recreational fishing. The most common baits are worms (Annelid Polychaetes) as *Marphysa sanguinea* (*muriddu*), *Nereis* sp. (*tremolina), Perinereis cultrifera*. These activities, many of which are now abandoned or marginal, or even prohibited because targeting protected species, may still be an occasional source of income or supplemental to other major activities. Many of these practices, part of the traditional culture of high-Adriatic populations, common in all the fishing villages from Marano to Comacchio, have helped to maintain local identity and community folklore.

Table VIII: Some typical product species harvested in past and/or present times in lagoons of the northern Adriatic area (Provincia di Venezia, 2009)

Resource	Species/Genus/Family/Type name	Main use
Algae	Green algae (*Ulva*, *Enteromorpha, Chaetomorpha*, etc.)	Fertilizer for agriculture (up to the 1990s), production of paper, chemical and pharmaceutical industry
Algae	Red algae (*Gracilaria* sp.pl.)	Alginates and pectines production for cannery industry, agar production for chemical and pharmaceutical industry
Plants	Saltmarsh vegetation (*Limonium*)	Ornamental flowers to be sold locally, usually dried; amateur harvesting
Plants	Saltmarsh vegetation (*Salicornia fruticosa*)	Amateur harvesting for consumption (in vinegar)
Plants	Reed marsh (*Phragmites australis, Arundo donax*)	Harvest for the lavorieri, serraglie, fences, roofs.
Anellids-Polichaetes	"Verme duro", "bissone" (*Marphysa sanguinea*)	Baits, amateur and professional harvest
Anellids-Polichaetes	"Saltarello" (*Perinereis cultrifera*)	Baits, amateur and professional harvest
Anellids-Polichaetes	"Tremolina" (*Nereis*)	Baits, amateur and professional harvest
Anellids-Polichaetes	Anellid tubicoli (Sabellidae)	Baits, amateur and professional harvest
Crustaceans	Corbola (*Upogebia litoralis (pusilla)*)	Baits, amateur and professional harvest
Molluscs - Gasteropods	Caragoi (*Nassarius (Hinia) reticulatus,*	Bijouterie jewels (necklaces, bracelets etc.)
Fishes	"nono" (*Aphanius fasciatus*)	Fertilizer for agriculture

6.6 Interactions among aquaculture, capture fisheries and the environment in coastal lagoon management

Interactions among aquaculture, capture fisheries and the environment in coastal lagoon management in Italy are quite strong, given the number and extent of these ecosystems along the Italian coastline. Interactions are sometimes on a conflict basis, but often result in positive interactions that allow to enhance the interactions. The most conflicting interactions are those that result in heavy environmental effects.

6.6.1 Interactions between commercial and recreational fisheries

In many coastal lagoons, no relevant interactions are reported to be present between commercial fishing and sport fishing, the latter representing a negligible activity. For example, in the Orbetello lagoon, recreational fishing does not bear any disturbance to commercial fishing for the low number of fixed fishing locations (around 42). Sport fishing in the lagoon is practiced from April to October in the 42 stations, allowed for three days a week (Friday, Saturday, Sunday), from 8 am to 6 pm. Only fishing rods are allowed. The fishing pressure may be considered for 110 fishers per week (three days) for the seven months of operation. The target species are the seabream, with eels as bycatch.

In the Lesina lagoon, interactions between commercial and recreational fishers (amateur fishers who are retired people) are peculiar, the second group exploiting the lagoon resources on the basis of civic uses without any further regulation. From these assumptions, it is clear that unavoidable frictions between the two teams, exacerbated or resolved often at a personal level, have often arisen.

Recreational fishing in the lagoons of the Veneto region (Venice, Caorle) is allowed on possession of a non-professional fishing licence and is regulated by a Provincial Regulation (Province of Venice, 2008). Besides the use of fishing rods with hooks and lines, the use of certain nets and traps, of the harpoon and the help of a light source (with a maximum power of 400 watts) is also allowed. Amateur fishing in the lagoons is practiced today by a consisting number of fishers. These can be ascribed to three types:

- Sporting fishers, usually equipped with adequate specific equipment for fishing, who focus primarily on catching valuable fish species. They are usually equipped with a fishing licence. The most common illegal catches are probably undersized specimens, fishing in areas that are not allowed and exceeding the maximum quota of fish.
- Fishers who operate similarly to those of commercial fishers, in terms of fishing effort (time allocated, gear, quantities caught). It is very likely that at least some of these fishers are retired professionals.
- Fishers/ gatherers, mainly dedicated to the harvest of bivalve molluscs, and who do not require special investments in equipment. The activity is practiced almost exclusively for direct consumption.

Of the more than 30 000 holders of a licence of B type in the Province of Venice, it is estimated that no fewer than 4 000 are operating in the lagoon or in the neighbouring sea. Many of these anglers catch valuable fish species (seabream, bream, croaker, seabass, etc.) by fishing rods or other fishing lines, operating both in the lagoon and at sea, depending on the tidal cycle. From May to September, many anglers concentrate daily in the vicinity of inlets, moving between the sea and the lagoon and vice versa by means of small boats with motor. The average number of fishing days each fisher was estimated at about thirty per year, with a catch average of about 2-3 kg per day. It was thus possible to hypothesize a total catch of the order of 240–360 tonnes per year (Province of Venice, 2000; Pellizzato *et al.*, 2006), a relevant share of the fish withdrawal.

Also relevant is the catch by the *bilancioni* (shore operated lift nets) in the lagoon of Venice; this type of gear is not allowed in other coastal lagoons of smaller size, but it is used in many rivers and channels in most regions. This gear targets nektonic species that make regular migrations (seasonal or related to the tide) between the lagoon and the sea. The relatively small mesh size, at least in the central portion of the gear, makes it vulnerable to the capture also the juvenile forms and undersize individuals. The *bilancioni* are usually placed strategically inside the tidal channels, also relatively shallow and narrow, close to sensitive habitats such as saltmarsh and mudflats areas, and they may represent a potential threat to fish moving between different lagoon habitats, or between the lagoon and the marine environment. The presence and impact of the *bilancioni* should also be evaluated taking into account other aspects, such as those related to the conservation of fragile habitats typical of the lagoon landscape (Provincia di Venezia, 2009).

6.6.2 Interactions among different fishers groups

In most coastal lagoons, no relevant interactions are reported among different fishers groups and conflicts between fishers/fish-farmers and public or private stakeholders. When touristic activities are present in the area, usually this creates a significant economic activity, also allowing some fishers to supplement the income with fishing tourism activities or other related activities.

Completely different is the interaction that arises in the lagoon of Venice due to the harvesting of Manila clam. The Province of Venice (1999) estimated the morphological damage consequent to *R. philippinarum* harvest in the lagoon of Venice in about 20 billion euros per year to collect and dispose residual materials and other 40 billion for the reconstruction of morphologies.

Harvest activities, lifting and suspending the sediment contribute to the erosion of salt marshes, also raising the bottom of the channels and promoting the loss of suspended material from the lagoon.

Conflicts also arise in relation to illegal fishing fight and prevention, based on seizures of the product either caught in prohibited waters or because it is under market size, boat confiscation, reporting and arresting.

6.6.3 Competition for space

The issue of competition for space between aquaculture and other uses of the lagoon, namely fisheries, is strongly felt with reference to the allocation of the concession areas for Manila clam culture and harvest in the lagoon of Venice.

In other coastal lagoons, the relationship between fisheries and the aquaculture industry has been constructive, as reported for the lagoon of Lesina, for example by providing hatchery seed for the restocking actions carried out by the Municipality of Lesina and by the Provinces. The shrimp farm (pens) present in the Lesina lagoon does not cause damage nor creates impacts on the fisheries, apart from the use of a limited area of the lagoon.

6.6.4 Product interaction on the market

Market interactions often have resulted in positive initiatives. In Orbetello, the company Orbetello Pesca Lagunare aimed to enhance local productions and diversify products from the lagoon, supported up to now by funding from the Regional Administration. In addition to artisanal fisheries, fish barriers management and management of one of the hatcheries also sustain processing initiatives of some typical products, such as the production of mullet roe (*bottarga*) and mullet smoked fillets, and manage a fish restaurant. In the Lesina lagoon, the fishers cooperatives have often set up initiatives and programmes to protect and enhance fish production of the lagoon, with the support of the Municipality of Lesina, through a mixed public-private partnership that also managed in the past a small shop and a processing unit for mullet roe production. The most relevant market interaction in recent years is the one occurring between fish from the *valli* and imported product (seabream and seabass), which caused a sharp fall in prices, also accentuated by the difficulty to label this product with appropriate marketing techniques (Persona *et al.*, 1996; Donati *et al.*, 1999).

6.6.5 Organic input from aquaculture activities

The most relevant situation of organic input from aquaculture activities is the one present in the lagoon of Orbetello, because of the presence of intensive fish farms discharging in the past in the lagoon, concurring to eutrophication and consequent dystrophic crises that occurred in 1991–1993. At present, the problem has been remediated by effluent waters treatment.

6.6.6 Environmental effects of aquaculture and capture fisheries on biodiversity conservation

With regards to the environmental effects of capture fisheries on biodiversity conservation, in most lagoons fishing gear is selective up to a certain measure, and this applies in particular to the fish barrier, that allows juveniles and sub-adult fish to escape. Thus, the environmental effects are to be ascribed to fishing effort intensity and result mostly in a depletion of fish stocks in conditions of intense fishing.

A relevant environmental effect of aquaculture on the lagoon environment is the one reported for the Manila clam harvesting in the lagoon of Venice, because the operation of the gear during harvest strongly affects the bottom, primarily by suspending the sediment. The greater part of the sediment lifted by the fishing gear resettles in the lagoon, thus increasing the silting of traits of the navigation channels, and is partly transported to the sea through the inlets. Manila clam harvesting was estimated to cause the loss of one billion cubic meters of sediments per year from the Venice Lagoon. These direct effects on the sediment may cause indirect effects on aquatic organisms and the ecosystem. Most authors (Pranovi and Giovanardi, 1994; Fontolan *et al*. 1995; Pranovi *et al*. 1998; Province of Venice, 1998) agree that the action of the gear for clam harvesting cause a general depletion of species and total biomass of the benthic community.

On the contrary, positive relationships can be described between extensive aquaculture activities carried out in the *valli* and the environment. In addition to farming, wildlife presence and hunting activities, the *valli* are of still of considerable importance because of their environmental and naturalistic value. The management of a *valle* foresees a number of interventions, the aim of which is ultimately to ensure habitat conservation (Donati *et al.,* 1999). The maintenance of a substantial ecological stability is the basis of long-term profitability of a *valle* (Ardizzone *et al*., 1988). An average of about 30 percent of the maintenance works being carried out in a *valle* are estimated to present a high environmental value.

Environmental effects linked to the presence of intensive aquaculture facilities discharging directly into the lagoon have been heavy in the past, and have brought about negative consequences to the whole ecosystem of the Orbetello lagoon, and to its biodiversity. A substantial impact on the environment, even if hardly measurable, is due to the wastewaters from the aquaculture facilities in other lagoons, such as the lagoon of Lesina, where some culture facilities discharge into the lagoon their effluent waters. This situation could bring about, apart from an increase of the trophic level of the lagoon, also the spreading of pathologies. The occurrence of the allochthonous species *Tilapia niloticus*, which has reached the lagoon from a nearby fish farm, is now established, and there is evidence that this species has now adapted to the lagoon environment.

6.6.7 Pathology spread

Pasteurella piscicida pathologies, probably derived from cultured European seabass and gilthead seabream in the surrounding fish farms, were reported in the Orbetello lagoon for some years for the large grey mullet (*Mugil cephalus)* specimens during spring and autumn.

6.6.8 Juveniles/spat collection in the wild for culture and/or restocking purposes

Fry specialist fisheries are a traditional harvesting activity in the lagoon of Venice surroundings that provide seed for stocking the *valli* and therefore sustain extensive culture practices. Details on fishing, quantities and use can be found in Granzotto *et al.* (2001).

6.6.9 Genetic impact of restocking actions / escape events on wild stocks

See above, the reporting of the Nile tilapia in the lagoon of Lesina that can survive in this lagoon also in winter owing to the presence of some warmer areas where spring water is hot.

6.6.10 Impact of ichthyophagous birds (species, migration routes, entity of predation, bird control)

This impact is unanimously reported to be present in all Italian coastal lagoons, mostly to be ascribed to great cormorants. In the area of the Fogliano coastal lake, about 2 000 cormorants were estimated to be present, and 800 of them wintering there, but the impact of their presence on the fish community has not been directly estimated. The impact of their presence is remarkable also in the Orbetello lagoon, given the presence of about 2 500–3 000 wintering cormorants since 2000 (Ceccarelli *et al*., 2005). Cormorants are the greatest negative impact that fishers have to endure also in the lagoon of Lesina, with some thousands of birds every year that during the migration period can cause the loss of large quantities of product. Over 11 700 cormorants were recorded in the Sardinian wetlands in 1995 (Cannas *et al*., 1995).

Ichthyophagous birds have a strong impact in the area of the lagoon of Venice and in all the northern Adriatic area, mainly in relation to fish predation in the *valli*, and represent one of the main causes of product loss. Predation by ichthyophagous birds represents the main factor limiting fish productions in these extensive aquaculture situations. On the other hand, the presence of other water birds represents a main attraction in these same sites as preys for hunting.

6.7 Environmental considerations

A number of problems affect fisheries and aquaculture in coastal lagoons in Italy, and most are related to environmental constraints of these ecosystems. Most of these constraints are not recent, and have been extensively described (Ardizzone *et al.*, 1988; Marino *et al.*, 2009), but the resolution of environmental problems is not easy, probably because of a lack of integration between ecological knowledge and their rendering in strategies and plans related to lagoon management.

The functionality of many coastal lagoons depends on the interactions between anthropogenic impacts and natural phenomena, which may influence the ecosystem dynamics and affect the trophic status of the lagoon, influencing productivity and sometimes the conservation and even survival of lagoon living resources. The permanence and preservation of the lagoon system thus depends on the physical characteristics and the status of biological resources in the area (inside and outside the lagoon), but also on the human activities carried out to improve lagoon morphology, hydrology and trophic status in these coastal ecosystems. Periodic dystrophic phenomena are a natural occurrence for many lagoons and represent the main cause of aquatic fauna mortalities and loss of fish product (Izzo and Hull, 1991).

A major environmental issue is the increasing pollution from freshwater inputs to coastal lagoons, particularly heavy where the exchanges with the sea are reduced or absent. The 2005 Report of the Italian Ministero dell'Ambiente e della Tutela del Territorio defined the Orbetello lagoon, the Comacchio *valli*, the Po delta, the Lesina and Varano lakes and the Latium coastal lakes as sensitive areas (art. 18, D.Lgs. 152/99). At present, the trophic state of many Italian coastal lagoons is increasing as a result of inputs of organic pollutants. Among the stressors, nitrogen rather than phosphorus loadings seems to have increased over time (Vitousek *et al.*, 1997; Howarth and Marino, 2006). In well-managed lagoons, this situation can lead to a growing trend in fish yield (Kapetsky and Lasserre, 1984) as in the Orbetello lagoon, but only too often it leads to a dystrophic state with periodic mass mortalities (Ardizzone, 1985).

In some lagoons, increased eutrophication is due to aquaculture and agricultural activities, as well as the discharge of treated/untreated urban wastewater. This has brought about qualitative and quantitative changes in the vegetation. Changes from seagrasses (phanerogams) to macroalgae and macroalgal blooms have been widely observed in Italian coastal lagoons, sometimes coupled with microalgal blooms. When blooms impair the penetration of the light through the water column, preventing photosynthesis, anaerobic degradation of organic matters is triggered. Dystrophic crises often occurred in the past in the Orbetello lagoon and in deeper lagoons where water circulation is reduced in the water column: examples are the lagoons of Sabaudia, Fondi and Lungo (Ardizzone *et al.*, 1988), but also in shallower lagoons such as many Sardinian ponds.

Lagoons are ultimately under strong anthropogenic pressure from watersheds, as they receive freshwater input, rich in organic and mineral nutrients drained from heavily exploited catchments and from the surrounding urban and industrial settlements (see, for example, the Venice lagoon). Heavy metals (Cr, Cd, Cu, Pb, Zn, As, Hg) in both the upper and lower sediment layers (Franchi *et al.*, 2003; Giordano *et al.*, 2003) are some of the xenobiotic substances found in certain Italian coastal lagoons. PCBs have been found in eels from many coastal lagoons (Mariottini *et al.*, 2006; Bettinetti *et al.*, 2010). All these anthropogenic pressures are responsible for important ecosystem alterations, i.e. eutrophication, bacterial contamination, algal blooms (toxic or not), anoxia and fish mortality, and the possible presence of contaminants in fish.

Local stressors have also combined with global processes. The Intergovernmental Panel on Climate Change (IPCC) report (2001) predicts an annual temperature increase in the Mediterranean area of between 0.2 and 0.6 °C per decade, an increase in short and intense precipitations and a greater seasonal differentiation in precipitation, with an increase of up to 4 percent in winter and a decrease of up to 5 percent in summer. Further, additional problems are caused by coastal erosion, subsidence and effects related to extreme meteorological events, typical of Mediterranean areas.

The protection of piscivorous birds led to a considerable increase in their populations; in several regions they have reached a level at which they cause heavy economic losses to most coastal lagoon fisheries and extensive aquaculture throughout Italy. Predation by ichthyophagous birds, in particular cormorants, is a main effect when the fish are in the wintering ponds in the *valli.*

Overfishing in coastal areas has led to a reduction of natural fish recruitment to lagoons, and also to a reduced availability of seed for restocking, an important practice to sustain fish production in the *vallicoltura*. This is particularly true for eel, a species typical of Italian, and Mediterranean, coastal lagoons.

Other constraints, for example in Sardegna, are linked to a progressive loss of the capacity to manage water exchanges between lagoon and sea, which brings about consequences on the stocks of euryhaline fish species migrating between sea and lagoons.

Most lagoons in Italy suffer from the consequences of general environmental changes linked to coastal erosion, subsidence, extreme meteorological events recently amplified (wider precipitation levels between seasons).

Other sources of constraints are linked to market, such as competition with intensive fish production, lack of continuity in market supply compared with the intensive product, lack of specific labels adding value to lagoon products and an inadequate legislative framework.

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7. MONTENEGRO

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7.1 Introduction

The length of the Montenegrin coastline is about 300 km, of which about two-thirds (200 km) face the open sea and one-third forms (105.7 km) the Boka Kotorska Bay. There are only a few small islands in Montenegrin waters, with total island coast length of about 11 km.

The interior waters of Montenegro cover about 360 km^2, territorial waters (extending 12 nautical miles, or 22.22 km, from the coastline) about 2 000 km^2 and the epicontinental belt around 3 900 km^2. The total sea area of Montenegro comes to about 6 400 km^2. The Montenegrin shelf area is relatively narrow, extending only a few nautical miles in the northern part, in front of the Boka Kotorska Bay, but going over 20 nautical miles in front of the Bojana river estuary (Fig. 1).

Figure 1. Map of Montenegro

7.2 Generalities on coastal lagoons

There are only two coastal lagoons in Montenegro: Tivat Salina and Ulcinj Salina.

Table I: List of coastal lagoons in Montenegro

Name of lagoon	Geographic coordinates	Surface (ha)
Tivat Salina	E 18^0 42′ N 42^0 23′	150
Ulcinj Salina	E 19^0 19′ N 41^0 55′	1 492

The Tivat Salina is situated in the wetland part of the coastal strip of the Boka Kotorska (Tivat) Bay. The saltpan is divided up into pools, each of which is approximately 3 ha; with depth from 0.1 to 0.4 m. Tivat Salina is in contact with the Tivat Bay (part of Bokakotorska Bay) in the southern part of the Bay in a width of about 2 km. Connection with the sea is through the channels.

Tivat Salina, photo ©A. Joksimović

Near the lagoon is the city of Tivat, with about 20 000 inhabitants and tourist resorts Ivory Đuraševići, Island of Flowers and Brdište. Tivat Airport is located in the saltpan contact zone. On the east side of the lagoon, there are the slopes of Mount Vrmac (700 m) and not so far away the slopes of Mount Lovćen (1 750 m). Agricultural land has not been regulated, and is mostly covered with bushes. On the south side of the lagoon, at a distance of 3-4 km, there is an industrial area with several factories (furniture, toiletries and cleaning products industries). In the Bay of Tivat, coastlines and beaches are mostly rocky. In the Bay of Tivat, there is a small coastal fishery with fishnet-gillnets, beach seines, longline and small purse seines. The whole area of the Bay of Tivat is an interesting touristic destination, especially during summer (Saveljić, 2007, 2008; Regner *et al.*, 2005; Joksimović, 2006; Mandić, 2004.)

The wind blows throughout the year from the southwest (15 percent). Other winds such as from the north, northeast and southeast are equally present, albeit much less frequent (8 percent). The average of the strongest north and northeast winds has a mean intensity of 3.9 knots. The main current that flows in the surface layer during winter has different directions. In the eastern part of the Bay, dynamics are of negligible intensity. In the central part of the Bay, current speed ranges from 0.1 to 0.45 knots (5-23 cm/sec). Current flow is located near the coast of the northern part of the Bay at the Verige – Kumbor junction, with the highest density in the central part; on the southern coast the dynamics are of lower intensity (Čubrović, 2005). The Tivat salina receives water from two small rivers draining the Tivat fields- the Široka and the Kološun. The Tivat Salina is an Emerald site under the Bern Convention and an important bird area in Montenegro (IBA).

Special Nature Reserve in Tivat Salina,
photo ©A. Joksimović

The Ulcinj Salina is located in the southernmost part of Montenegro, in the region with the most sunshine on the Adriatic (2 567 hours) and the largest number of tropical days in this part of the Balkan peninsula. There used to be Zogajsko blato, "Zogaj mudflats" ("zog" meaning "bird" in Albanian language) in the area of the present Salina, a wetland with brackish water that began to be significantly influenced by anthropogenic infrastructural intervention in the late 1830s. Hydro-regulation of the Zogaj mudflats began in 1913, when the Port Milena drainage channel was dug. Thus, the Ulcinj Salina was created from the sea and represents a "cultural lagoon". The Salina is among the most important birds areas in the Adriatic: Velika plaža, Ada Bojana, the Šasko lake, Skadar lake and Velipoja (Saveljić, 2008).

The Ulcinj salina has a connection with the sea by the Port Milena channel. Around Salina are the Bojana River, Šasko lake and Skadar lake. The saltpan basins are surrounded by channels that drain the nearby swamps and depressions, taking the water into the Port Milena channel and thereafter into the sea (Saveljić, 2008).

In the vicinity of Ulcinj Salina, there is a town with 20 000 inhabitants and attractive beaches, the most famous of all being the Great Beach (12 km). On surroundings fields, agriculture (citrus, olives) and livestock developed. Near the town, there is the Bojana River, with the large tourist complex of Ada Bojana. On the River Bojana, as well as in the open sea, different activities of fishing, mostly small-scale fisheries, are represented (Borović *et al.*, 2000; Madić *et al.*, 2004; Regner *et al.*, 2005).

The temperature of the sea in Ulcinj from the beginning of May to the end of October exceeds 20°C. From October to March, this location has a rainy period with the highest rainfall in Europe. Winter temperatures do not fall below 5°C. The strongest winter wind is from the south. In Ulcinj, winters are mild, snow is very rare, and the air temperature is 10°C. The spring and early autumn are generally warm with moderate temperatures both in the air and in the sea (in spring temperature it is about 14°C while in autumn it is about 17°C).

The South Adriatic coast where Ulcinj is located is considered to be the cleanest sky area in the Mediterranean. The average annual humidity is 67 percent, except for July and August when humidity reaches 63 percent, but it is 71-72 percent in May and November, indicating the proper relationship of temperature and humidity. Mean annual rainfall, (rain only), is 134 mm/m².

The most characteristic winds are the north wind, south wind and the mistral. The north wind blows from the northeastern direction. and it is usually a cold wind blowing in the late fall and winter. Coastal winds such as sirocco blow in Ulcinj in the fall, winter or spring, and bring rain. The sirocco usually brings about big waves at sea. The mistral wind comes from the west - southwest. It is a pleasant wind that brings refreshment from the heat in the hottest summer hours. The highest intensity that mistral can blow at is 10 m/sec (Saveljić, 2008).

An important bird area in Montenegro (IBA) and Emerald site under the Bern Convention, Salina will soon be listed in the Ramsar List of Wetlands of International Importance. It is the first private natural park in Montenegro (Saveljić, 2008).

7.3 Living resources

7.3.1 Flora

The area of Tivat Salina is characterised by vegetation populating halophyte wetlands. These are primarily meadows of Salicornia and Limonietela, *Junicetalia maritime* and brackish water vegetation such as Phragmitetalia. The distribution of certain halophyte species participating to the construction of this vegetation in Montenegro is limited to this area and the Ulcinj Salina only. Therefore, the species registered for these two saltpans are protected by national legislation. List of important flora: *Salicornia fruticosa, Salicornia herbacea, Suaeda maritime, Limonium angustifolium, Scripus litoralis, Juncus acutus, Plantago maritime* (Savlejić, 2007).

Currently, 114 plant species have been described in the Ulcinj Salina. Besides open fields of halophytes (60 ha), there are more than 8 ha of *Phragmites reedbeds*. The dikes are no less interesting: meadows of orchids in the spring, mostly *Ophrys bertolinii* and *Orchis laxiflora*, give way to xenomorphic vegetation during the hot summer days. *Salicornia herbacea* is the dominant species in the Salicornietum herbaceae association, together with Sueda maritima, *Limonium angustifolium* and *Artiplex portulacoides*. In addition, the *Archocnemetum fruticosi* association is also sometimes recorded. Vegetation growing in the sludge of the Ulcinj Salina is mostly present in the channels where water and ground salinity are much lower. This vegetation is represented by *Narcissus tarzetta* and *Romulea bulbocodium*. Later in the year, these give way to *Avena barbata*, *Phragmites communis*, *Carex* sp., *Tripholium nigricens* and others. They are rather aggressive and have expanded more and more over the years, *Tamarix africana, Juncus acutus* and *Juncus maritimus* grow adjacent to the reeds. *Beta vulgaris ssp.* maritime is a species that in Montenegro lives only in the Ulcinj Salina (Saveljić, 2008).

7.3.2 Aquatic fauna

Crustaceans: Kanjoč, *Upogebia pusila* and 14 species of amphibians and reptiles are registered for the territory of Tivat salina. Ten vulnerable and three endangered species are on the IUCN Red list of endangered species. Species of particular interest protection in the Tivat salina are the Skadar frog, *Rana shqiperica* and the European legless lizard, *Ophisaurus apodus*.

Amphibians: Hyla arborea, *Rana shqiperica, Triturus vulgaris*

Fish species: *Mugil cephalus, Liza ramada, Chlelon labrosus*, *Atherina hepsetu, Diplodus puntazzo, Gobius geniporus* (Borović, *et al.*, 2000, Saveljić, 2008, Jokismović, 2006).

Reptiles: *Caretta caretta, Emys orbicularis*, *Ophisaurus apodus, Testudo hermani, Vipera amodytes*

In Ulcinj Salina, 23 economically important species are recorded: Mugilidae, *Liza Ramada, Liza saliens, Liza aurata, Chelon labrosus, Mugil cephalus,* eel, *Anquilla anquilla*, European seabass, *Dicentrachus labrax*, Atherinidae and Cyprinodontidae. In basins and channels where salinity increased (beyond 100 percent), only eels and killifish (*Aphanius fasciatus*) can be found (Borović, 2000; Mandić, 2004; Saveljić, 2008).

Twelve species of amphibians and 28 species of reptiles survive in the hot summer conditions of Ulcinj Salina. Amphibians barely survive in the salty or freshwater channels, where they are an easy catch for numerous birds. Along with numerous insects, these make the ideal food for the reptiles-unless they are eaten by birds themselves. Amphibians can hide in the high grass and in the numerous stone walls or cavities in the dikes (Mandić, 2004, Saveljić, 2008).

Brine shrimps, *Artemia salina*, are recorded in the Ulcinj Salina. Brine shrimp are used in food and in the pharmaceutical industry. More than 24 tonnes of this shrimp were present in 1999 in the lagoon (Mandić, 2004; Saveljić, 2008).

Some insects, such as *Oecanthus pellucens, Pteronemobius heydenii, Xya cf. variegata, Anacridium aegyptiacum* and *Locusta migratoria* are often present on dikes. Butterflies (Lepidoptera) are numerous in summer. Dragonflies (Odonata) are mainly found near channels or halophyte vegetation. However, keeping in mind the large areas under water, dikes and large vegetation cover, great diversity of ground and water insects is expected (Mandić, 2004; Saveljić, 2008).

7.3.3 Wildlife

Shallow salty water with fish and sludgy ground, and rich in benthic organisms, attracts water birds for feeding, wintering and resting during their autumn and spring migrations. Until now, 47 species of birds associated with water habitats have been registered in the Tivat Salina. Four of them are permanently present, approximately 35 are wintering and six are probably nesting. With other bird species such as passerines, raptors, a total of 111 species of birds have so far been registered in the Tivat Salina. However, the list is not even nearly complete because every year, a few new species for the area are registered. The number of birds present in this lagoon corresponds to 21 percent of the total species of European avifauna.

Nesting birds: *Alcedo attis, Actitis hypoleuctos, Cettia cetti, Charadrius alexandrinus, Rallus aquaticus.*

Wintering birds: *Anas penelope, Ardea cinerea, Charadrius dubius, Egretta alba, Egretta garzetta, Fulica atra, Galinago galinago, Phalacrocorax pygmeus, Tringa tetanus.*

Migrating: *Anas querquedula, Limosa limosa, Vanelus vanelus* (Saveljić, 2008; White, 2001; Sadoul, 1998).

Currently, 241 bird species have been registered in this "cultural lagoon", Ulcinj Salina, which is 50 percent of total bird species in Europe. Results of the IWC winter census, which has been performed since 1999 in the Ulcinj Salina, show the presence of 20 000 birds every year. Regarding the IUCN Red List of endangered species, Ulcinj Salina is a residence for one bird species –the slender-billed curlew, *Numenius tenuirostris*, which is critically endangered, and 3 vulnerable bird species: the Dalamatian pelican, *Pelecanus crispus*, the lesser white-fronted goose, *Anser erythropus* and the spotted eagle, *Aquila clanga* (Saveljić, 2008).

7.4 Land and water management

There are no management activities in the Tivat Salina. On the other hand, the Ulcinj Salina is filled with seawater. At the beginning of April, strong pumps (3 000 l/sec) start drawing water and pump it into shallow basins with an average depth of 20-30 cm. From the entry to the saltpans until crystallisations, the water travels several dozen kilometres and under the influence of the sun and strong wind it evaporates. From the initial 3.8 g/l salt, it reaches 235 g/l salt at the end of production (Savlejić, 2008).

7.5 Lagoon exploitation

There are no fishing or aquaculture activities in the lagoons. Fishers periodically manually collect a crab, locally called *kanjoč*, *Upogebia pusilla,* in the Tivat Salina. These crabs are used as excellent bait for longline fishing for sparids (Joksimović, 2006).

The only production of the area is the one reported from a shellfish farm just outside the Tivat lagoon, which probably has an influence on it. Its annual production of Mediterranean mussel is 40 tonnes.

The monitoring of birds populations, including ichthyophagous species and their interactions with fish populations, is placed under the responsibility of the Natural Protection Institute of Podgorica.

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8. MOROCCO

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8.1 Introduction

The Kingdom of Morocco is geographically located in the northwest of Africa. Covering an area of 710 850 km², it is bordered by Gibraltar Strat and Mediterranean Sea in the north, Algeria in the east, Mauritania in the south and Atlantic Ocean in the west (Berkat & Tazi, 2006). Its coastline extends over 2 934 km along the Atlantic coast and 512 km along the Mediterranean coast. In 2004, Morocco has a total population of about 29.6 million (HCR, 2004). Morocco has a variety of landscapes, from the desert to the mountains through the fertile plains.

The policy of international cooperation has resulted in the signing or ratification of a number of conventions and international agreements, among which those directly or indirectly related to the management of coastal areas. Several conventions are related to risks of marine pollution, seven of which are specific to the Mediterranean Sea. Morocco is a contracting party to the Barcelona Convention and is committed to the Action Plan for the Mediterranean (Morocco: country reports, 2011).

8.2 General information on coastal lagoons

Only one coastal lagoon, Nador, is located on the Moroccan Mediterranean coast, between "Cap des trois fourches" and "Cap de l'eau", the meridians 02°45' and 02°55'W and the parallels 35°16' and 35°06' N (Fig. 1). It is also known as "Mar Chica" (small sea) or "Sebkha Bou-Areg". Its surface is about 115 km², it communicates with the sea by a single gateway and has great fisheries and aquaculture potential. The Nador lagoon is listed as a site of biological and ecological interest.

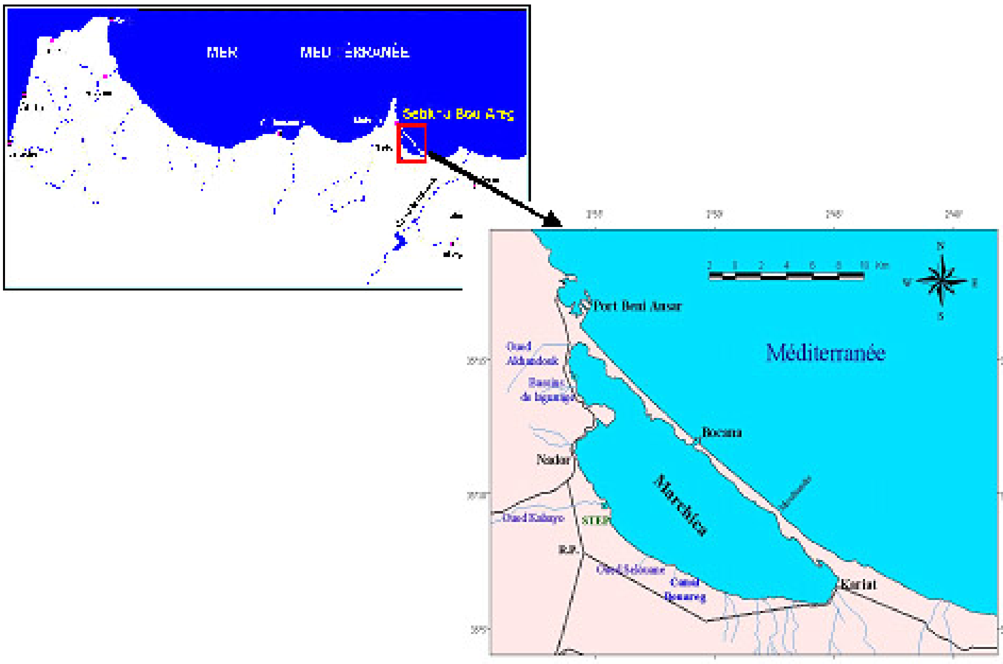


Figure 1. Nador lagoon – geographical location

Table I: Nador lagoon – General information

Name of lagoon	Country	Geographic coordinates	Surface (ha)
Nador lagoon	Morocco	02°45′ and 02°55′ W 35°16′ and 35°06′N	11 500

Competent authority	Ownership	Users
- Water and Forest Department - Marine Fisheries Department - Public Work Department	Marine Public Domain	Fishers, aqua-culturists, tourists

From the geomorphologic point of view, the Nador lagoon is a natural depression formed by the action of movement of subsidence and eustatic forces. It is a micro-tidal paralic environment with an oval shape and its main direction is northwest - southeast. In the northeast, it is separated from the sea by a 25 km long consolidated dunes strip (called lido), aged from the Pleistocene; while in the southwest, it is separated from the continental land by the Gourougo massif and the Bou-Areg plain. This very dynamic environment undergoes significant changes related to both marine and inland intrusions. The lagoon bathymetry ranges between 1 and 8 m, with a maximum located in the central part (Houssa & Abdellaoui, 2002). Its bottom is characterized by fine fractions predominance (fine sand, clay silt). More than 90 percent of the sampling points showed sand that contains some organic detritus and sandy mud rich in organic matter localized in the central lagoon part (Abdellaoui *et al.*, 2005).

In the past, the Nador lagoon was connecting with the sea through only one channel approximately 80 m wide. At the end of the 1970s, this channel was closed and a new 300 m wide channel was dug in the early 1980s. At the beginning of 2011, this communicating gateway was voluntary closed and a new one was opened in a closer area to ascertain sufficient exchanges between lagoon and sea. It is 300 m wide and is 6 m deeper; it is intended to improve seawater exchange and quality in this lagoon.

In recent years, increased urban development and population growth augmented the volume of wastewater that is unfortunately in most cases directly discharged into the lagoon (MedWetCoast, 2003). Wastewater treatment issues, increasing containment in the extreme areas and overall weak hydrodynamics have generated a long-term eutrophication, which could have a negative impact on ecosystem development and on its preservation.

The Nador lagoon belongs to the public maritime domain. The coastal dune separating the lagoon from the sea is part of the forest domain (private domain of the State). Resources are managed by the Marine Fisheries Department. The lagoon surface area was entirely allocated for aquaculture to Marost Company before its liquidation in 2006.

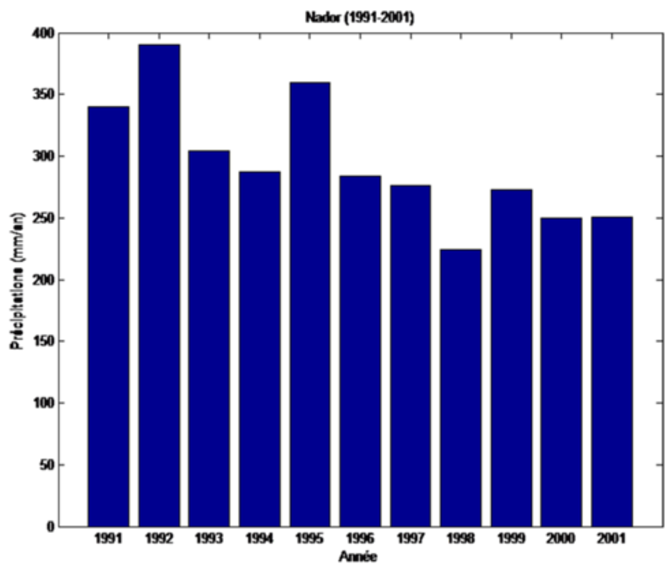
8.3 Physical and chemical characteristics of the lagoon

8.3.1 Climatology

Rainfalls: the Nador lagoon climate is part of the eastern Rif climate, which is semi-arid with a temperate to warm winter where the annual variability is particularly marked. Rainfall is low and much irregular, alternating between dry and wet periods. Over the period 1933-1963, the average BouAreg plain rainfall was 401 mm.

Temperature: Monthly air temperature averages ranges from 7 to 17°C in January and from 20 to 28°C in August. The minimum temperature is recorded in January (1°C) and the maximum in August (35°C).

Winds: The wind in the Nador region has two dominant directions: east-northeast to east from May to October and west-southwest to west between November and May.



The most important rivers around the lagoon basin are the Kabayo and Selouane rivers. According to Frisoni *et al.* (1982), the freshwater volume that reaches the lagoon is evaluated in 40–200.10^6 m^3/year provided by streaming and to 18.10^6 m^3/year provided by groundwater flowing. There are some water inputs coming from wastewater treatment provided by domestic wastewater city treatment plants of Nador, Beni Ansar and Kariat Arekmane.

Figure 2. Nador lagoon – Average annual rainfall over the period 1991–2001 (Arid et al., 2005)

8.3.2 Hydrology

Tides: As the general case in the Mediterranean coast of Morocco, the Nador lagoon tide regimen is mainly semi-diurnal (M2 type of period of 12.42 h). The most common heaves are those coming from east (21.3 percent), east-northeast (15.19 percent) and west (17.37 percent).

Seawater circulation:
Seawater circulation in the Nador lagoon is mainly related to the local dominant winds as shown in Figure 3. The double-ended zones of this lagoon seem always to be its most confined areas.

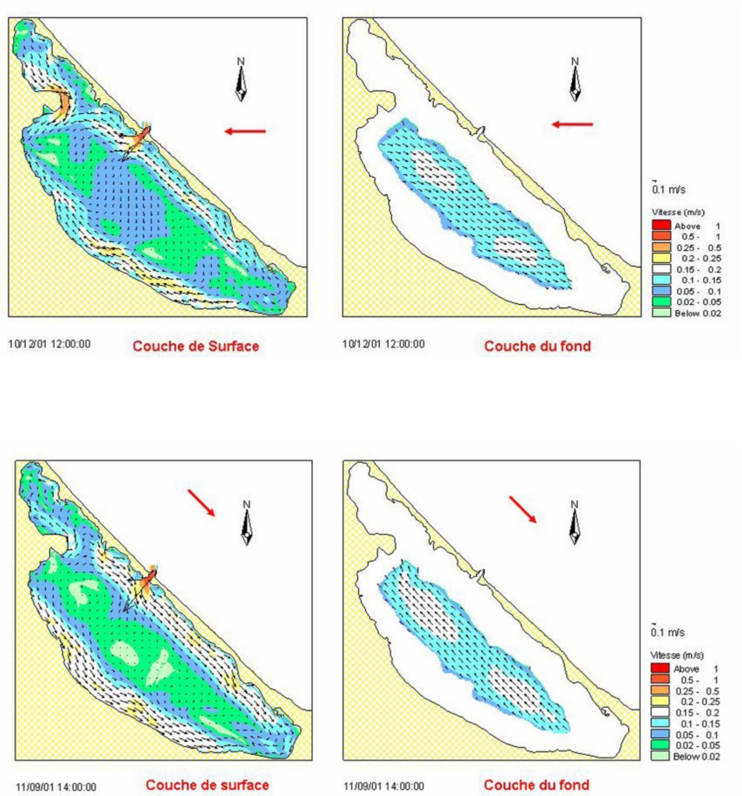


Figure 3. Nador lagoon – Three-dimensional seawater surface and bottom circulation (Hilmi et al., 2003, Hilmi, 2005).

8.3.3 Physico-chemical characteristics of the water column

Seawater temperature: Seawater temperature generally ranges between 18 and 26°C in winter and 25 to 30°C in summer. In the latter, mainly in July, temperature increase seems to support the metabolic activity of organisms and consequently allows more oxygen consumption in the summer time compared with the winter. The average concentration of dissolved oxygen is 12.4 mg/l in the winter and 4.8 mg/l in the summer.

Salinity: Nador lagoon salinity is typical of marine waters, ranging between 36 to 42‰, with higher values related to the containment areas near Beni Ansar village in the northwest of the lagoon and near the Kariat Arekmane village in the southeast of the lagoon.

Consequently, freshwater inputs coming from these two areas do not have significant influence over salinity. Freshwater is always localized in the northern part of the lagoon, near the lido.

Phosphates: Phosphate values vary on average between 0.001 to 0.02 mg/l in July and 0.3 to 0.4 mg/l in March. The highest values were recorded in the area near continental margin, near wastewater treatment plants and near aquaculture sites of Marost Company (up to 4 mg / l).

Nitrites: Nitrite values vary from a low of 0.01 to 0.1 mg/l in winter (March) and from 0.001 to 0.04 mg/l in summer (July). Inland waters are the main sources of nitrite. Even if the values remain very low for the entire lagoon, the highest concentrations were recorded near the continental margin. Irrigation water from the Bou-Areg plain appears as the main sources of this element. Surface waters are relatively richer in nitrite than bottom waters. This reflects the fact that the ammonium-nitrate transformation is usually happening on the water surface.

Nitrates: The maximum values of nitrates were recorded in the lagoon near the continental margin. In general, the nitrate levels in the lagoon are very high; an average of about 0.36 mg/l in the rainy season and 0.21 mg/l in the dry season. Surface waters are much rich in nitrate than bottom waters. Irrigation water from the plain of Bou-Areg and wastewater from Nador city are the main sources of this element.

8.3.4 Physico-chemical characteristics of the sediments

In terms of the hydro-lagoon system, although the freshwater and the transported continental materials during floods are rich in trace elements such as manganese, zinc, copper, lead, etc. (Tesson, 1977; Mahjoubi, 1991), the search of micro-pollutants (heavy metals) in the lagoon did not highlight the presence of these elements in the aqueous phase (Inani, 1995). Indeed, the physical and chemical characteristics of Nador lagoon seawater (including alkaline pH and organic matter abundance) do not favour the presence of these metals in the dissolved phase, which are generally in particulate phase or trapped in sediment by organic matter. Therefore, even if heavy metals seem to be unimportant in the aqueous phase (Inani, 1995), their transfer through the food chain components could have a potential impact in the areas most affected by discharges.

8.4 Living resources

8.4.1 Flora

The aquatic vegetation is characterized by endemic sea grass composed of eelgrass and Cymodocea. These habitats appear to host an important part of the Nador lagoon's biodiversity and play an important role in preserving its biological diversity.

8.4.2 Aquatic fauna

Biodiversity in the Nador lagoon is relatively high. According to Zine (2003), there are about 374 invertebrate species in this paralic environment. These species consist mainly of mollusks (211 species, including 108 gastropods and 92 bivalves), crustaceans (74 species) and annelids (44 species). Fish species totalized at least 77 among marine and lagoon species, with a large proportion of migratory forms (eel, sea-bass, white bream, grey mullets, etc.).

Among these significant elements of biodiversity, 24 species have an important economic value, and some of them have been already bred, cultured and grown in this lagoon. The most important species are: European flat oyster (*Ostrea edulis*), grooved carpet shell (*Ruditapes decussatus*), Pacific cupped oyster (*Crassostrea gigas),* Mediterranean mussels (*Mytilus galloprovincialis)* among bivalves; Mediterranean prawn (*Penaeus kerathurus*) and Japanese shrimp (*Penaeus japonicus*) among shrimps and gilthead sea bream (*Sparus aurata*), European sea bass (*Dicentrarchus labrax*), spotted sea-bass (*Dicentrarchus punctatus*) and snout sea-bream (*Puntazzo puntazzo*) among finfish. Three of these cultured species were introduced into the lagoon (Japanese prawn, Pacific cupped oyster and spotted sea bream).

8.4.3 Wildlife

The Nador lagoon is well known for its ornithological attraction. Species of birds frequenting this lagoon include dabbling ducks, flamingos and shorebirds. They are found in the containment areas (northwestern and southeastern lagoon-shores of the lagoon, salt marshes of Arkmane, Sansouires waters). Gulls make frequent moves between the sea and the lagoon; the latter is usually considered as a rest environment for these birds.

8.5 Land and water management

The Nador lagoon has often faced problems in closing its gateway. The latter has changed place due to strong storms or sometimes artificially performed by managing authorities. Recently, a new gateway was voluntary performed to stabilize lagoon/sea connection, promote seawater circulation inside the lagoon, attenuate the growing containment state in the extreme areas, limit hyper-salinity in the containment areas, reduce sedimentation and organic/pollutant load, etc. The new gateway was made in a canal shape 300 m wide and 6 m deep.

8.6 Lagoon exploitation

8.6.1 Aquaculture and capture fisheries

Aquaculture was promoted in the Nador lagoon by Marost Company with the support of the former Scientific Institute of Marine Fisheries (ISPM which became INRH since 1996) and MEDRAP (Regional project of FAO for promotion of aquaculture development in the Mediterranean). This farming company was founded in 1985; it carried out several aquaculture activities, particularly shellfish culture, finfish culture and shrimp culture including captive breeding, pre-growing and growing phases. Finfish culture was mainly focused on sea-bass and sea-bream (cultured in floating net-cages), shellfish culture on Japanese cupped oyster (cultured in longlines and fixed rafts), soft clam (cultured in peripheral lagoon parks) and shrimp culture on Mediterranean prawn and Japanese prawn (cultured in lagoon side-line pens).

Aquaculture sites were mainly limited to the Atayoun area (situated in the west center of the surface area of the lagoon) and in the surrounding area of the sea/lagoon connection. These sites were selected for their environmental characteristics, which were favorable to aquaculture. As Marost alone had the exclusive right to exploit the lagoon water surface, no one else could undertake any other activity except local fishers who were allowed to fish in non-cultured areas of the lagoon. However, since early 2006, when Marost ceased all its aquaculture activities in the lagoon, the latter was only been exploited by local artisanal fishers. A new fishing activity, algae harvesting, started in 2007. Twenty boats of a private Company (SETEXAM), specialized in algae processing and Agar production, were introduced to collect *Gracilaria* algae, which naturally grow in the Nador lagoon. This company also underwent some algae culture experimental trials in the lagoon with INRH technical support, though results were not so satisfactory.

A new investment program mainly focused on touristic development around the Nador lagoon started three years ago. Since 2009, the Marine Fisheries Department launched a study aiming at identifying suitable places for aquaculture with an environmental integration and sustainability purpose. The objective was to promote sustainable aquaculture activities based on local planning, taking into account environmental requirements and socio-economic constraints. Up to today, artisanal fishing is still the only activity carried out in the lagoon. Captured fish production is relatively important but there is also some artisanal shellfish fishing; this kind of fishing is less important and mainly concerns the collection of grooved carpet shell, knives and sometimes dates of Wed.

Facilities

Fishing gear

Three types of fishing gear are used by fishers in the lagoon: trammel nets, Palanza and beach seine.

Boats

Rowing/motor boats

The majority of fishers use outboard engines with a capacity ranging from 4 to 15 horsepower (hp) and an average age of 5 years. For those who own large boats, they use more powerful engines of 18 hp on average.

Buildings and infrastructures

There is a total absence of infrastructures related to fisheries on the Nador lagoon, with the exception of a small harbour (called Sidi Ali), located in the south side of the lagoon and used for artisanal fishery landing. There is a lack of road linking the sixteen undeveloped landing sites of artisanal fisheries surrounding the lagoon and a platform to sell or market the freezing chamber except at the great port of Béni Ansar.

Workforce, establishments and institutions

With the exception of the southern part of the lagoon, which is the urban city of Nador, basic infrastructures such as roads, electricity, water, education institute, fuel stations and hospitals are absent in the eastern part of the lagoon.

For all the municipalities surrounding the lagoon, the sector that occupies most human force is trade (28 percent), followed by government, education, health and social action (14.3 percent),services (14.1 percent), buildings and public works (12.9 percent), agriculture, livestock and fisheries(11.8 percent), trade and industry (11.4 percent) and other activities with 7.5 percent.

On the scale of rural communes, the sector employing more people is obviously that of agriculture, livestock and fisheries, while for the urban communities, trade is ranked the first and uses 32 percent and 27 percent of the working population in the municipalities of Nador and Beni Ansar respectively. The service sector employs about 23 percent and public administration nearly 16 percent, with little difference between the two municipalities (Nador and Beni Ansar).

Aquaculture and capture fisheries management

There were three hatcheries functioning in the Atayoun site (Marost), producing seeds of cultured species of fish (from 1989 to 2005), shellfish (from 1986 to 2004) and prawns (from 1987 to 1990). There were iron tables for oysters' suspended culture or for supporting fish culture nets. Also, there were floating net-cages for fish culture. When Marost was in operation, it used to have two important nurseries, one for shellfish spat pre-growing and another for fish fry pre-growing. No restocking, predator control or selective fishery were being carried out.

Shellfish raft culture was employed by Marost. This technique consisted in the use of iron tables, which were similar as to those used in the Thau lagoon in France.

According to Abdellaoui *et al.* (2006), Gracilaria beds were recorded to be developed and a collecting activity was undertaken in a few years, but there is now seaweeds control.

Except aquaculture in this lagoon waters and Marost hatcheries and nurseries, there were no intensive aquaculture activities in the surrounding lands.

Lagoon productions 1980–2010

Aquaculture

Gilthead sea-bream production: maximum production was achieved in 1994 of around 792 tons
European sea-bass: maximum production was achieved in 2005 of about 845 tons.

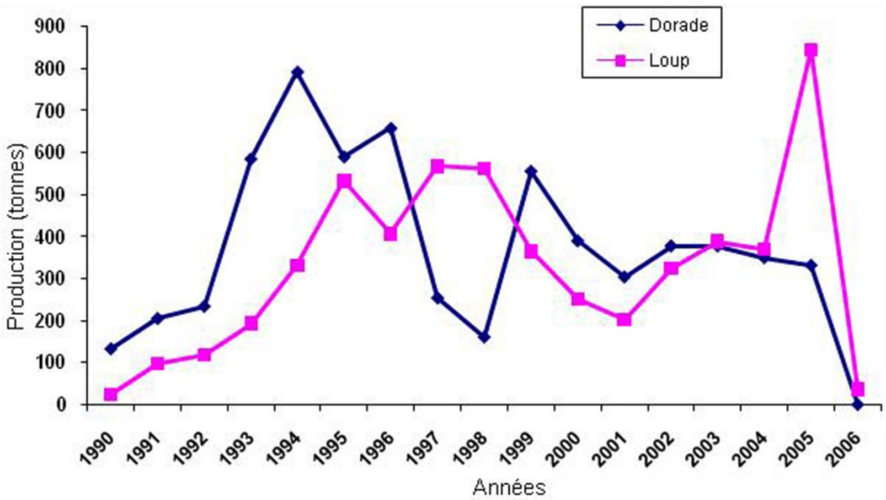


Figure 4. Evolution of aquaculture production of seabream and seabass in Morocco.
Source: Department of Marine Fisheries

Capture fisheries

Gracilaria: a single fishing season was carried out in 2007, for a production of 265 tons of wet seaweed during the period from July to September.

Caramota is a prawn of great commercial value. Almost all of its catch is destined for export, mainly through Melilla, for Spanish markets. Its total catch is about 20 tons (Malouli Idrissi *et al.*, 2003).

Other species such as octopus, breams and grey mullet are also caught and may have an economic interest for fishers.

Anchovy is a species that appears in this lagoon only during a specific period of the year, between November and January (Malouli Idrissi and Zahri, 2002; Malouli Idrissi *et al.*, 2003).

8.6.2 Other uses

Recreational activities (hunting, game fishing, wildlife observation, walking and trekking, boat tours, bathing and swimming, sailing and canoeing, lagoon products sales and restaurant).

Recreational fishing is a very common practice in the lagoon of Nador, particularly in the area of the gateway (sea-lagoon connection). Several species are caught, mainly breams (Gilthead sea-bream, white bream, bogue, etc.).

With the enhancement of Nador city, of the coastal lagoon area and of the roads, the construction of Nador international airport and the development of sightseeing boats, the lagoon started to be known as an attractive touristic site and attracts new tourism business investment.

8.7 Interactions among aquaculture, capture fisheries and the environment in coastal lagoon management

Interactions among different fishers groups and conflicts between fishers/fish farmers and public or private stakeholders

Aquaculture has been carried out in the period of 1985–2006 in the Nador lagoon by one farm (Marost), which mainly produces fish (sea-bream and sea-bass) but also, at lower extent, bivalves (flat oyster and European soft clam) and shrimps (Mediterranean shrimp and Japanese prawn).

Since the settlement of aquaculture activities in this lagoon, there were many complaints from artisanal fishers concerning the use and the exploitation of the lagoon water space. This conflict was resolved by the employment of fisher's families by the aquaculture farm.

Since the beginning of 2006, no aquaculture activity has been carried out any more in the Nador lagoon. Artisanal fishing became the main socioeconomic marine activity in this lagoon. It represents the only source of revenue for artisanal fishers.

Competition for space (location of aquaculture facilities in fishing grounds, existence of "planning management" for lagoon areas, etc.)

When Marost started its first aquaculture attempts, it was undergoing experiments in many areas of the lagoon. To do this, this aquaculture farm had the control on the overall lagoon space, which resulted in conflicts with artisanal lagoon fishers. Therefore, the location of culture facilities has then been established on a concerted basis between artisanal fishers and local authorities.

Product interaction on the market (product from aquaculture vs from capture fisheries; presence of private/ public label for fishery products)

The Nador aquaculture lagoon products were almost totally exported. A very low quantity was sold at the national level, exclusively in some specific markets of important cities, such as supermarkets and high standard restaurants.

Organic input from aquaculture activities

Many studies have been carried by the Farm Company as well as by Moroccan and foreign universities. Results have shown that there was an organic input detected in sediment analysis (Mahjoubi, 1991; Lefebvre *et al.*, 1997).

Moreover, wastewater has been discharged in this lagoon after gross treatment through an under-designed "lagunage" treatment unit. This could have contributed to the increase of organic matter in sediment. Recently, a wastewater treatment plant has been built and could help reducing the amount of organic matter in sediments in the Nador lagoon. Moreover, this lagoon is subject to a site cleanup and removal of hazardous solid wastes (such as plastic matter, etc.). These operations are carried out by the Marchica Agency with the support of the French Environment Fund.

Environmental effects of aquaculture and capture fisheries on biodiversity conservation

There are no official recorded data, but fishers reported that the presence of aquaculture facilities might have enhanced the multiplication of some captured species. This was observed through their fishing landings.

Juveniles/spat collection in the wild for culture and/or restocking purposes

The need of fish fry and shellfish spat for culture was produced by local hatcheries (Marost).

Impact of ichthyophagous birds (species, migration routes, entity of predation, bird control)

The Nador lagoon is known to be one of the famous sites on the north of Morocco in which many migratory aquatic birds winter. No data available of their impact on fish population.

According to Dakki *et al.* (2003), the composition of lagoon aquatic birds is dominated by diving (coots, grebes, cormorants, etc.), dabbling ducks and flamingos. Divers birds are often far from the lagoon banks; their location and density probably depend on the movement of food resources (fish, shrimp, etc.). Dabbling ducks, flamingos and shorebirds are concentrated in the containment areas (northwest and southeast shores of the lagoon, salt of Arkmane's saline, Sansouires river water). The gulls make constant trips between the sea and the lagoon, the latter usually constitutes a resting area where birds stand on water or on abandoned stakes in the former aquaculture sites. However, it is common to observe gulls and terns fishing. The sea beaches (and the adjacent dunes) are the usual resting places for gulls and feeding area for small waders. Ducks, shorebirds, herons, coots and moorhens frequent the lagoon and use some specific area during their nesting period.

Energy and other environmental factors

- Electric power is available along the lagoon shore, serving Nador city, Beni Ansar city, Kariate Arekmane village, and many other small urban agglomerations. Until now, it seems that there is still no need for alternative/eco-friendly power (Eolic and sunlight energy).
- Urban wastewaters are treated before rejection in the lagoon. Moreover, the latter is subject to site cleanup and removal of hazardous solid wastes (such as plastic matter, etc.).
- A great effort and investment were made to ensure urban waste treatments, packaging, advancement/ requalification/ rebuilding of natural/ public areas, etc.
- In the past, a collective effort was made to protect the lagoon area from petrol pollution generated from sea-sprit tanker accidents. Also, the regional delegates of the Fisheries Department and of the Equipment and Transport Department undergo controls on fishing boats in surrounding harbors.
- Before ceasing its activities, Marost released its stock of cultured fish species (sea-bream and sea-bass) into the lagoon. This operation had a significant impact on the increase of artisanal capture fishery in the lagoon.

A new gateway was constructed in November 2010 in the framework of the lagoon management programme, in order to facilitate the airworthiness and improve marine water exchange between the lagoon and the sea. This new gateway was opened on the lido while the old one, commonly called "*bokana*", was closed and converted into a marina harbor with two sides, one facing the sea and the other facing the lagoon.

The new gateway is 1.5 km from the old one. Its geographic coordinates are 35°12'29.4''N and 02°51'39.1''W. Its width is 300 m and its depth is 6 m. The scope of the dikes in the sea and inside the lagoon is 1.5 km long.

According to the Marchica Agency (a public institution created in 2010 with the aim of ensuring an ecotourism project development in the region in in a coherent and integrated manner),the new gateway reduces water velocity induced by the tides to a maximum of 2 knots against 4 knots recorded at the oldest gateway. It allows an increase in the exchanged marine water volume between the sea and the lagoon from 12 million m^3/day (through the old gateway) to 22 million m^3/day.

Moreover, the Marchica Agency intends to develop and enhance an ecotourism areas project of 20 000 hectares around the Nador lagoon, mainly in four neighboring municipalities (Nador, Beni Ansar, Bou-Areg and Kariate Arekmane). This project is generating a series of planned changes in the configuration in the lagoon to provide a series of eco-friendly infrastructures. The work of the agency, based on the respect and the preservation of the natural environment and of the lagoon's ecosystem, is intended to create a new tourism destination in the Mediterranean, thus providing an effective contribution towards sustainable economic and social development in the region.

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9. SPAIN

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9.1 Introduction

Spain has an area of 504 645 km², being the fourth largest country of the European continent after Russia, Ukraine and France. With an average altitude of 650 meters, it is one of the most mountainous countries in Europe. The Spanish population is around 47 million people, according to the municipal census of 2010 (INE, 2011).

The Spanish coast is 5 968 km long, 3 904 km along peninsular Spain, 910 km around the Balearic Islands, 1 125 km around the Canary Islands and 29 km in the African territories. Most of the Spanish coast stretches along the Atlantic shelf and oceanic ridge, partly constituted by the 359 km of the Cantabrian coast, whereas the Mediterranean basin has a coast 2 580 km long.

The waters of the Atlantic and Cantabrian systems are very dynamic, with currents, tides, waves, etc. and an average salinity of 35–36 percent, unlike the Mediterranean waters which are less dynamic, with negligible tides and higher temperatures with 37–38 percent salinity. In general, the temperature is warmer in the Mediterranean than in the Atlantic (Basurco B. & Larrazabal G., 2000).

The Mediterranean coast also has very contrasting features. The northeastern coast (Catalonia) has: small coastal plains, coasts with cliffs and some deltas. The eastern coast (Valencia) is characterized by the presence of a number of deltas stretching out into the sea, as well as sandy isthmuses linking small rocky islands to the mainland. There are also many coastal lagoons such as the Albufera of Valencia. The south-eastern and southern coasts (Murcia and Andalusia) are also much contrasted, with many cliffs alternating with long sections of low coasts, steep-sided torrential valleys and a narrow, almost continuous coastal plain. Mediterranean water temperature may range from 11 to 26°C.

Spain is a maritime country in which fishing is a traditional activity. It has one of the most important fishing fleets in the world, and contributes significantly to the national economy. The main data characterizing the sectors of fisheries and aquaculture in Spain is shown below:

Fishing fleet: In the latest data published in the 2009 census operational fishing fleet, the Spanish fleet among European countries represented in number of vessels 13 percent of the EU total, ranking at the third place after Greece and Italy; 80 percent of these vessels are inshore or traditional, more sustainable in principle (STECF, 2009).

Fish captures: Spanish fisheries production reached 1 020 908 tonnes in 2007 according to the European Commission data (European Commission, 2010), which represented 15.84 percent of EU countries total production.

Aquaculture: Spain is the main aquaculture producer of the EU with more than 280 000 tonnes, taking into account that most of it is mussels (European Commission, 2010).

Employment: With respect to employment in the fisheries sector, Spain, with more than 35 000 people in 2007, was the EU country with more jobs linked to the productive sector (European Commission, 2010).

Fish imports and exports: In 2007, Spain imported about 1 500 000 tonnes of fishery products and exported 934 793 tonnes, being one of the major importing countries in Europe (European Commission, 2010).

Fish consumption *per capita*: Regarding the consumption of seafood, Spain is the second country in the EU, behind Portugal, with about 41.2 kg per inhabitant per year, with the EU average being about 22.3 kg (European Commission, 2010).

Processing industry: In 2007, the processing industry in Spain generated a value of approximately 4 million euros, being the first country in the EU (European Commission, 2010).

9.2 General information on coastal lagoons

There are fourteen coastal lagoons in the Mediterranean coast of Spain, for a total surface of 58 695 ha[18]. In addition to these coastal lagoons, two other coastal lagoons from the south Atlantic coast of Spain should be added, due to their fisheries and aquaculture activity. It is important to highlight that all Mediterranean coastal lagoons in Spain are wetlands listed as Ramsar sites.

In the last century, the wetlands in Spain have undergone a major regression in size and environmental quality. It is estimated that 60 percent of Spanish wetlands have disappeared in the last 40 years (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2000). As a result, the SSPW is an instrument for the coordination and control of different actions for the conservation of these ecosystems:

a) Guarantee the conservation and wise use of wetlands;
b) Integrate conservation and wise use of wetlands in sectoral policies (water, coastal, land use, forestry, agriculture, fisheries, etc.);
c) Contribute to the fulfillment of the agreements, directives, policies and European and international agreements associated to wetlands.

The Strategic Plan highlights the need to develop and keep an updated Spanish inventory of wetlands to improve the knowledge on these and enhance the conservation of biodiversity. In 2004, the Spanish Government published the Spanish Inventory of Wetlands, where 237 wetlands covering an area of 164 493 ha were identified (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2000).

Inventory data show that most Spanish wetlands are inland waters (92 percent), although they do not reach 14 percent of the total surface. Coastal wetlands occupy 86 percent of the total area, notably: the marshes of the Guadalquivir, the Bay of Cadiz, the Ebro delta, the Mar Menor, the Albufera of Valencia and the marshes of the Empordà. This inventory includes coastal lagoons, but the Murcia and Catalonia regions, where there are significant wetlands and lagoons areas, are not considered.

As a complement, Spanish Mediterranean regions have their respective inventories or catalogs of wetlands, which are:

Region of Andalusia: Inventory of Wetlands of Andalusia (Junta de Andalucía, 2004).
Region of Murcia: Wetlands and *Ramblas* in the Region of Murcia (Comunidad Autónoma de la Región de Murcia, 2003).
Region of Valencia: Catalog of Wetlands of Valencia (Generalitat Valenciana, 2002).
Region Catalonia: Inventory of Wetlands of Catalonia (Generalitat de Catalunya, 2005).
Region of Balearic Islands: Technical Report to characterization, classification and inventory of Wetlands in Balearic Island (Govern de les Illes Balears, 2007).

The coastal lagoons present in the Spanish regions of Andalusia, Murcia, Valencia, Catalonia and the Balearics are analyzed hereafter.

[18] This surface has been calculated from data extracted from the sheets of each Ramsar site. In some cases such as the Ebro delta, this area is not the same as the water surface of lagoons, and therefore, the total area of the Mediterranean coastal lagoons in Spain could be less.

Spanish coastal lagoons develop diverse activities, among which are fisheries, shellfish and aquaculture. Estuaries, deltas, lagoons and other coastal wetlands provide protected habitats rich in nutrients that fish use as spawning, nursery or habitat areas.

In the next figure are shown all the coastal lagoons in the Mediterranean coast and some in the south Atlantic coast, included in the Ramsar list in Spain by the Ministry of Environment, Rural and Marine Affairs.

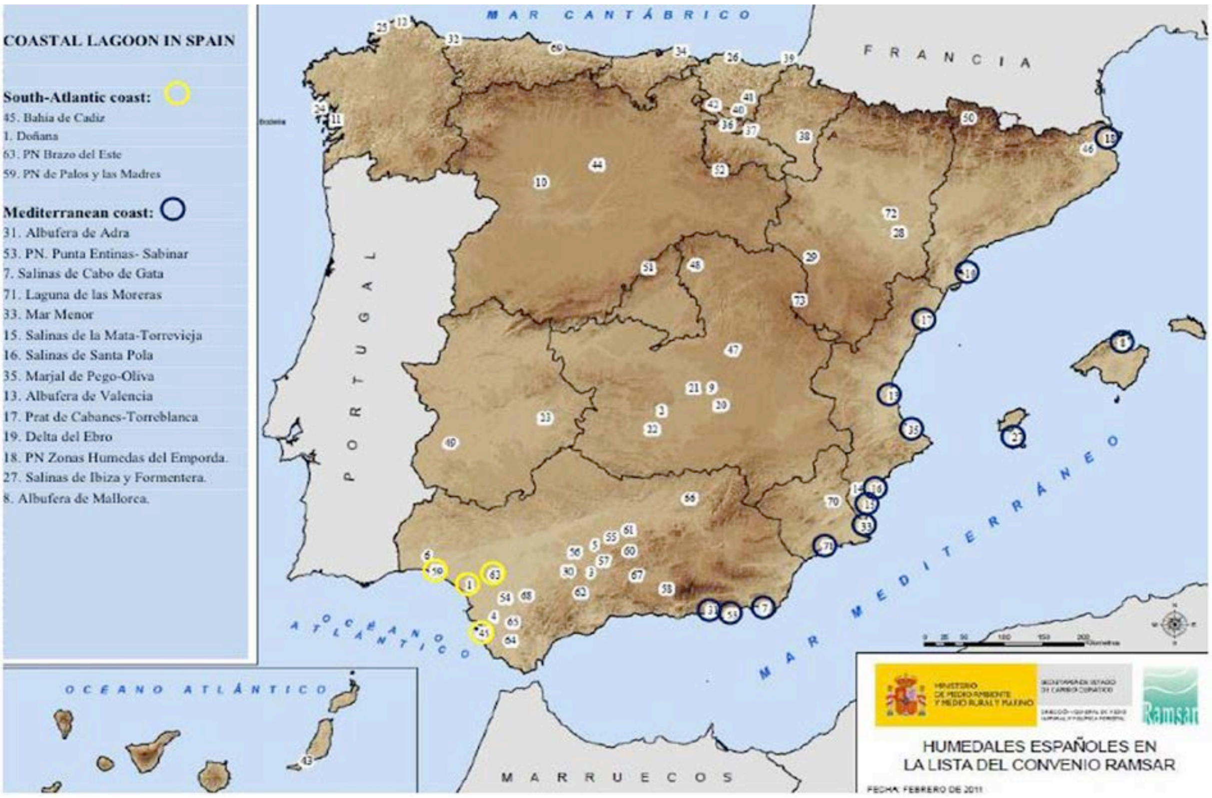

Figure 1. Geographical location of the wetlands in Spain. Mediterranean and South Atlantic area (Source: Ministry of Environment, Rural and Marine Affairs)

The following table shows Mediterranean Spanish coastal lagoons, by geographic area and by county and region, included in the Ramsar list.

Table I: Spanish Mediterranean coastal lagoons included in the Ramsar Convention

	Region	County	Nº Ramsar	Surface (ha)	Lagoon[19]	Type by Ramsar criteria
Mediterranean	**Andalusia**	Almeria	448	300	Salt marshes of Cabo de Gata	Marine-Coastal: E, J Artificial: 5
			704	75	Albufera of Adra	Marine-Coastal: H Artificial: 3
			1 677	1 948	Natural Place Punta Entinas-Sabinar	Marine-Coastal: E,J Artificial: 5,7
	Balearic	Ibiza/ Formentera	641	1 640	Salt marshes of Ibiza and Formentera	Marine-Coastal: A,D,E,H,J Artificial: 5
		Mallorca	449	1 700	Albufera of Mallorca	Marine-Coastal: F, H Artificial: 4.5.9
	Catalonia	Tarragona	593	7 736	Ebro delta	Marine-Coastal: A.B,E.F,G,H,J, E.F,G,H,J Artificial: 1.3.4.5.9
		Gerona	592	4 730	Natural Park wetland Area of E´mpordá	Marine-Coastal: A,E,H,J,K Artificial: 3,4,8,9
	Murcia	Murcia	706	14 933	Mar Menor	Marine-Coastal: E, J Artificial: 5
			30	72.6	Lagoons of Moreras	Continental: N Artificial: 6
	Valencia	Alicante	456	3.7	Salt marshes of La Mata-Torrevieja	Marine-Coastal: J Artificial: 5
			457	2 496	Salt marshes of Santa Pola	Marine-Coastal: D,H Artificial: 5
		Castellon	458	812	Prat de Cabanes-Torreblanca	Marine-Coastal: E,K Artificial:
		Valencia	454	21 000	Albufera of Valencia	Marine-Coastal: E, K Artificial: 3
		Valencia/ Alicante	708	1 248.7	Marjal of Pego-Oliva	Marine-Coastal: K Artificial: 3.5
Total surface in hectares				**58 695**		

[19] Some of these coastal lagoons are individual and others areas such as the Ebro delta, where there are eight lagoons on site, include other lagoons. Therefore, the number of lagoons could be larger, but this has been adopted as a criteria.

Table II: Spanish South Atlantic coastal lagoons included in the Ramsar Convention

	Region	County	Nº Ramsar	Surface (ha)	Name of lagoon	Type of lagoon by Ramsar criteria
Atlantic Area with Mediterranean	**Andalusia**	Cadiz	1265	10 000	Bay of Cadiz	Marine-Coastal: A,D,E,G,H Artificial: 1,5
		Huelva/ Seville	234	111 646	Doñana	Marine-Coastal: A,E,F,G,H Artificial: 1,3,5,7
		Seville	1675	1 362	Natural Place Brazo del Este*	Marine-Coastal: F, H, J Artificial: 3.4.9

* Near this wetland and within PN Doñana is located "Veta la Palma", considered in the context of this report as an example of management and ecological value.

Legal framework

At the State level, there are different legal and strategic instruments that establish the importance of wetlands (and coastal lagoons) and the need for conservation.

Water Law 29/1985 establishes a definition of wetland, the need for inventory and delineation, development of management plans, inclusion in the public inland waters (both surface and groundwater), natural channels, the beds of lakes and reservoirs and underground aquifers, and provides for the protection, restoration and wetland creation.

Law 4/1989 on Conservation of Natural Areas and Wildlife also provides for the establishment of a national inventory of wetlands with protective measures in the river basin. Coastal Law 22/1988 aims at the identification, protection, use and policing of maritime-terrestrial domain and especially the seashore.

Among the strategic and planning instruments with an implication on wetlands are the future National Hydrological Plan and the National Irrigation Plan, the various Basin Water Plans, the National Forest Strategy, the Spanish Strategy for the Conservation and Sustainable Use Biological Diversity and the White Paper on Environmental Education in Spain (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2000).

At the regional level, there are numerous instruments and initiatives for the conservation and wise use of wetlands, incidence variable by region. Among them are many legal rules that consider wetlands protection.In addition, several regions developed or are developing wetland inventories or catalogs, as is the case of Andalusia, the Balearic Islands, Castilla and León, Castilla-La Mancha, Catalonia, Extremadura, Galicia, Madrid, Murcia, Navarra, Basque Country and Valencia.

In the Spanish Mediterranean area, within the framework of the Barcelona Convention and the Action Plan for the Mediterranean (MAP), the *Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean* was adopted in 1995, which establishes the need for special protection measures for endangered animals and plants in the Mediterranean, as well as of areas considered vital to their survival.

Moreover, the Specially Protected Areas of Mediterranean Importance (SPAMI) was created to ensure the protection of, *inter alia*, the coastal areas of high ecological importance and those that contain representative ecosystems, including several coastal wetlands. The Resolution of Barcelona for the Environment and Sustainable Development in the Mediterranean Basin was adopted in 1995 as a tool for implementing the second phase of the MAP, the Barcelona Convention and its Protocols.

Most of the information reported below is derived from data of some Mediterranean coastal lagoons selected as case studies, for the presence of fishing activities or aquaculture in them and in addition, two lagoons located on the Atlantic area but with an obvious Mediterranean climatic influence were included.

The origin, typology and characteristics of Spanish lagoons are very diverse, and in some cases, these lagoons are coastal ecosystems where water management has created a privileged habitat from an ecological and environmental viewpoint.

Spanish lagoons on the Mediterranean climatic influence zone are extensive areas of tidal influence where the transformation and land management has led to the permanent flooding of the space, creating lagoon systems of great ecological value.

In the other side, several small and medium coastal lagoons areas are found along the Mediterranean Spanish coast, from the French border down to the Atlantic limit in the southwest, and have different typology, uses and human activities interrelation.

From Atlantic lagoons to the Ebro delta lagoons, located in the north Mediterranean coast of Spain, all are influenced by the Mediterranean climate. Only the existence of tides gives different characteristics to the Atlantic coastal lagoons. So, in Mediterranean lagoons, tides are typically small, with amplitudes of up to 30 cm, which undoubtedly means that the renewal and flood capacity of the lagoons is low and depends on other meteorological factors, such as heavy rains and storms (Ramsar, 2012).

The capacity of water renewal is normally managed by gates that store water in the rise of tides, and water retained or disposed of in the fall of the tide. The existence of this phenomenon undoubtedly contributes to greater biological richness and a greater potential for the exploitation of aquatic resources.

All Spanish lagoons show a great richness and diversity, and provide foraging and shelter for birds, making these ecosystems increase their ecological value.

In Spain, all coastal lagoons are protected by some environmental "protection scheme", with a different level of activities allowed. Strong modifications and the intervention of human activities along the Spanish coasts partly explain why there is a relatively low number of lagoons.

Regarding the geomorphology of the coast, the Atlantic sector is characterized by a low-gradient continental platform, with large areas of wetlands and large rivers flowing into the sea, while the Mediterranean area is characterized by a steeper sloping platform, a coastline with low presence of large rivers and estuaries and some coastal lagoons, Albuferas and the Ebro delta, as is illustrated in the previous geographical table.

With regards to the extension of the case studies areas, two magnitudes should be taken into consideration: on the one hand the surface of the protected areas as a whole and on the other hand the extent of the lagoon within them. In most cases, lagoons are usually a small part within protected areas.

In general terms, the surface of the Spanish lagoons is very small, ranging from the 235 acres of some lagoons in the delta del Ebro, to 15 000 ha of the Mar Menor. Except for the Doñana wetland, which has a larger surface area, the average remaining lagoons is approximately 4 355 ha (Ramsar, 2012).

Regarding the origin or entry of water in the lagoons, almost all tend to have freshwater input and other inputs from salt or brackish water. The percentage of each of these, i.e., the quantity and quality of water, is usually related to water management systems. Water features are related to the origin of water sources in the lagoons. In general, the type of water in the lagoon is mixed, and the degree of dominance will be related to rainfall, storms and to hydrology. The lagoons physical characteristics will depend ultimately on the use and management, and there is a direct relationship between the use for aquaculture and fisheries and the water state of conservation of it.

The presence of an important fish community should be linked to good conditions for aquatic life and the existence of fishing activity somehow reflects the health of the lagoons. In general, the lagoons receive inputs of freshwater usually from rivers and sea inputs.

Depth depends on the lagoon type, hence in areas such as Atlantic lagoons where there was a transformation of land for the development of aquaculture, the average depth is around 1m, while the depth in lagoons of the Ebro delta or Albuferas is minimal, ranging of 30-50 cm. Mar Menor is the deepest lagoon because in reality it is a bucket of geological origin, and so has distinct hydrological and environmental conditions (Ramsar, 2012).

Salinity varies according to the amount of seawater received annually. However, salinity ranges are much higher in shallower as the "Albufera" or the delta lagoons. In general, lagoons in the Mediterranean have higher values of salinity as a consequence of lower depth and more evaporation.

The connection with the sea in the coastal lagoons is essential for the water renewal and the entire lagoon ecosystem. In those lagoons where the connection with the sea is greater, the amount and diversity of aquatic resources is bigger too.

All lagoons are connected with the sea. Regarding drainage water, all collected water runoff and some aquifers are located around the lagoons; the level of this contribution is closely related to the annual rainfalls and the presence of aquifers.

9.3 Living resources

9.3.1 Flora

The coastal lagoons flora depends on the type of water and physical and chemical conditions. Because each coastal lagoon has its own characteristics and is generally different in water inputs, hydraulic management and human handling, differences exist between the main species in each lagoon.

Vegetation in Spanish coastal lagoons varies with salinity and depth and permanence of the water. The flora is composed of submerged aquatic plants adapted to salinity (halophiles) as *Najas, Ruppia, Althenia, Zannichellia, Elatine or Callitriche*, hydrophytes floating leaves as *Ranunculus peltatus* or amphibian as *Eleocharis parvula* (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2005). In the lagoon surroundings there are formations linked to soil moisture, and thickets of succulent Chenopodiaceae *Arthrocnemum*, Sarcocornia or Suaeda in mosaic with *Salicornia europaea* as a pioneer halophilic and other annual, or rushes, less halophilic, or even masegares, sword-signals and reeds in nearly sweet water (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2005)

Channel in Albufera de Majora, photo ©PNAlbufera, 2011

9.3.2 Aquatic fauna

In coastal lagoons freshwater, brackish and marine species live, depending on the percentages of the water type received at each location.

Typical marine species are gilthead seabream, European seabass, grey mullets, European eel, meagre and others more specific of the local zones. Brackish water species are grey mullets, eels, shrimp, red crab; and freshwaters species are carp and salmonids (Ramsar, 2012).

It should be noted that a number of valuable wildlife species, cited by Pardo L. (1942), are now extinct in some areas, and among them are the fartet (*Aphanius iberus*) and the samaruc (*Valencia hispanica*). Both are endemic Iberian-Levantine with a very restricted distribution of certain wetlands on the Mediterranean coast. In the case of samaruc, its distribution is further restricted, and it is now relegated to a few small wetlands around Valencia. Both species are very beneficial to man, being large-eating mosquitoes (Culicidae). Until the 1920s, they were often sold as aquarium animals.

9.3.3 Wildlife

Spanish coastal lagoons are important wintering and staging areas for migratory populations of water birds. Birds are the most representative group of fauna. The highlight is the greater flamingo (*Phoenicopterus ruber*), a true specialist in the salt marshes and coastal lagoons, which obtains its food by filtering the water with its beak, or the common avocet (*Recurvirostra avosetta*) and common stilt (*Himantophus himantophus*), wading with their long legs the shores in search of their prey (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2005). No endangered mammalian species are recorded.

9.4 Land and water management

In general terms, almost all the lagoons are public ownership and public management, except some Atlantic lagoons (10 percent) and the Ebro delta (18 percent), where areas are also private property and other privately managed.

On this point, it is important to examine the role of water management in the lagoons with regard to their sustainability and protection. In most cases, almost all wetlands examined have some kind of environmental protection, however these places are not always available for use and management plans.

These plans are essential for an integrated management of the lagoons, as in addition to protection they are important to take the resources and their use into account, and all this is closely related to the type of property and the system management.

In lagoons where water management is performed through private gates, the rate of renewal is quite high. At the end, the management of land and water in the lagoons is an important aspect for achieving sustainability of the lagoons, and for proper water management it is necessary to provide intervention plans and being responsible for these.

The management of water will depend heavily on the maintenance work and hydraulic performances that are made. However, when these proceedings depend on public statements, the maintenance of the lagoons tends to be minimal, while if a private party is involved in the management, interests are different and the level of action to the maintenance of the lagoon much higher.

Hydraulic works and maintenance of these zones is essential for lagoon sustainability, and regardless of who owns or whom the responsibility to preserve and maintain the lagoons is on, a plan of action should be referred to and followed. However, these types of measures are rarely present in the Spanish Mediterranean lagoons.

All this is linked to the activities carried out in the lagoons surroundings and to the priorities in economic management. Thus, in areas where agriculture plays a large role in the local economy, water management is closely related to this activity, such as the Ebro delta, the Albufera of Valencia or the Albufera de Mallorca.

It is important to emphasize that when there is a lack of water management in a lagoon, the contribution of fisheries for the local economy is minimum, while in lagoons with handling of water (normally associated to private management), the quality of the aquatic environment and the quantity of fish resources is much greater. This occurs mainly in Ebro delta and in Atlantic lagoons with Mediterranean influence, especially Bay of Cadiz.

Therefore, lagoon quality is a limiting factor for fisheries productivity; hence water management becomes a priority for the local communities that live around the lagoons. The Mar Menor is in an intermediate position, where water management in the lagoon only depends on meteorological and oceanographic conditions.

However, in general terms, there are a number of risk factors linked with the management in Spanish lagoons, generally related to the habitats that affect animal communities (Ramsar, 2012), such as:

- Tourism caused the transformation of natural areas into urban areas, often with no good planning;
- Agriculture activities need space and sometimes cause the land desiccation;
- The creation of industrial zones have seriously affected, among other factors, coastal dynamics;
- Water pollution from urban and industrial waste and shipping;
- Drying and transformation of marshes and salt marshes; and
- Construction of communication routes that have encouraged silting.

9.5 Lagoon exploitation

9.5.1 Aquaculture and capture fisheries

The contribution of lagoon capture fisheries to fish production in Mediterranean coast is minimum and meaningless, as the presence of fisheries and aquaculture activities in coastal lagoons is generally poor, except in South-Atlantic lagoons with Mediterranean influence, where the linkage to aquaculture allowed improves the sustainability of these lagoons. The development of aquaculture in the latter lagoons mainly contributed to the flooding of these areas, which has favoured the creation and maintenance of wetlands.

Fishing in Bay of Cadiz, photo ©Ctaqua, 2011.

Fishing gear

Several types of fishing gear are used in Spanish Mediterranean coastal lagoons, and can be distinguished into three groups:

- Fixed traditional gear such as "Pantene" is used in the Ebro delta and other fixed gear are like labyrinths that will drive the fish into a central lagoon as Encañizadas used in the Albufera of Valencia. These types of fishing gear are not much used today, and their use is almost exclusively for recreational activities. Another traditional gear but not fixed is the "ganguil" in the Albufera of Valencia.

- Other types of small traditional fishing gear include networks like traps, trammel nets, or encircling nets used in ponds, canals or small areas to accumulate the fish.
- Longlines are only used in the deepest areas of all lagoons, but are mainly used in the Mar Menor (Valero Palmero, 1972).

Most of the current fishing activities in Spanish lagoons are carried out without the help of boats, which were more common when the lagoons were deeper and had more fishing activities. Therefore, except for Mar Menor, where there is a small fleet of smaller gear, and the Albufera of Valencia, where there are usually no motor boats, in the other lagoons only very small boats are present.

Currently, in the Albufera of Valencia there is an ordinance regulating the register of ships of the Albufera lagoon.

Employment and institutions

The number of jobs linked to the exploitation of aquatic resources in the Mediterranean coastal lagoons is a highly complicated exercise due the scarcity of activity, which influences the lack of statistics data.

An important fact to keep in mind is that the coastal lagoons analysed are located in five different regions or autonomous regions. Aspects related to the management of these lagoons are placed under the responsibility of five different regional governments.

The main area with employment associated is Ebro delta, where the work force is usually linked with fishing, and the number of people directly related with fisheries in coastal lagoons since 1985 are 36 (Generalitat de Catalunya, 2014). Aquaculture employment is still carried out as a complement of fishing, and few in number.

Nevertheless, it is true that time ago when the activity was greater, there were cooperatives that organized and sold the catch, such as the Cofradia of El Palmar in the Albufera of Valencia or the Cofradia of San Carlos de la Rapita in the Ebro delta.

The level of association linked directly with fisheries in lagoons a long time ago was high, and although a number of these organizations maintain their links with the fisheries world in the lagoons, it is minimal at present.

South Atlantic area

The employment generated in South Atlantic lagoons is linked to the aquaculture activity or maintenance of the salt marshes and Esteros. There are 200 jobs linked to the development of aquaculture, and specifically around 80–90 with extensive aquaculture (artisanal fisheries) in this area (Junta de Andalucía, 2010). On the subject of fisheries work force, there are 252 shell-fishing (on foot) licences in the Bay of Cadiz and there are other important fisheries groups that working in areas closeby. In addition, in the Bay of Cadiz, there is an important fishing force: the recreational marine fisheries. The Regional Agriculture and Fisheries Authority regulates this activity and normalizes the issuance of licences of recreational marine fisheries.

Aquaculture and capture fishery management

The management of coastal fisheries and aquaculture in Spain depends in most cases on a Regional Government that has competence in activities such as agriculture and fishing.

However, responsibility for environmental protection is often associated to other different authorities such as the Environment Ministry, and this situation means that, although there is a strong control over the protection of these areas, there is little follow up on the catches of aquatic resources, mainly because these are activities of little importance.

Therefore, the most common situation is that the regional government with responsibility for fishery catch has all the information available for capture fisheries, shellfish harvest and aquaculture, while the regional government with responsibility for the Environment only has information in the environmental field.

Fish production

Fish production in the lagoons has dropped significantly over the last 20-30 years to very low levels. The production in the lagoons of the south-Atlantic area is mainly linked to extensive aquaculture, while the production of lagoons (225.45 tonnes in 2010) in the Spanish Levant is entirely from seasonal wild catch (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2010).

The major species in almost all the lagoons are primarily marine and brackish, with some presence of freshwater species, especially in lagoons as the Ebro delta, where freshwater inputs are higher.

The main species are gilthead bream, seabass, grey mullet, eels and species of freshwater carp and fartet (*Aphanius iberus*).

The three species with the highest percentage of production in Spanish lagoons are the grey mullets, seabream and seabass, followed by eel and carp. According to statistics analysed by the various ministries of fisheries in the different Spanish regions, it could be extracted that these five species represent over 80 percent of production.

The following tables and figures show production of capture fisheries in different Mediterranean Spanish coastal lagoons. As shown in the table as in the graph, the main species captured in the Mediterranean lagoons are eel, seabream, seabass and grey mullet. It is important to note also the catches of elvers in some lagoons like the Albufera of Valencia, the Ebro delta and the Albufera de Mallorca.

Table III: Fish production in Mediterranean lagoons (tonnes) main species (1980–2010). Source: Ministry of Agriculture and Fisheries in Regional Governments of of Murcia, Valencia, Catalonia and Balearic Island, 2010

Year	Eel (*Anguilla anguilla*)	Gilthead seabream (*Sparus aurata*)	European seabass (*D. labrax*)	Grey mullets	Elvers (*Anguilla anguilla*)	Carpa (*Cyprinus carpio* and *Carassius carassius*)	Sole	Other species	*Atherina boyeri*
1980	44.8	0.5	4.5	22.2	3.8	20	0	0	0
1981	44.4	0.5	9.7	28.6	3.9	5	0	0	0
1982	32.2	0.2	4.6	15.6	2.9	21.8	0.3	0	0
1983	40.6	1	7	30.5	4.1	16.2	0	0	3.1
1984	28.4	1	9.4	14.5	4.5	12.5	1.2	0	1.1
1985	18.3	1.2	1.1	12	0.7	16.6	0	0	1.1
1986	31.6	2.2	3.8	12.3	5	3.1	0.4	0	1.2
1987	8.9	0	0	0	4.2	0	0	0	0
1988	6.9	0	0	0	2.5	0	0	0	0
1989	22.3	0.4	6.5	19	2.4	2.9	0.1	0	0.6
1990	19.6	1.4	8.7	30	1.8	0.6	0.2	0	1.5
1991	22	5.2	3.3	15	1.1	0.2	0.4	0	0.1
1992	18.3	0.2	14.8	12.3	1	6.6	0.1	0	0.2
1993	16.2	2.7	6.3	9.7	0.6	2.2	0.6	0	0.4
1994	17.4	4.3	15	18	0.4	2.8	0.1	0	1.5
1995	11.5	7.3	8.4	20	0.7	2.2	0.1	0	2
1996	17.8	26	3.5	7.5	0.8	2.6	0.8	0	0.6

Year	Eel (*Anguilla anguilla*)	Gilthead seabream (*Sparus aurata*)	European seabass (*D. labrax)*	Grey mullets	Elvers (*Anguilla anguilla*)	Carpa (*Cyprinus carpio* and *Carassius carassius*)	Sole	Other species	*Atherina boyeri*
1997	14.3	3.7	9.5	16	1	1.7	0.7	0	2.4
1998	14.7	2	8.8	15.2	0.5	6	0.2	0	0.1
1999	13.5	2.1	6.1	33.5	0.1	1.7	0.1	0	0.4
2000	32	4.6	9.6	12	1.3	4.4	0.5	0	0.2
2001	23.3	5.1	7.9	16.5	1	3.7	0.2	0	2
2002	15.5	3.9	10.1	15	1.5	2.1	0.5	0	10.5
2003	12	1.1	3.3	8.6	0.5	7.2	0.3	0	0.3
2004	12.2	3.8	7.3	21.1	0.2	4.8	0.2	0	0.1
2005	42	68.7	9.7	24.2	0.4	16.7	0.2	61.2	0.5
2006	22.7	73.7	3.3	7.3	0	1	0	59.7	0
2007	35	75.8	18.7	20.3	0.3	20.4	0.8	64.2	5
2008	46.2	112	6.8	26.7	0.4	4.3	1	51.4	3
2009	44.3	77.2	17.4	27.6	0.4	2.8	0.6	68	0.8
2010	34.8	75.1	19.3	19.6	0.35	2.2	0.3	72.7	1.1

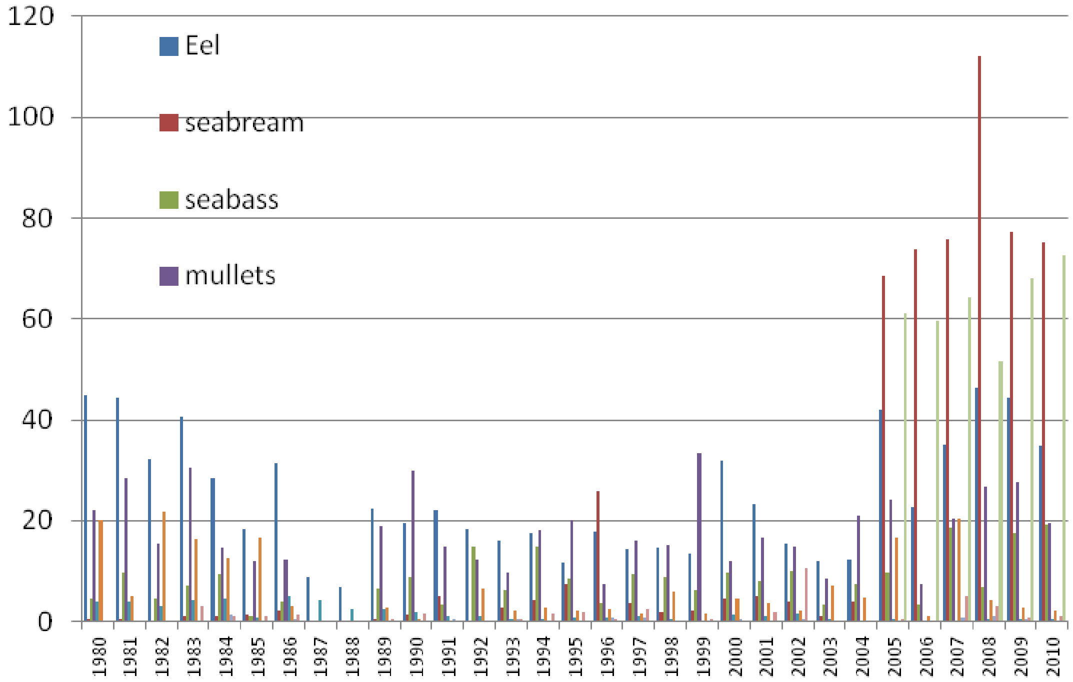

Figure 2. Fish production in Mediterranean lagoons (tonnes) main species (1980-2010) (Source: Ministry of Agriculture and Fisheries. Regional Governments of Murcia, Valencia, Catalonia and Balearic Island, 2010)

The production from capture fisheries in the lagoons located in the South Atlantic area of Spain is important to emphasize the volume of captures and maintenance over time.

Table IV: Fish production in South Atlantic lagoons (tonnes) main species (1987–2010) (Source: Andalusia Regional Government. Ministry of Agriculture and Fisheries)

Year	Eel (*Anguilla anguilla*)	Gilthead seabream (*Sparus aurata)*	European seabass (*D. labrax*)	Mullets	Sole (*Solea solea*)	Meagre (*Argyrosomus regius*)	Others species
1987	73.6	117.7	26.7	14.2	9.5	3.2	0.9
1988	76.6	117.7	3.2	14.2	9.5	3.2	0.9
1989	8.3	21.1	4.0	24.8	12.8	0.1	17.5
1990	4.7	16.7	2.7	43.7	10.7	0	0
1991	7.1	885.2	8.9	94.7	9.6	0	12.1
1992	18.8	66.3	3.1	44.3	13.7	0	1.2
1993	5.8	110.8	15.2	15.5	12.3	9.8	9.8
1994	8.7	294.1	42.1	121.7	19	1	9.8
1995	16.1	1577.6	74.8	122.2	17.5	1	2.7
1996	35	3225.5	31.4	98.4	16	7	18.2
1997	23	1864.8	100.2	173.4	10.5	0	7.2
1998	16	1556	209.5	157.5	11.9	0	11
1999	25	1497.6	164.2	190.2	18.8	1.5	2.7
2000	16.1	1847.6	205.8	133.3	7.8	6	5
2001	34	1427.5	376.3	112.5	19	0	9.3
2002	21.4	1167.9	432	86.4	16.3	0	10.7
2003	22.1	1079.8	541.6	107.2	9.5	0	7.7
2004	23.7	1252.5	509	119	15.2	0	5.4
2005	21	884.1	382	108	2	0	1.1
2006	19.5	1066	564.6	135	3	0.6	5.4
2007	15.9	628.5	662.5	131.3	7.4	2.2	2.7
2008	12	4	552	98	0	6	0
2009	11.8	2	559	98.5	0	26.5	0
2010	10.2	1	656	95	0.2	14.5	0

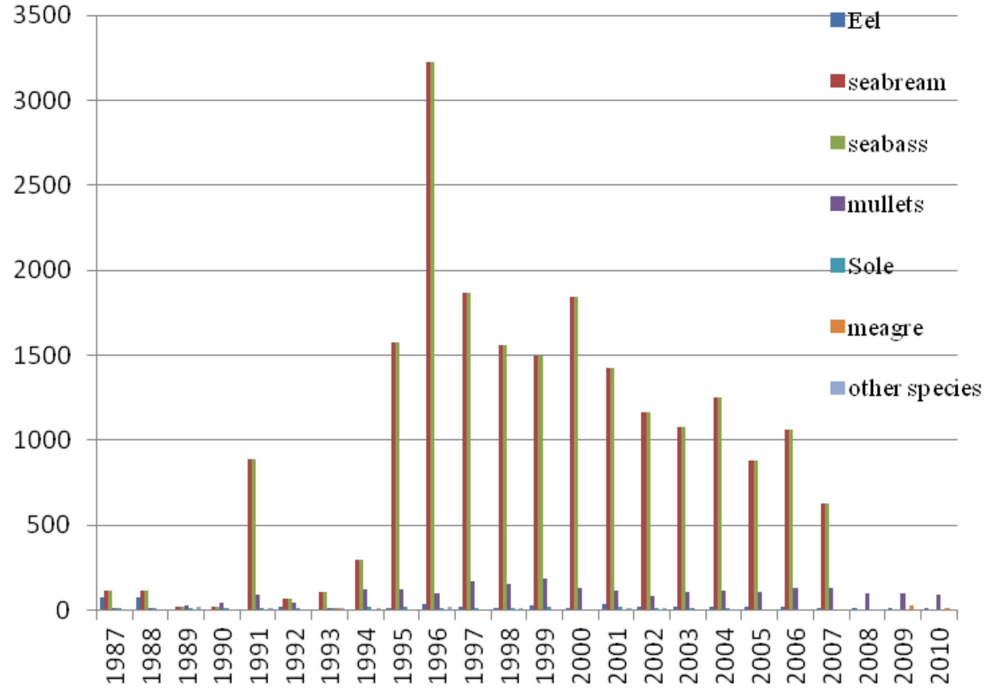

Figure 3. Fish production in South Atlantic lagoons (tonnes) main species (1987–2010). Source: Andalusia Regional Government. Ministry of Agriculture and Fisheries.

Table V: Crustacean production in South Atlantic lagoons (tonnes) main species (1987–2010).Source: Andalusia Regional Government. Ministry of Agriculture and Fisheries.

Year	*Penaeus kerathurus*	*Palaemon sp.*
1987	3.4	0
1988	2	0
1989	0.7	0
1990	7.2	17
1991	5.1	61.9
1992	1	111.2
1993	1.1	130
1994	1.6	90
1995	0.8	110
1996	1	136
1997	1.3	177
1998	0.2	163
1999	0.3	100.8
2000	0.1	165
2001	0.3	82
2002	0.1	85
2003	0.8	86.1
2004	1.2	61.3
2005	0.2	65.5
2006	0.4	75.1
2007	0.5	65.2
2008	0	68
2009	0	88
2010	0	75

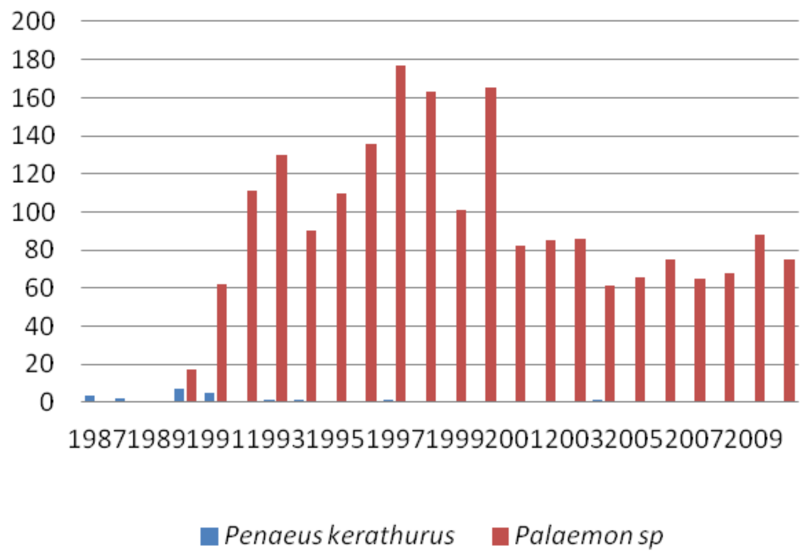

Figure 4. Crustacean production in South Atlantic lagoons (tonnes) main species (1987–2010). (Source: Andalusia Regional Government. Ministry of Agriculture and Fisheries)

Table VI: Mollusc production in South Atlantic lagoons (tonnes) main species (1987–2010) (Source: Andalusia Regional Government. Ministry of Agriculture and Fisheries)

Year	Japanese carpet shell (*Ruditapes philippinarum*)	Pacific cupped oyster (*Crassostrea gigas*)
1987	4	4.9
1988	8.5	4.9
1989	10.4	0
1990	20.8	12
1991	13.9	2.5
1992	10.9	13
1993	22.4	15.6
1994	15.2	21.5
1995	27.2	21.6
1996	20.4	24.5
1997	20.1	24.4
1998	13.4	21.3
1999	7.2	14.8
2000	14.6	19.7
2001	10.8	21
2002	14	14.2
2003	9.2	72.4
2004	7.5	15.5
2005	5.9	12.1
2006	2.9	16.4
2007	2.1	10.5
2008	0	0
2009	0	0
2010	0	0

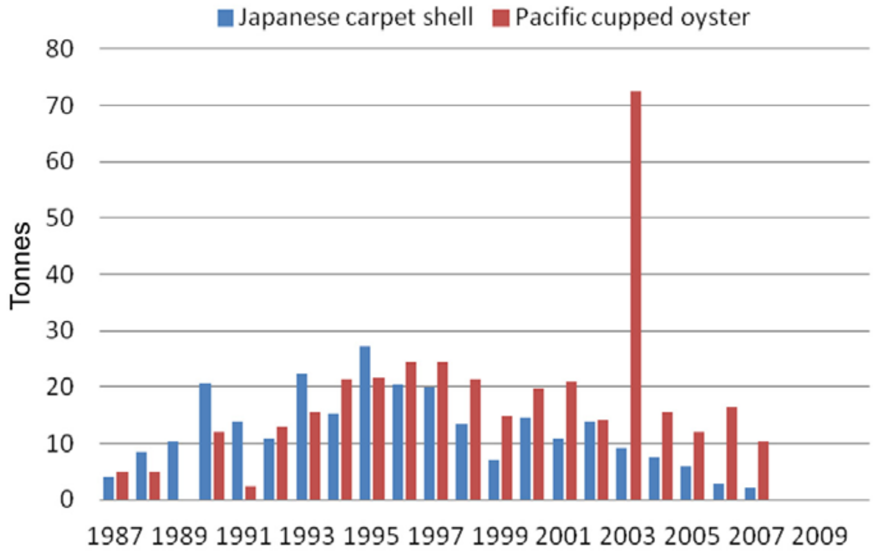

Figure 5. Mollusc production in South Atlantic lagoons (tonnes) main species (1987-2010). (Source: Andalusia Regional Government. Ministry of Agriculture and Fisheries)

Aquaculture production directly linked only with the South Atlantic lagoons is approximately 2 000 tonnes as annual average. This represents about 30–35 percent of aquaculture production in the Andalusia region, where these lagoons are located. Nonetheless, total aquaculture production in Spain reached 280 000 tonnes in 2010, taking into account mussel production (216 000 tonnes); therefore, without mussels, production would be approximately 60 000 tonnes (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2010).

However, if it an analysis in the Atlantic lagoons was to be made, the contribution of aquaculture production obtained is about 40 percent from the production of aquaculture in Andalusia, and therefore in regions where the lagoons are taking advantage for aquaculture activities, their contribution to the aquaculture sector is important.

Table VII: Aquaculture- Fish production in South Atlantic lagoons (tonnes) main species (1987–2010) (Source: Andalusia Regional Government. Ministry of Agriculture and Fisheries)

Year	Seabream (*Sparus aurata*)	European seabass (*D. labrax*)	Sole (*Solea solea*)	Meagre (*Argyrosumus regius*)	Total
1987	95.1	23.5	0.0	0.0	0.12
1988	95.0	23.5	0.0	0.0	0.12
1989	220.0	53.2	0.0	0.0	0.27
1992	798.1	70.2	0.0	0.0	0.87
1994	798.1	75.2	0.0	0.0	0.87
1995	970.0	102.0	10.0	0.0	1.08
1996	1.400.0	71.6	14.0	0.0	1.49
1997	1.420.0	25.0	0.0	0.0	1.45
1998	1.410.0	0.0	0.0	0.0	1.41
1999	2.622.0	0.0	0.0	0.0	2.62
2000	1.363.0	8.0	8.0	0.0	1.38
2001	1.217.0	10.0	0.0	0.0	1.23
2002	1.344.0	11.4	0.0	0.0	1.36
2003	1.585.0	8.8	0.0	0.0	1.59
2004	1.284.0	18.4	0.0	0.0	1.30
2005	1.017.0	9.0	0.0	0.0	1.03
2006	933.0	4.1	0.0	35.4	0.97
2007	1.042.0	9.7	0.0	1.6	1.05
2008	833.0	50.0	0.0	0.0	0.88
2009	1.057.0	16.0	0.0	0.0	1.07
2010	617.0	6.0	0.0	20.4	0.64

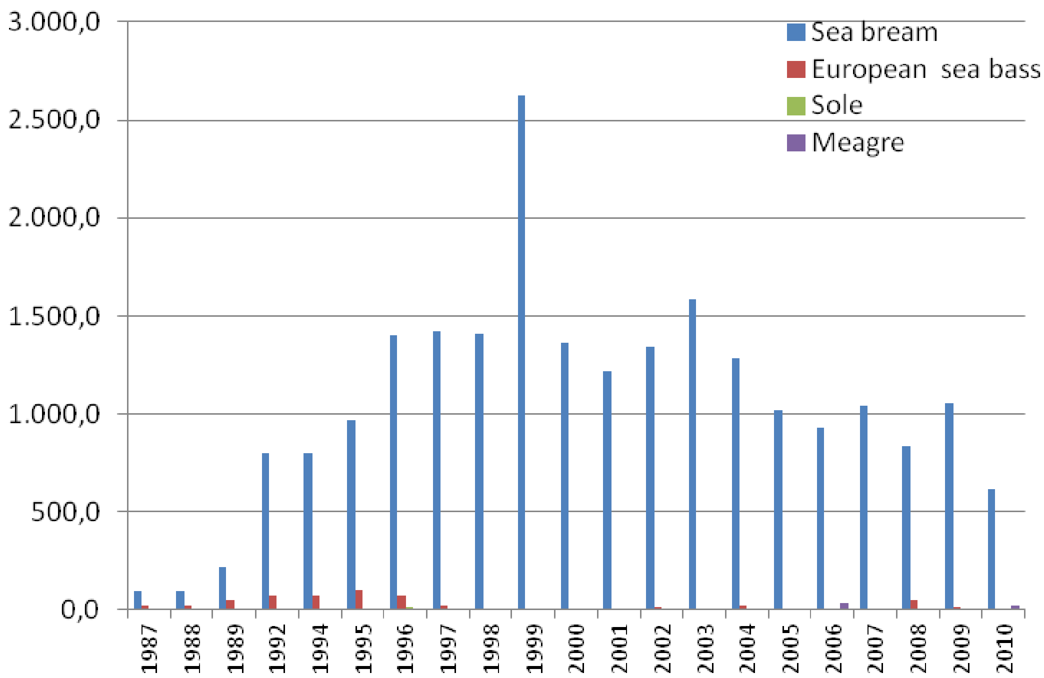

Figure 6. Aquaculture – Fish production in South Atlantic lagoons (tonnes) main species (1987–2010) (Source: Andalusia Regional Government. Ministry of Agriculture and Fisheries)

Table VIII: Aquaculture – Shellfish production in South Atlantic lagoons (tonnes) main species (1987–2010)
(Source: Andalusia Regional Government. Ministry of Agriculture and Fisheries)

Year	Carpet shell (*Ruditapes decussatus* and *phillipinarum*)	Pacific cupped oyster (*Crassostrea gigas*)	Total
1987	6.0	32.0	32.0
1988	12.0	3.3	15.3
1989	15.7	0.0	15.7
1992	31.3	8.0	39.3
1994	20.9	1.7	22.6
1995	16.4	8.7	25.1
1996	33.6	10.4	44.0
1997	22.8	14.3	37.1
1998	41.4	14.4	55.8
1999	30.6	16.3	46.9
2000	30.1	16.2	46.3
2001	20.1	14.3	34.4
2002	10.8	9.8	20.6
2003	21.9	13.1	35.0
2004	16.2	14.2	30.4
2005	21.3	9.4	30.7
2006	13.8	4.8	18,6
2007	11.3	10.3	21.6
2008	8.9	5.5	14.4
2009	4.4	10.9	15.3
2010	3.2	7.0	10.2

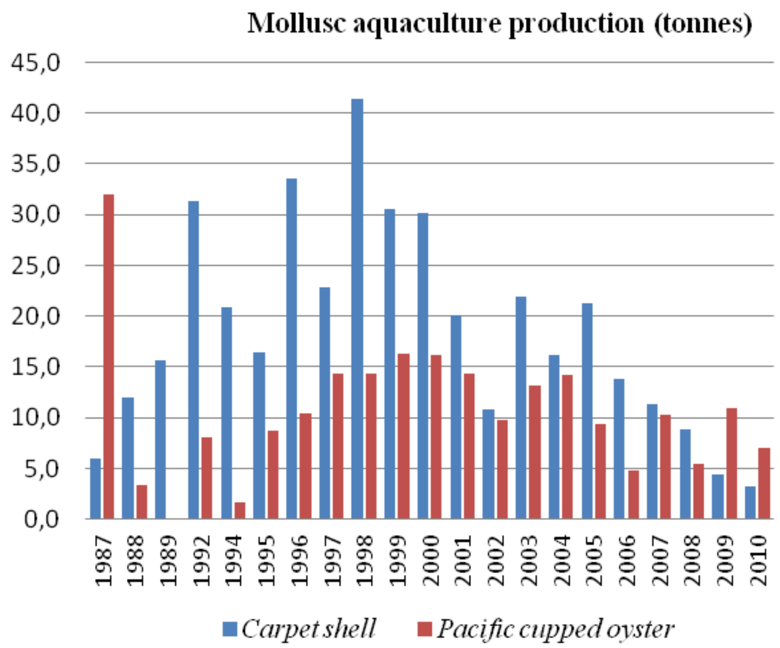

Figure 7. Aquaculture-Shellfish production in South Atlantic lagoons (tonnes) main species (1987–2010) (Source: Andalusia Regional Government. Ministry of Agriculture and Fisheries)

Table IX: Aquaculture – Crustaceans production in South Atlantic lagoons (tonnes) main species (1987–2010)
(Source: Andalusia Regional Government. Ministry of Agriculture and Fisheries)

Year	*Penaeus kerathurus*	Total
1987	2.3	2.3
1988	1.2	1.2
1989	0.5	0.5
1992	4.8	4.8
1994	3.5	3.5
1995	0.7	0.7
1996	0.7	0.7
1997	1.1	1.1
1998	0.6	0.6
1999	0.7	0.7
2000	0.9	0.9
2001	0.3	0.3
2002	0.4	0.4
2003	0.1	0.1
2004	0.4	0.4
2005	0.0	0.0
2006	0.8	0.8
2007	10.0	10.0
2008	0.2	0.2
2009	0.2	0.2
2010	0.3	0.3

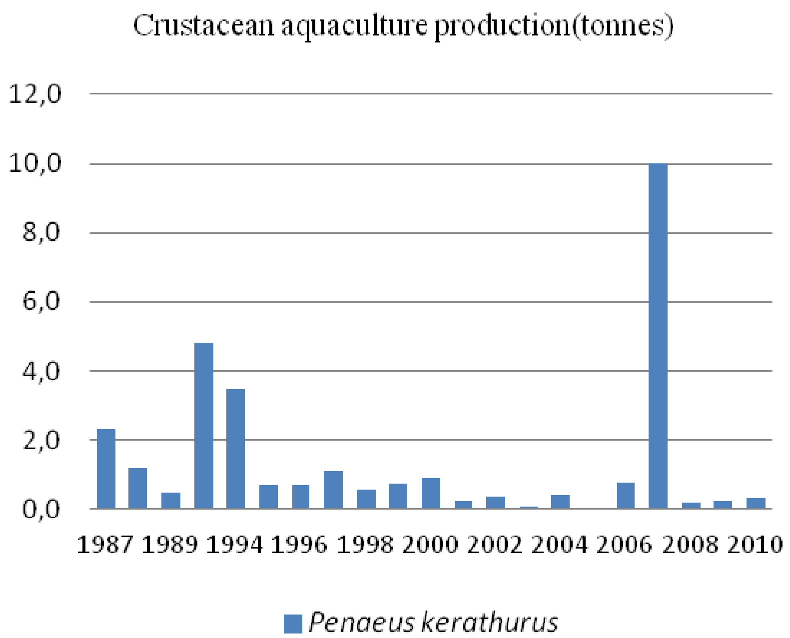

Figure 8. Aquaculture – Crustacean production in South Atlantic lagoons (tonnes) main species (1987–2010) (Source: Andalusia Regional Government. Ministry of Agriculture and Fisheries)

As a conclusion, the contribution of catches of fish, molluscs and crustaceans from the Spanish

Mediterranean lagoons to national fisheries production is almost negligible (total annual production of 225 tonnes in 2010). It reflects the low degree of exploitation of aquatic resources and the scarcity of fishing in the lagoons, which in turn might be a symptom of the state of these ecosystems.

9.5.2 Other uses

The uses identified in the surroundings of the Mediterranean lagoons are usually very similar, with dominant agriculture and the presence of villages, populations, cities, transport and communication infrastructure, etc.

It should be noted that in the past years, activities related to ecological or environmental tourism have proliferated, especially bird watching, which undoubtedly contributes to increase the value of these ecosystems, and also to promote the protection of them, this being an asset of the place.

9.6 Interactions among aquaculture, capture fisheries and the environment in coastal lagoon management

9.6.1 Interactions between commercial and recreational fisheries

Some recreational fishing is carried out in the surroundings of some coastal lagoons as the Albufera of Valencia and parts of Ebro delta, but there are no strong interactions with commercial fisheries. In any case, licences and authorizations are necessary for recreational fishing.

Recreational fishers sometimes sell their products on the local market, which represents a competition for commercial fishing. In the Mar Menor, both forms of fishing also coexist, but they are regulated and require licences.

In almost all these areas there are sports fishing associations, the aims of which are primarily recreational, and which have a weak control over catches.

9.6.2 Interactions among different fishers groups and conflicts between fishers/fish-farmers and public or private stakeholders

In some lagoons, sometimes there are people who are developing recreational fishing and shellfish harvest without authorization and consequently there is no registry of their catch and its relative value. Moreover, there are no associations defending the interests of the sector in marketing the product and fishers sell their production directly to consumers (individuals, restaurants, local fish markets, etc.). This generated major conflicts with authorized commercial fishers.

South Atlantic area

In south Atlantic lagoons, fish is stolen inside the culture facilities and the lagoons. This type of actions is common in the Bay of Cadiz, where the theft of fish by people is a rather serious problem affecting the viability of the companies exploiting the lagoons in some cases.

Illegal fishing steals the aquaculture productivity and they damage economic production and production processes.

9.6.3 Competition for space

In general, there is no competition for space, but what there is the need to improve the use of space. Some sites, which are protected as natural parks, have a planning management and zoning based on conservation and environmental protection of their ecological values through the management of their uses. Each one of the areas has a degree of protection to manage space, through authorizing compatible activities. Both lagoon management and government control are very strong due to environmental protection.

9.6.4 *Product interaction on the market*

No significant interactions occur between the products of fishing and aquaculture, as they usually are different species and sizes. Both types of products are well differentiated in the fish market and each product has its own market.

As coastal lagoon fisheries and aquaculture provide very small productions, they do not cause disturbances or instability in the market.

9.6.5 *Organic input from aquaculture activities*

For the extensive or semi-intensive aquaculture activities carried out in lagoons do not produce wastewater rich with organic substances; only in some areas where aquaculture activity is more intense, for example in the Bay of Cadiz, wastewater flowing out of aquaculture facilities is controlled and monitored by the environment authorities.

However, considering the production levels, they will not generate significant organic inputs. In any case, wastewaters in most lagoons derive from other activities such as agriculture and villages built near the lagoons and often affect lagoon water quality.

9.6.6 *Environmental effects of aquaculture and capture fisheries on biodiversity conservation*

Nowadays, the environmental effects of aquaculture and fishing activities are not well quantified, nevertheless, it is recognized that aquaculture developed in this area is compatible with environmental protection. The development of aquaculture supports the conservation of natural areas (marshes and salt marshes) and helps to keep the flooded areas by increasing biodiversity (birds, fish, mollusks and plants).

9.6.7 *Impact of ichthyophagous birds*

In Atlantic areas, there have been many studies on the influence of the presence of cormorant (*Phalacrocorax* sp.) populations in aquaculture.

Studies on the incidence of fish-eating birds demonstrate that there is a significant impact they can have on aquaculture facilities and on production (Perez-Hurtado *et al*., 1997). According to producer associations, in some extensive aquaculture facilities, cormorants may prey on 40–60 percent of the production.

9.6.8 *Elements for green accounting and ecological services*

The main sources of energy in the environment of coastal lagoons examined come from the electricity network, while renewable energy is rarely used.

In most of the regions analyzed, there are inventories of wastewaters in quality and quantity flowing into coastal lagoons, therefore there is a monitoring of potential discharges that could affect lagoons. These inventories normally depend on the corresponding authority responsible for the environment in each Spanish region.

- The fees in the lagoons are mainly related with the use of public space, for which the operator of the lagoon or part of it has to pay a price per occupied or used square meter. In Mediterranean coastal lagoons, rates are oriented towards the places where discharges occur.
- With regard to marketing, producers and the authorities responsible for food security in every region should track product processing and production quality control.
- In recent years, there have been some accidents or oil spills near the lagoons, as it occurred near Veta la Palma, where the breaking of a tailings pond (mining industry) affected the whole surrounding area. Also in the Ebro delta, an oil spill from a platform located along the coast of Tarragona was close to entering the delta and to affecting the whole ecosystem.

- There is no significant evidence of industrial accidents linked to fisheries and aquaculture in the lagoons studied.

The environmental benefits generated by most lagoons are related to the maintenance of wintering and/or migratory bird communities, and the ecological value is generated by the protection of flora and fauna.

Maintaining the landscape has become increasingly difficult in some cases, as the Mar Menor, where urban development and infrastructure are a real risk to the visibility of natural areas.

9.7 Environmental considerations

As a general consideration and key issues on the interaction among aquaculture, capture fisheries and the environment in Spanish coastal lagoons, it is observed that in most of lagoons aquaculture does not exist and fishing activity is usually unimportant.

Thus, among the Mediterranean lagoon areas analysed, in only two of them there are aquaculture and fisheries activities, and the rest are just coastal wetlands where fisheries is practically missing. Usually when the aquaculture activity is abandoned, the marsh tends to dry out and lose the flood, and consequently the productivity is lower.

Regarding the fishing activities performed in lagoon areas, in general there is a problem of control over the catch. Indeed it is very difficult to obtain data on catches and therefore it is difficult to estimate the utilization of natural resources.

An important aspect is that all Mediterranean coastal lagoons are protected with a normative figure; however, all of them must improve their integrated management for sustainability of ecosystems.

9.8 General remarks

The situation and characteristics of Spanish Mediterranean coastal lagoons show the significant recession they have suffered in the past and the new focus on protection of those that still exist.

The factors that led to such a loss of wetlands are usually common, nevertheless in addition each lagoon also presents particular threats. In general, the most common threats found in Mediterranean coastal lagoons are related to agriculture activities, hunting, siltation and water regulation, loss of hydrologic force, creation of industrial parks, pollution from urban waste water, urban infrastructure and impact on the landscape.

From the implementation of this review on lagoons areas in Spanish Mediterranean, it could be deduced that the regression produced during the last 50 years is severe, and has limited the extent and protection of ecosystems.

As a direct result of this, while environmental protection is very high, a considerable step backwards has been done in exploiting fisheries and aquaculture in these areas, only remaining in those places where there is private ownership and where aquaculture is an activity that contributes to the system's value (because it allows inundation, avoiding siltation).

A relevant aspect is the low level of inter-coordination between the administrations that have expertise in the lagoons and limited monitoring of the fishing and aquaculture activities within them.

All the lagoons assessed are Ramsar sites, and the Spanish State has also assigned to all of them a different level of protection with different limitations. However, barely any of them have a usage and management plan that includes traditional extractive activities like fishing and extensive aquaculture. Therefore, the protection level is very high, but there is no comprehensive view and integrated management of these spaces, and activities such as these could play a much more important role than today.

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10. TUNISIA

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10.1 Introduction

Tunisia is located within the northern part of Africa opening on the northern and southeastern Mediterranean Sea; it is bordered by Algeria on the west, the Mediterranean Sea on the north and east, Libya on the south-east and the Sahara on the south. Its coastline is 1 300 km long with five lagoons and one lake with a total surface of more than 50 000 ha; the biggest lagoon, El Bibane, covers over 23 000 ha (40 percent of the lagoons' total surface). The country surface is about 160 000 km^2 with a population of 11 million inhabitants (according to the last census in 2004). Fisheries is an active sector producing more than 100 000 tonnes/year (102 000 tonnes in 2010), with 4 500 tonnes from aquaculture (including inland aquaculture) and about 450 tonnes from lagoons, and offers job opportunities (both directly and indirectly) to more than 100 000 people. Coastal lagoons are less productive than in the past (650 tonnes in 1995 and more than 1 000 tonnes during the 1980s). The country exports about 20 000 tonnes and imports about 50 000 tonnes of fish products, making the apparent pro capita fish consumption up to about 13 kg, something that is considered as not enough when compared with the 2010 worldwide consumption of 17 kg (DGPA, 1995–2009).

The development of the fishery sector is considered as a priority by public authorities, and several actions are planned, especially concerning the development of marine aquaculture to boost fish production with the aim of meeting the growing demand for proteins. Unfortunately, coastal lagoons are suffering from many natural and human impacts, requesting urgent interventions to improve their environment conditions and to allow their rapid recovering.

10.2 Generalities on Tunisian coastal lagoons

Tunisia hosts five lagoons and one lake with the main following characteristics (Tables I and II; Fig. 1) located on a 1 000 km shore line (over 1 300 km of coastline) with a total surface of 50 000 ha (Table I).

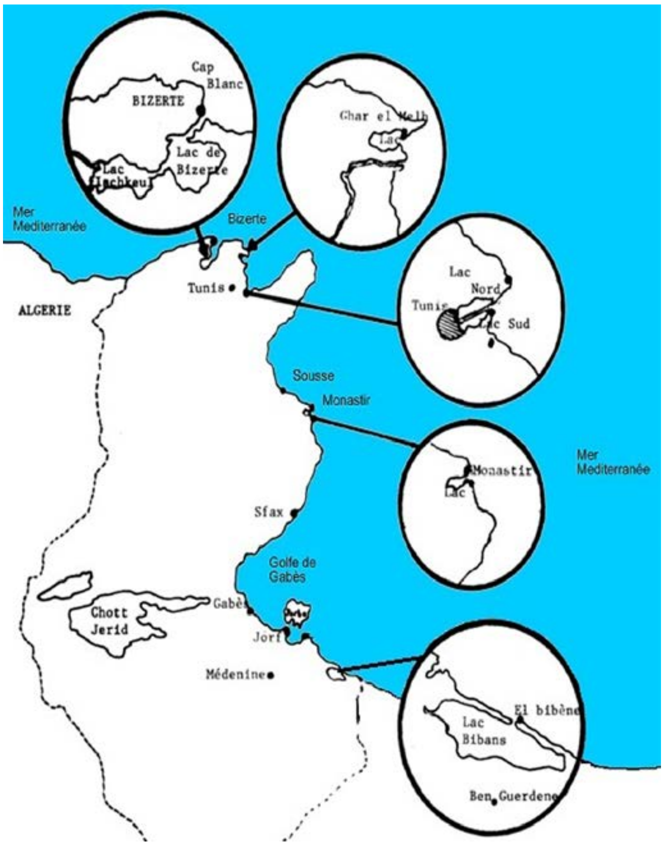


Figure 1. Map of Tunisian lagoons

Table I: Surfaces of the Tunisian lagoons and lake (ha)

Lagoon	Ichkeul lake	Bizerte lagoon	Ghar el Melh	Tunis lake	Monastir lagoon	El Bibane	Total surface
Surface (ha)	8 500	12 800	3 000	2 500	150	23 000	about 50 000

Table II: Physical characteristics of Tunisian lagoons: depth, environments and salinity

Lagoon	Depth	Water characteristics	Salinity (ppt) min-max
Ichkeul	1.2-2.2 (1)	Fresh + marine	14-70 (1)
Bizerte	4.06 (mean depth)-16	Marine+ fresh	36,3-40.87 (2)
Ghar el Melh	1.5-2.5	sea	45 (mean) (3)
Tunis	0.5-2 (6 at max.)	sea	32-43
El Bibane	7 (mean depth); max.:16	sea	45 (mean) (4)

(1) Romdhane (2004) (2) Bellakhal-Fartouna (2004) (3) Sangbe Mbaiasbe (2008);(4): Idea Consult (2008)

The Monastir lagoon is situated on the east coast, very close to the INSTM (Institut national des sciences et technologies de la mer) experimental station. It has never been exploited for legal fish capture and no licence has been issued for that purpose. During the 1980s it was used by the former national aquaculture centre to process some trials on mussel and fish growing up.

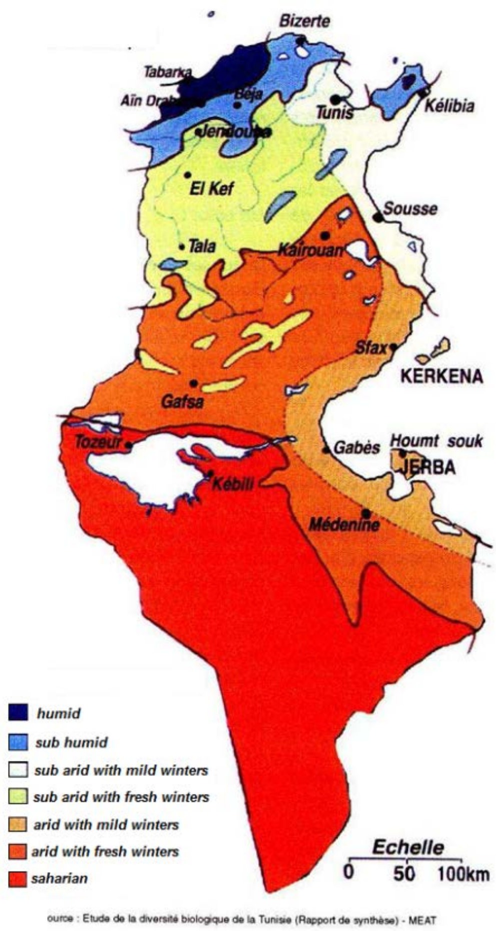


Figure 2. Tunisia's climatic zones

Communication with the sea

The Bizerte, Ghar el Melh, Tunis, Monastir and El Bibane lagoons are connected to the Mediterranean Sea while the Ichkeul lake is communicating with the Bizerte lagoon through a 5 km small river locally named oued Tinja. The Bizerte lagoon is connected to the sea through an artificial channel dredged many years ago to link the dockyard of Menzel Bourguiba to the sea. In spite of their communication with the sea, some of these lagoons are suffering from the limitation of water flow from the sea which is deemed as not enough to refresh their entire water volume, especially in the case of the Tunis lake, in which water renewal needs more than 20 days (Ben Charada, 1992).

Climate

The Tunisian climate goes from humid and subhumid in the north to arid and Sahara climate in the south (Fig. 2).

Freshwater input

The northern part of the country, where four lagoons and one lake are located, receives more than 500 mm of rain per year, whereas the lagoon of El Bibane (situated at the extreme south part of the country close to the Libyan border) receives less than 200 mm per year, with a predominating Sahara climate. The only lagoon that receives significant freshwater quantities is the Ichkeul lake, where several small size rivers (oueds) discharge large volumes of water especially during winter and spring. As a result, the water regime in this lake is highly fluctuating with salinity ranging from less than 4 ppt in winter to more than 30 ppt in summer. Salinity reaches more than 40 ppt in the other lagoons; bathymetry varies from one to more than six meters as a whole with different depths inside the lagoons. The Bizerte lagoon is drastically suffering from the decrease of freshwater flowing from lake Ichkeul (165 million m^3 before the water management works: the construction of several dams and a lock gate settled a few years ago with the aim of regulating the water level inside the lake).

With the exception of the El Bibane lagoon, which does not receive significant organic pollutants (except for the agriculture run off), all other lagoons suffer from eutrophication due to the discharge of huge amounts of organic matter (Romdhane, 2002). In the Tunis lagoon, this phenomenon culminated before the restoring works undertaken in the early 1980s. For a long time, this lagoon received large volumes of sewage from the surrounding urban agglomerations and is currently going to become a marine waterbody following the restoring works that took place in the early 1980s. The mean depth of the lagoons never goes over 5 meters, the minimum being 1–1.5 and the maximum 6 meters, with a bathymetry varying inside the lagoon to reach more than 10 meters in dredged zones.

Main ecological features

The main ecological features derive from the nature of local systems, which go from semi-arid (average rain rate of 550 mm/year) to arid sub zones (200 mm/year). As a result, they are influenced by the surrounding inland and marine environment (the west Mediterranean basin in the north part and the south-east one for the El Bibane lagoon), which is under the direct impact of the Gulf of Gabes, characterized by an extended, smooth and biologically rich continental shelf.

Lagoon typology, ownership and management

The Tunisian lagoons are located along a littoral portion of about 1 000 km. The water exchanges of the lagoons with their surrounding environment (watershed and sea) highly influence their ecology. The Ichkeul lake water varies from fresh to brackish, while the other lagoons are known as marine bodies with high salinity, reaching more than 40 ppt. The lagoons belong to the state of Tunisia through the hydraulic and maritime domains, which are managed by the Ministry of Agriculture and Environment as far as capture fisheries aquaculture and the environment are concerned. The Ministry is represented at the regional level (governorates) by 26 regional Commissariats for agriculture development (CRDAs), which include fishery and aquaculture districts as well as water managing services (in the Ichkeul lagoon's case).

Legal framework and constraints

The Tunisian littoral is protected by several legislative texts, among them those related to the law on public maritime domain (especially its provision that created the Agency for the Protection and Management of the Littoral [APAL]), the code of water (1974), the fishery code (1992) and the code of urbanism and territory management.

The main concerns related to pollution really exist in the lagoon of Bizerte, which is suffering from land-based outfalls (industrial and urban contamination), the North Tunis lake (eutrophication caused by sewages and petroleum pollution) and the Ichkeul lake (agriculture outfalls with high levels of organic loads and nutriments and growing salinity rates following the water managements works). The El Bibane lagoon is particularly suffering from overfishing and poor fishing practices, including non-selective gear and hazardous state of the fixed gear (bordigue).

Three marine protected areas were established in Tunisia, which are the Galite/Galiton archipelagos situated off the north coast, the Zembra/Zembretta Islands (northeast of the Tunis gulf) and the ornithological zone of Kneis (southeast of the country). Other zones of environmental interest are going to be established within the framework of PAM protocol of marines protected areas.

The Ichkeul lake is a Ramsar site as well as a MAB/ Unesco one; it belongs to a National park that encompasses the surrounding Djebel (a little mountain) and a set of marshes. The El Bibane lagoon is also a Ramsar site, specifically for its ornithological interest.

10.3 Living resources

The Tunisian lagoons host about 1 000 living species with 200 micro flora, 245 micro fauna, 142 macro flora, 45 fish species, two turtle species, one aquatic mammal species and 220 bird species.

No conservation-oriented studies were specifically realized on the issue. However, some research on the impacts of pollutants and other anthropogenic releases were implemented in certain lagoon areas such as those executed in the framework of the water management in the Ichkeul lake, the eutrophication of the lagoon environment of the Bizerte, Tunis and Ghar el Melh and multidisciplinary studies related to biology, ecology and physico-chemistry.

10.3.1 Flora and fauna

The main outputs reflect the interrelation between the flora and fauna composition and distribution and the changes of the water quality. For example, the Ichkeul lagoon is highly influenced by the salinity caused by the freshwater flowing through the water shed around the lake, leading to an important vegetal development at the west subzone of the lake and near the communication with the Bizerte lagoon (where *Ruppia cirrhosa* substitutes *Potamogeton pectinatus* with a strong development of the green algae *Cheatomorpha linum*, Chlorophycea, in the *Rupia* surrounding zones whereas seeds and bulbs of Potamogeton still exist in the sediment, *Potamogeton* being the main feed provider for the fowl population). Due to salinity increase in the lake, *Scirpus maritimus* is being invaded by *Salicornia arabica,* which was never reported until 1967. The global trend of the marshes ranges from marsh vegetation to a sebkha one, a situation that highly influences the ornithological richness of the area (the last observation reported a net decrease in the avifauna of the lake). Such a trend could be balanced towards the original vegetation by a suitable management of the water level in the lake by means of a lock gate installed a few years ago (Romdhane, 2002).

Thus far, 17 fish species were reported compared with 22 in 1993/1994, including 10 of commercial importance such as: *Anguilla anguilla, Barbus callensis, Belone belone, Dicentrarchus labrax, Engraulis encrasicolus, Liza aurata, Liza ramada, Mugil cephalus, Solea vulgaris, Sparus aurata* and seven migratory and sedentary species like *Aphanius fasciatus*, *Atherina boyeri, Gambusia affinis, Hyporhamphus picarti*.

As far as landscape is concerned, the Ichkeul site is of exceptional beauty with its set of marshes, the mountain, the loamy waters that reinforce the forestry relief and the contrast with the surrounding region (the Djebel raising allows a panorama of the Bizerte lagoon and the Mediterranean coast).

The other lagoons are marine predominant media, where the salinity is close to the Mediterranean surrounding areas. As a result, the flora and fauna are similar to those characterizing the marine environment. For example, in the Ghar el Melh lagoon, the benthic fauna encompasses three biotopes, according to the distance of the area from the sea. Eighteen species belonging to three phyla are reported (Gnassingbé-Maisbe, 2008). The macro fauna is subject to the negative effects of shallow water and to the limited water exchanges with the sea. The capture fish species belong to three groups, which are of sedentary, migratory and casual species nature (SCET-ERI, 2000).

The Bizerte lagoon is influenced, on one part by the seawater that enters into it through an artificial channel and on another part by the high amount of sewage that is discharging organic matter, source of severe eutrophication. Several toxic phytoplankton species are reported to be causing shellfish contamination by biotoxin. Phytoplankton blooms with toxic species such as *Gymnodinium sanguineum, Alexandrium spp, Prorocentrum lima, Pseudo-nitschia delicatissima* and *Peridinium quiquecorne* were also reported (Bellakhal-Fortuna, 2004). In 1966, 23 dinoflagellate species and 33 diatoms were reported (Azzouz, 1996); since that time diatoms are decreasing. In 1985, 33 species were reported, with 11 Ulvophycae of which *Codium fragile*, 18 Rodophycae and 4 Phaeophycae (Djellouli, 1985). Fifty per cent of the lagoon sediment is covered by *Caulerpa prolifer*a.

The El Bibane lagoon hosts the longest algal reef of Neogoniolithion notarsii in the Mediterranean. Eighty percent of its sediments are covered by *Cymodoce nodosa*. The lagoon is directly influenced by the nearby gulf of Gabes, which is considered among the rare areas with significant continental shelves in the Mediterranean.

The Tunis lagoon has undergone big changes after the restoration works, which were implemented in the early 1980s, leading to the improvement of the water circulation inside the lagoon, the rectification of its borders and the decrease of its surface (from 3 000 to 2 500 ha): 38 macrophytes species were identified compared with 10 before the restoration works (Ben Maiz, 1993, Shili 1995 and Trabelsi 1995). It is important to note that *Ulva rigida* highly decreased when phanerogams appeared (*Rupia cirrhosa, Zostera noltii* and *Cymodocea nodosa*). Ben Maiz reported in 2008, 36 dinoflagellates, 33 diatoms, two euglenophycae and one cyanophycae.

The lagoon aquatic fauna diversity has improved after the restoration works due to the entrance of typically marine species: 39 fish species were identified (M'timet, 1995; Ben Hamouda, 1998) compared with 24 before the restoration works (Chauvet, 1986), *Sparus aurata* and *Dicentrarchus labrax* becoming abundant species. In 2004, 118 invertebrate species (of which 69 shellfish with 45 Gasteropods and 17 bivalves) and 57 species (identified for the first time) were reported, *Mytilus galloprovincialis* and *Tapes decussatus* being the most important shellfish species (Ben Maiz, 2008).

10.3.2 Wildlife

As far as ornithological richness is concerned, Tunisia is considered as an important ornithological country with 395 bird species, fowls being the most important migratory species observed. Around the Gulf of Gabes, the El Bibane lagoon is hosting a large part of those fowls (79 species belonging to 35 families). The global number of fowls that winter in the lagoon is up to 20,000 individuals, among them the big size cormorant, *Phacrocorax carbo*, the pink flamingo, *Phoenicopterus roseus* and *Platalea leucorodia.*

In Tunisia, three marine protected areas were established: the Galite/Galiton archipelagos, the Zembra/Zembretta Island and the ornithological zone of Kneis. Other marine areas of environmental interest are going to be established within the framework of the MAP (Mediterranean Action Plan) protocol on marine specially protected areas.

10.4 Land and water management

The Tunis lagoon lost more than 15 percent of its surface after the restoration works implemented during the 1980s with the aim of improving water circulation inside the lagoon, decreasing the surface of the lake and combating eutrophication phenomena. To improve the water circulation within the Tunis lagoon, dredging works were done according to a water circulation model. which also included the construction of a 10 km bridge linking the bordigue to the Chekly Island situated inside the lagoon on its northwest part. In the frame of water management in the Ichkeul lake, a lock gate was installed, including the settlement of facilities securing juveniles entry into the lagoon, especially eels. As far as other lagoons are concerned, the main maintenance works affect the bordigue, especially for the El Bibane lagoon where old fishing fixed gear is frequently damaged.

10.5 Lagoon exploitation

Table III: Main activities carried out on Tunisia coastal lagoons (+++ High activity, ++ moderate activity, + low activity and – no activity)

Lagoon	Ownership	Capt. fisheries	Aquaculture	Cultural	Tourism	Bird hunting
Ichkeul	Public domain	+++	–	++	++	+
Bizerte	Public domain	+++	+	_	–	_
Ghar el Melh	Public domain	+++	-	_	+	_
Tunis	Public domain	+++	-	+	–	_
El Bibane	Public domain	+++	–	++	+	_
Monastir	Public domain	–	–			

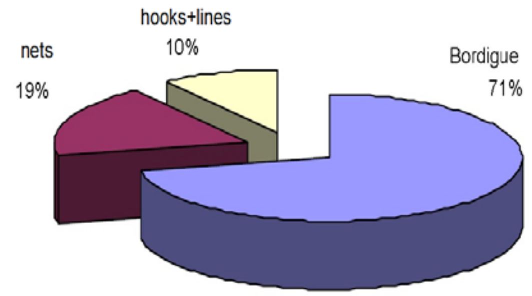
10.5.1 Aquaculture and capture fisheries

Facilities

Fishing gear

Four types of fishing gear are currently used for fish capture in the lagoons, which are the old fixed gear named *bordigue* (conceived and used since the nineteenth century), *capetchades* ("*Massayda*") to fish eels, fixed nets and trammel nets, hooks and lines. For shellfish culture, mussels are reared on suspended ropes in the Bizerte lagoon. *Capetchades* are used in the lagoons with eels (Ichkeul, Ghar el Melh and Tunis lagoons), whereas bordigues in Ichkeul, Tunis and el Bibane lagoons represent the most productive gear with up to 70 percent of the total capture in the el Bibane lagoon. Adding to this fishing gear, *Tapes decussates* is being manually collected by fishers who use ancestral means in the Tunis, Bizerte and el Bibane lagoons (the technique is called "*pêche à pied*"). The El Bibane bordigue is the longest existing fixed fishing gear in the Mediterranean (2 km over an opening lagoon-sea of 2 500 km long). Lines are used to catch fish of high commercial value such as seabass, seabream, *Lichia amia* and *Pomatomus saltatrix,* whereas the bordigue allows to catch those species plus others, especially *Dilpodus annularis,* annular seabream and sand streenbass. Fixed nets are used to catch *Salpa salpa*, mullet like species, *Sparus aurata* and shrimp (*Penaeus kerathurus*). In the El Bibane lagoon, the capture shares of fixed gear are as follows: 71 percent with the bordigue, 19 percent with hooks and lines and 11 percent with fixed nets (Fig. 3).

El Bibane lagoon fish trap, photo ©BRL Ingenierie IDEA Consult. 2008.



Conservation measures applying to the lagoons are those provisions in force for artisanal fisheries. The fishing seasons are closely linked to the biology and trophic needs of the target fishes (spring-winter for eels, summer for shrimp and other times for fish species depending of their biology).

Figure 3. Share of each fishing gear in the El Bibane lagoon

Boats

No motor boats are allowed within the lagoons in principle. The lagoon of El Bibane, however, hosts four motor boats devoted to the transport of personnel and fishing material. The fishing fleet belongs to the companies to which concessions are granted through the fisheries regional authorities. Several boats are not operating, for example in the El Bibane lagoon, five out of 20 boats fishing with hooks are immobilized (112 licences were granted in 2010 but many illegal operators are actively fishing inside and/or on the lagoon border).

The fish products are exclusively sold to the licence-holders at fixed prices communally agreed between the company and the private fishers. The issue is frequently the subject of several conflicts between the two parts.

Buildings and infrastructures

The facilities offered by the companies which are exploiting the lagoons include warehouses for gear and nets handling as well as for products conditioning and storage; those facilities exist at the Ichkeul, Bizerte, Tunis and el Bibane lagoons. In the Ghar el Melh lagoon, fishers and their cooperatives rent warehouses inside the nearby fishing port to stock fishing materials and equipments.

El Bibane lagoon: bordigue and traditional fishing boat, photo ©BRL Ingenierie Idea Consult, 2008

Employment and institutions

Since all the lagoons belong to the public authorities, which are acting through the Ministry of agriculture and environment (for licensing and fishing control), and also through the Agency of

Environment and Agency of littoral protection and management (for lease and monitoring of the maritime water and inland space), the lagoon exploitation is used by means of licences granted to private fishers (112 licences in 2010 in the El Bibane lagoon for example) and by lease contracts to private companies. In the past, these lagoons were exclusively conceded to a public body named Office National des Peches (ONP); the latter was dissolved by the mid-1990s and its activities transferred to the private sector**.**

Aquaculture and capture fisheries management

Five lagoons are of interest for fisheries and aquaculture production as well as for ecological relevance, which are ranked as follows (on the basis of their fish production in 2009):

El Bibane, with about 210 tonnes in 2009 compared with 185.5 in 1995; Bizerte with 76 tonnes of fish and 200 tonnes of shellfish in 2009 compared with 203 and 130 tonnes respectively in 1995, Ichkeul with 73.5 tonnes in 2009 compared with 138 in 1995, Ghar el Melh with 53 tonnes in 2009 compared with 52.5 in 1995 and north Tunis with 85.6 tonnes in 1995. The production of the Khnis lake is insignificant; the lagoon is being used for experimentation. The whole lagoon capture production decreased from 665 tonnes in 1995 to 410.5 in 2009, i.e. 245 tonnes less (minus 38 percent in 15 years) if we do not take into account the Tunis lagoon production in 2009, for which no data are available.

Ecologically speaking, the three most interesting lagoons are Ichkeul, Bizerte and El Bibane. The first one hosts, adding to its importance for capture fisheries, a large bird population that winters inside the lagoon and in the surrounding marshes thanks to the important availability of feed. This lagoon, with a special hydrologic regime, is included within a national park that benefits of protection/conservation measures. Its environmental importance and specificity allowed classifying the park as a MAB/Unesco site, as a Ramsar wetland and as a national park by the Tunisian authorities.

The Bizerte lagoon is of interest for aquaculture, particularly shellfish (mussel and oyster) culture. Five farms are already settled on the lagoon within a limited zone of a few hectares, but larger opportunities of development exist, including for fish culture. The lagoon is potentially interesting when considering the large decontamination project that is on the way to be run, and which will allow expanding aquaculture activities

The El Bibane lagoon is interesting on account of more than one aspect since it represents the largest lagoon in the country (it yielded a fish production of about 600 tonnes/year in the past). The absence of a management plan and of relevant conservation/development measures led to the current bad situation with an average production of 250 tonnes/year. The lagoon is classified as a Ramsar site since 2007 and requires more attention.

No hatcheries exist around any of the lagoons for the moment; the activities inside the lagoons are focusing on capture fisheries, except in the Bizerte lagoon, which hosts five shellfish culture farms that are importing their fry from outside the country. There are no intensive culture ponds around the lagoons**.**

Restocking

The fish juveniles, especially of mullet species, are collected from the wild and restocked in the inland water bodies (dams' reservoirs).

Selective fishery

The conservation measures are those in force for artisanal fisheries management (mesh size, number of authorized nets, minimum fish capture size, fishing zones and seasons, etc.)

Raft culture (shellfish)

In the Bizerte lagoon, mussels (on suspended ropes) and oysters are cultured.

Other actions to enhance productivity

Inside the Tunis lake, *Ulva lactuca* is regularly and mechanically removed in order to combat the proliferation of macro flora, to limit phytoplankton blooms and to improve water oxygenation.

The sediment of this lagoon includes high amounts of organic matter, phosphorus and nitrogen components accumulated during many years before the restoration works.

Productions from coastal lagoons (tonnes)

The production statistics data are made available by the General Directorate of Fisheries and Aquaculture (Record books of production statistics), which is collecting those data through its representatives at the regional level. The fishery districts are acting in the global framework of the CRDA. The lagoon production data are not available in the case of the Tunis lagoon for 2009. Except the case of the El Bibane lagoon, for which time series exist from 1984, all the data are available from 1995. No processed products are reported. All the fish products are sold in fresh, except for eels, which are essentially handled alive.

The whole lagoon production decreased from 1995 to 2009, even when the estimated production of the Tunis lake (180 tonnes) is considered (Table IV and Fig. 4).

Table IV: Evolution of the lagoons fish production between 1995 and 2009

Lagoon	Capture production in 1995 (kg)	Capture production in 2009 (kg)	Differences	%
Ichkeul	137 794	73 534	-64,26	-46,6
Bizerte	203 198	76 17	-126,6	-62,3
Ghar el Melh	52 405	52 869	0,464	0,88
Tunis	86 408	180 (estimate)		
El Bibane	185 532	208 021	22,49	12
Total	665 337	590 594	-74.743	-11

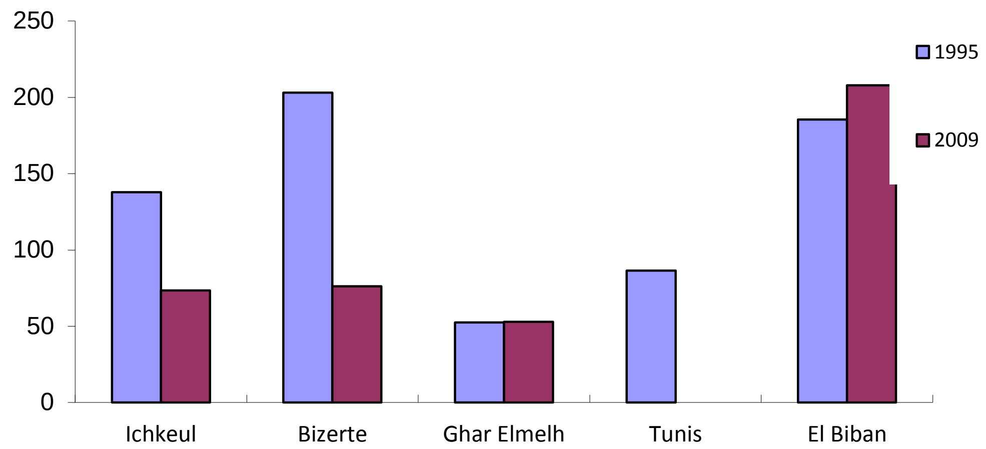


Figure 4. Lagoons fish production in 1995 and 2009

Table V: Capture fishery production from different environments (DGPA, 2010)

Coastal lagoon	Production from capture fisheries (tonnes)	Percentage of total production (%)
Ichkeul Bizerte Ghar el Melh Tunis El Bibane Total from coastal lagoons	73.5 76.2 53 180(estimate): 208.6 590.6	0.5
Aquaculture, including Inland water bodies (dams)	4 553 (1 210 tonnes from inland + 3 343 from marine aquaculture)	4.4
Mediterranean Sea	97 000	95.1
Total fish catch (tonnes)	**102 000**	**100**

Table VI: Crustacean (*Penaeus kerathurus*) production
(Source: DGPA (1995–2009)

Year	Production (tonnes)
1986	5 430
1987	5 160
1988	12 925
1989	13 297
1990	8 750
1991	16 860
1992	20 870
1993	22 253
1994	N A
1995	15 436
1996	16 930
1997	16 458
1998	13 551
1999	30 086
2000	4 921
2001	14 074
2002	11 466
2003	10 345
2004	13 969
2005	2 577
2006	6 440
2007	3 939
2008	10 837
2009	3 890

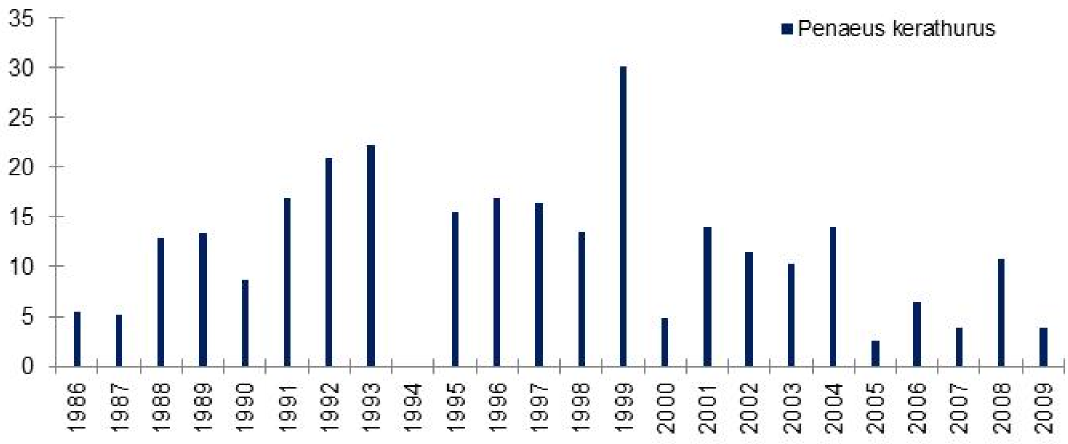


Figure 5. Crustacean production (in tonnes) (1986–2009)

The El Bibane lagoon is the main productive lagoon for shrimp, in which this crustacean is fished with fixed trammel nets. Its production is decreasing in time (Fig. 5). No culture exists for this species since the introduction of alien species is not allowed for the moment and *Penaeus kerathurus* (the local species) is not adapted for culture purposes, as shown by several trials.

Table VII Other fish species captured in the el Bibane lagoon (in tonnes, in 2009)

Year	Lichia amia	Sargus sargus	Salpa salpa	Seriola seriola	Trachurus sp.
1995	1 523	1 074	1 166	4 276	1 373
1996	1 604	2 529	6 622	2 191	655
1997	566	635	23 604	1 031	1 743
1998	518		3 002	165	2 359
1999	2 423	64	11 298	390	1 613
2000	1 389	11 548	15 532	221	1 536
2001	1 933	10 074	1 670	295	1 670
2002	2 369	21 235	28 332	1 624	1 698
2003	1 935	8 518	19 816	1 624	1 681
2004	1 937	8 538	34 974	342	2 292
2005	1 789	18 965	21 984	320	1 063
2006	988	18 965	21 964	320	1 063
2007	549		11 818	450	385
2008	518		3 002	165	93
2009	2 043	43	14 298	390	5 049

Production of other species

It is strongly deemed that *Ascidium*-like species were harvested in the El Bibane lagoon for many years but no accurate related data are available at the relevant fisheries authority.

10.6 Interactions among aquaculture, capture fisheries and the environment in coastal lagoon management

Most parts of the lagoons are suffering of severe pollution impacts, especially the Bizerte and Tunis lagoons, which receive organic and industrial outfalls and urban wastes, including sewages, respectively. The Ichkeul lake seems to be mostly influenced by its surrounding watersheds and, to a lesser degree, by solid wastes coming from these areas. No pollution-oriented survey nor exhaustive studies have ever been realized on the identification of the possible damages and to establish the current state of confinement within the lagoon, something that could allow identifying the suitable zones for fish and/or other species rearing.

The lagoon of Bizerte receives pollutants from the surrounding agriculture and industrial areas. A decontamination-oriented study is being undertaken under the supervision of the National Agency of Environment Protection (ANPE), but unfortunately this study does not sufficiently take into consideration aquaculture activities.

As far as marine capture fisheries are concerned, some signs of overfishing seem to be related to the important decrease of global production and of some fish species which are becoming drastically scarce. Unfortunately, there are no studies oriented towards stock assessment for the lagoons, instead, several studies are going to be done in relation to the small-scale pelagic and demersal fish. As a result, it is not easy to estimate to what extent lagoon fish stocks are moderately or overfished.

10.6.1 Interactions among different fishers groups and conflicts between fishers/fish-farmers and public or private stakeholders

The only lagoon that hosts aquaculture activities is the Bizerte one, with five shellfish farms located within a limited zone close to the lagoon-sea communication. Severe conflicts exist between the farmers and the fishers in terms of space and possible impacts on the free circulation of the boats and pollutants release. The regional fisheries authorities are trying to manage and settle such conflicts. The situation must be addressed in a sustainable manner, something that could be reached by the establishment of a plan including aquaculture allocated zones.

As far as the other lagoons are concerned, the main conflicts are related to the relationship between fishers and the private companies to which exclusive licences were granted for a certain time (30 years at maximum). The main weaknesses consist in the absence of professional organizations on one side and the non-compliance of the companies toward their commitments in matter of good practices and respect for the environment (their main concern is to increase their profit) on the other. The Ichkeul lake represents a specific case with its special water regime, which is highly impacting the fisheries and possible aquaculture activities. An exhaustive study is being performed to manage sustainably the water resources, taking into account the development of fish culture (Eco Ichkeul, 2009).

10.6.2 Competition for space (location of aquaculture facilities in fishing grounds, existence of "planning management" for lagoon areas, etc.)

No serious planning of space and water bodies was done yet. It is a matter of urgency if the public authorities seriously think about the necessity to save the lagoons, to enhance their productivity and to conserve their biodiversity.

10.6.3 Product interaction on the market (product from aquaculture vs from capture fisheries; presence of private/ public label for fishery products)

Aquaculture is a relatively recent activity, which fills the gap of the lack of similar fish of sea origin (seabass and seabream) on the local market. The preference of the consumer goes to aquaculture products, which are cheaper. At the same time, no official label exists for fish products but the difference between the sea fish and the aquaculture ones is easily perceived by the consumer. At the export level, some lagoon products are highly appreciated, especially eels and prawn, on the Spanish and Italian markets.

10.6.4 Environmental effects of aquaculture and capture fisheries on biodiversity conservation

No specific studies were performed to assess the impacts of aquaculture on biodiversity. With regard to fisheries, several researches and studies were performed to evaluate the effects of fishing gear and practices on the coastal zones, especially in the gulf of Gabes.

10.6.5 Juveniles/spat collection in the wild for culture and/or restocking purposes

Capture-based aquaculture (capture of juveniles in the wild) is oriented to restocking purposes in the inland water bodies, especially dams and reservoirs.

10.6.6 Genetic impact of restocking actions / escape events on wild stocks

No specific studies were realized to assess the effects of fish escaping since those events are not reported.

10.6.7 Elements for green accounting and ecological services

The main source of energy is of fossil origin, especially gasoil. Special prices are granted to the coastal fishers (20 percent less than the current price). The gasoil tonne costs about US$ 700. No renewable energy is used.

The most important taxes and tributes paid for using natural resources (i.e. waste treatments, packaging, advancement/requalification/rebuilding of natural/public areas). A global tax is being paid by the water users; the relevant fees are indexed to the water consumption volumes.

The packaging boxes used to sell fresh fish are made of polyethylene. The clams (mussels and oysters as well as *Tapes decussatus*) are packaged in plastic and/or jute bags.

The sanitary control on fish flesh is currently exercised by the veterinary services, which are depending on the Ministry of agriculture and environment

The control on production facilities is under the aegis of the General Directorate of fisheries and aquaculture through its regional services.

No significant outputs could be drawn up from the lagoon ecological goods and services for the moment, but several stakeholders are claiming more attention toward those sensitive media, especially with regard to their exploitation for the benefit of the local work forces (the lagoon surrounding population suffers from unemployment and relative poverty).

There is significant awareness about the importance of lagoons in matters of economic, social and environmental interest, especially from the side of NGOs and civil society as a whole. This aspect was raised during the meetings which were organized with the aquaculture stakeholders when setting the main elements of the sustainable development of aquaculture (in the framework of the GFCM CAQ working group on sustainability of aquaculture development), but something should be done to orient that interest and to focus on the urgent matter of lagoons restoration and improvement.

10.7 Environmental considerations

Many salient problems that could cause inconveniencies and lead to conflicts are summarized as follows for each lagoon:

- The Ichkeul lake is facing three main problems that constitute a conflict of interest for the use of water (between the users for that water for irrigation and to supply the surrounding and far away populations with drinking water), an antagonist position from the surrounding populations toward the concessioner company (that is exclusively using the lake to catch eels and other fish by the three main types of fishing gear: bordigue, nets and capetchades) and the decrease of fish juveniles recruitment, especially juveniles of eels, a problem which is mostly due to the settlements which have been installed with the aim of safely managing water within the lake (for example the "*escalier à poisons*" for eels).
- The Bizerte lagoon is facing a problem of environmental quality, especially as far as the sewage from the surrounding towns and the nearby industrial factory is concerned. Some zones within the lagoon are suffering from eutrophication with its numerous negative effects on the environment. Another problem should be raised, coming from

the absence of a management plan, something that should avoid or at least decrease the conflicts between farmers and fishers.

- The Tunis lagoon is suffering from its position being close to the overpopulated capital and suburban areas, history and the recent restoration works which improved the water flow but, at the same time, caused a drastic drop in fishing productivity and biodiversity. The other weakness consists in the disorder that is prevailing at the level of the stakeholders (fishery, tourism and culture) on the one part and the absence of a serious "*cahier de charges*" for the proper exploitation of the lagoons on the other part.
- In the case of the Ghar El Melh lagoon, the main handicap is related to the communication with the sea, which is frequently obstructed. In order to meet the fishers claims to allow their boats to enter into the nearby fishing port (on the north side of lagoon) frequent works are being done to open the obstructed communication and to refresh the water into the lagoon. A management plan should be prepared starting from a solution that must be found out to secure an acceptable seawater entry.
- The El Bibane lagoon is the largest and the most productive one. The current exploitation system is not good, especially since the lagoon was licensed to private companies that did not respect their commitments toward its responsible exploitation. The current exploitation system is essentially based on the "*bordigue*", which assures the largest part of the fish capture. However, this device is very heavy to handle in terms of cost and manpower.

The development perspectives and interventions from the public administration are as follows:

- The public administration in charge of fisheries and aquaculture produced many valuable rules for the rational exploitation of fisheries resources and the protection of wild life (minimum fish size, protection of sensitive areas, safeguard of birds' communities, etc.), including sensitive habitats and ecosystems. The issue that is now a matter of urgency is the application of the specific provisions of such rules and legislations. A plan for the conservation of eels was prepared to meet the requirements of the EU.
- As far as the lake Ichkeul is concerned, a large and exhaustive study is being carried out, including the use of the lake for fisheries and aquaculture (Gestion Intégrée des resources en eau du basin versant de l'Ichkeul: GIRE éco-Ichkeul, May 2009–December 2011). Meanwhile, the private company to which a 30 years concession was granted continues to exploit the lake without limitations, causing severe problems to the surrounding populations and NGOs.
- The Ghar el Melh lagoon is suffering of problems coming essentially form the limitation of the sea-lagoon water exchanges. A solution was found to timely limit sand accumulation on the shoreline, particularly to meet the fishers' requirement for their access to the fishing harbour, situated nearby; but the current bad state of the lagoon with regard to its communication with the sea is a real problem that prevents the proper exploitation of the lagoon.
- In the El Bibane lagoon, many studies were or are in the process to be performed; but what is urgently required is a study oriented to improve the exploitation of the lagoon for fisheries and possibly for aquaculture. Such a study should start by making an exhaustive anaylis of the status quo, including the damages that were caused by the irrational exploitation in the last 10 years (a shrimp-oriented fisheries, use of unacceptable gear, exploitation of flora like species, etc.) and overfishing of certain species with a fishing effort that leads to catches being over the maximum sustainable yield.
- In spite of their efforts (although limited for the moment) to contribute to some investigations, the relevant research institutes should prepare and implement fisheries and aquaculture oriented projects; something that has been proposed through the National Commission for the evaluation of research (an official body working under the authority of the Ministry of High School and Research).

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11. TURKEY

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11.1 Introduction

Turkey is a peninsula, and has a wide selection of lakes, dam lakes, ponds, reservoirs, rivers and springs, it has a major potential for aquaculture. With a coastal line of 8 333 km and 177 714 km of rivers, the marine and inland water sources suitable for aquaculture are approximately 26 million ha (Tables I and II). It is known that there are 247 species in the Black Sea, 200 in the Sea of Marmara, 300 in the Aegean Sea and 500 in the Mediterranean. However, only few species of commercial interest represent almost the 60 percent of the total Turkish production (Deniz & Karasubenli, 2010).

Turkey view from the space

Table I: Sea resources in Turkey (Source: MoFAL)

Marine Resources	Coastlines (km)	Surface Area (ha)
Mediterranean, Aegean Sea, Marmara Sea and Black Sea	7 144	23 475 000
Istanbul and Dardanelles	1 189	1 133 200
Total	8 333	24 607 200

Table II: Freshwater resources in Turkey (Source: MoFAL)

Freshwater Resources	No of Resources	Surface Area (ha)	Length (km)
Natural lakes	200	900 118	-
Dam lakes	159	342 377	-
Ponds	750	15 500	-
Rivers	33	-	177 714
Total	1 142	1 261 995	177 714

Official figures indicate that total fisheries production in 2009 was 623 191 tonnes (Table III), comprising 76 percent fisheries and 26 percent aquaculture (Deniz, 2010).

Table III: Fishery and aquaculture production in Turkey in 1998-2010 (tonnes)

Year	Inland aquaculture	Marine aquaculture	Total Aquaculture	Total fisheries production	Percentage of total fisheries production
1998	33 290	23 410	56 700	543 900	10
1999	37 770	25 230	63 000	636 824	10
2000	43 385	35 646	79 031	582 376	14
2001	37 514	29 730	67 244	594 977	11
2002	34 297	26 868	61 165	627 847	10
2003	40 217	39 726	79 943	587 715	14
2004	44 115	49 895	94 010	644 492	15
2005	48 604	69 673	118 277	544 773	22
2006	56 694	72 249	128 943	661 991	20
2007	59 033	80 840	139 873	772 323	18
2008	66 527	85 629	152 186	646 310	24
2009	71 019	82 481	158 728	623 191	25
2010	78 568	88 573	167 141	653 080	26

11.2 Generalities on coastal lagoons

There are 72 lagoons with a total 37 389 ha surface area in Turkey, which are present along all the four coastal areas (Deniz, 2010), the Marmara Sea, the Aegean Sea and the Mediterranean Sea *sensu strictu* (all included in the Mediterranean Region according to the GFCM) and the Black Sea (Table IV).

Table IV: Number and surface areas of Turkish coastal lagoons by region (Source: MoFAL)

Coastal areas	Number	Surface area (ha)
Black Sea	14	3 139
Marmara Sea	12	2 650
Aegean Sea	29	20 000
Mediterranean s.s.	17	11 600
Sub-total for the Mediterranean Region	58	34 250
TOTAL	72	37 389

Black Sea lagoons

The Black Sea is a semi-enclosed basin whose inshore waters present estuarine characteristics, significant pollution loads and high hydro dynamism. Along its southern border, salinity ranges between 16 and 18 ppt, rarely exceeding 21 ppt. Surface water temperatures show a winter minimum of around 7°C and a maximum of around 25°C in summer. Surface waters are very dynamic, with main currents flowing from west to east.

According to the nutrient levels, its waters are classified as mesotrophic. The major sources of nutrients are the disposal of Istanbul's sewage and the Danube delta, which also provide the highest loads of pollutants. Other sources of pollution are the coastal towns, whose effluents are usually pumped into the sea untreated.

Fourteen lagoons covering a total surface of 3 139 ha are found along the Turkish side of the Black Sea (Table V). Their annual fish production is about 131 tonnes, which is almost entirely given by the lagoon complex of Bafra, where production is about 56 kg/ha.

Table V: Lagoons along the Black Sea coast of Turkey (Source: MoFAL)

Lagoon	Surface (ha)	Province	District
Simenlik+Akgöl	200	Samsun	Terme
Ahubaba lakes	22	Samsun	Terme
Balık	1 300	Samsun	Bafra
Uzun	293	Samsun	Bafra
Cernek	589	Samsun	Bafra
Gıcı	125	Samsun	Bafra
Tatlı	52	Samsun	Bafra
Liman	200	Samsun	Bafra
Karabogaz	166	Samsun	Bafra
Sarıkum	102	Samsun	Bafra
Küçükboğaz	30	Sinop	Sinop Center
Erikli	5	Kırklareli	İğneada
Mert	50	Kırklareli	İğneada
Saka	5	Kırklareli	İğneada

The lagoons along the Black Sea coast are mainly concentrated at the large delta of the Kizilirmak River – the Bafra lagoon complex – which hosts a large wetland area that is also exploited for fishing. At present, the remaining lagoons are either abandoned or not exploited, with a fishing output resulting as negligible in the overall picture (Hollis and Thompson, 1992)

Moving from east to west, the first lagoons are the ones dotting the Yesilirmak river delta, the second and last delta of this region. Simenlik and Akgol are two interconnected stretches of water on the eastern side of the river, whereas the tiny Ahubaba lagoon complex is found on its western side. All lakes are affected by sedimentation, growing submersed vegetation cover and a lack of maintenance. Fishing management has been progressively abandoned and catches have declined greatly with respect to their importance of only relatively few years ago.

Sarıkum lagoon in the Black Sea coast, photo ©H. Deniz

Only two lagoons of the Bafra lagoon complex still exist today: Liman and Karabogaz. The former is an isolated lake at the northernmost tip of the delta where no fishing is practised at present. The implementation of the Bafra Plain Irrigation Scheme by DSI will provide the lagoon with three sources of clean freshwater, diverting the present discharge of drainage waters from the lake to the sea. This could improve the environmental conditions of this lagoon, which is currently in danger from excessive vegetation and agrochemical inputs. Its difficult accessibility hampers a fishing exploitation and makes it a prime candidate for a wildlife sanctuary.

Karabogaz is the only lagoon along the western side of the delta. The cooperative renting it decided to ban fishing in it for three years due to the sharp decline of its catches. Its limited size and the reported absence of pressure by local inhabitants to exploit it to make a living, make it suitable for conversion into a wildlife refuge and the provision of protected-area status. The Sarikum lagoon has been a Nature Conservation Area since 1987 and the large amount of wildlife it hosts confirms that this is its most appropriate use. The remaining enclosed water areas along the coast are small lakes whose importance is restricted to recreational activities. Erikli, Saka and Mert should be included within the Wildlife Protected Area of the Demirkoy Forest, which they border.

Marmara Sea lagoons

The Sea of Marmara is a small enclosed basin linking the Black Sea to the Aegean Sea. Salinity is less than 30 ppt due to the Black Sea waters flowing from east to west. During the summer, pure seawater enters through the Dardanelles Strait.

Surface temperatures range from approximately 6°C in winter to around 24°C in summer.

Pollution and nutrients levels are increasing at an alarming rate due to the huge conurbation of Istanbul, the industrial zone of Izmit and the large holiday housing settlements along its northern and south-western coasts, together with other minor industrial centres in Bandirma, Tekirdag and Marmara.

The 12 lagoons of the smallest Turkish sea add up to a water surface of about 2 650 ha (Table VI), with a negligible yearly fish catch of less than 13 tonnes, mostly produced by the lagoons of Küçükçekmece, Dalyan and Poyraz. In the latter two, the unit production is about 43 kg/ha (STM and MARA, 1997).

Table VI: Marmara Sea Lagoons of Turkey (Source: MoFAL)

Lagoon	Surface (ha)	Province	District
Küçükçekmece	1 400	Istanbul	-
Tuzla	70	Istanbul	-
Hersek	150	Yalova	Karamürsel
Arap Ciftliği	550	Bursa	Karacabey
Dalyan & Poyraz	170	Bursa	Karacabey
Yarıntı	19	Balıkesir	Misakça
Tahir	5	Balıkesir	Misakça
Tuzluazmak	6	Balıkesir	Misakça
Hoyrat	10	Çanakkale	Karabiga
Karabiga Gölleri	80	Çanakkale	Karabiga
Cardak Buruniçi	180	Çanakkale	Lapseki
Catalazmak Gölleri	10	Çanakkale	Umurbay

Once very productive and renowned for the taste of their fish, most of them are now in a critical state due to pollution and neglect (Velioglu *et al.*, 2008).

Küçükçekmece is the largest lagoon of the Marmara but its environment is in a critical status due to the heavy pollution discharged into it by the large human settlements and the industrial areas of its catchment area.

Bücürmene lagoon in the Marmara Sea coast, photo ©H. Deniz

A group of medium-size lagoons - Tuzla, Hersek and Arapcifligi - that were once highly productive are now abandoned and being gradually filled with sediment since their connection to the sea is completely silted up.

Çardak Buruniçi is a coastal lagoon with full marine conditions, which could host a diversified aquaculture activity.

The other water bodies investigated are remainders of oxbow lakes (in Turkish: azmak). Their small dimensions, the difficult access and the surrounding tourist settlements that are mushrooming along the Marmara coast barely warrant the kind of rehabilitation works proposed for larger lagoons aimed at the environment and at fish production.

The feasibility plan therefore foresees the following interventions for the family-scale fishing model with limited restoration interventions could be applied only in the most favourable azmak, such as Tuzluazmak.

Aegean Sea lagoons

The Aegean coast stretches from the border with Greece southward to the Dalaman peninsula, which is conventionally used to delineate the border with the Mediterranean Sea (STM & MARA, 1997). It is an oligotrophic full strength saline sea with a complex coastline profile dotted with many islands that create complex current patterns. Salinity is typically around 38 ppt.

Due to their limited number, major rivers that flow into the Aegean have only local effects in reducing salinity in the estuarine areas.

On average, surface temperatures are higher than in the Black and Marmara Seas and increase from North to South, from around 11^{0}C in winter to around 24^{0}C in summer. Pollution and high nutrient levels occur in a limited number of places, the industrial zones of Izmir and Dalaman in particular.

Sewage inputs come from the major tourist centres and harbours and from the large holiday housing settlements.

The Aegean coastline is the richest in terms of lagoon number (29), area (20 000 ha) and fish production (562 tonnes). However, two lagoons (Bafa and Koycegiz) account for 60 percent of the total area, whilst their fish production stands at 22 and 350 tonnes respectively. The latter accounts for about 40 percent of the total Turkish lagoon catch (Deniz, 2002). Both were marine gulfs during the Roman age, the huge amount of sediments caused by deforestation and subsequent erosion of the Anatolian Plain caused them to evolve into landlocked lakes. Table VII shows the Aegean lagoons (see the three photos below).

Karina lagoon in the Aegean Sea coast, photo ©H. Deniz

Table VII: Aegean coastal lagoons of Turkey (Source: MoFAL)

Lagoon	Surface (ha)	Province	District
Taşaltı Golu	30	Edirne	Enez
Dalyan Gölü	250	Edirne	Enez
Bucurmene	50	Edirne	Enez
Karagöl	300	Edirne	Enez
Vakıf Tuzla Gölü	80	Edirne	Vakıf
Tuzla Gölü	340	Edirne	Erikli
Anafarta Tuz Gölü	400	Çanakkale	Eceabat
Tuz Gölü	250	Çanakkale	Gökçeada
Diremli Azmağı	?	Çanakkale	Gülpınar
Çıkrıkçı Dalyanı	10	Balıkesir	Edremit
Alibey Dalyanı	30	Balıkesir	Ayvalık
Uzun Göl	4	Balıkesir	Altınova
Dalyan Gölü	50	İzmir	Çandarlı
Zeytindağ Dalyanı	57	İzmir	Çandarlı
Homa + K.Kırdeniz	1 400	İzmir	Merkez
Rauf Paşa Dalyanı	850	İzmir	Çandarlı
Çakal Burnu Dalyanı	150	İzmir	Çandarlı
Gebekilise Gölü	60	İzmir	Selçuk
Karina Gölü	2 460	Aydın	Söke
Arapça Gölü	130	Aydın	Yenihisar
Karaca Dalyanı	538	Aydın	Yenihisar
Bölme Dalyanı	195	Aydın	Yenihisar
Kabahayıt Dalyanı	305	Aydın	Yenihisar
Bafa Gölü	6 500	Aydın	Yenihisar
Güllük Dalyanı	25	Mugla	Milas
Tuzla Lagünü	320	Mugla	Milas
Köyceğiz Gölü	5 500	Mugla	Köyceğiz

From the national border with Greece, delineated by the River Merit, southward to Izmir, the most important is the Enez lagoon complex (Tatli, Dalyan and Bucurmene lagoons). At present, the remaining lagoons along this stretch of coastline receive little interest for exploitation for fishing and aquaculture. Most of them are abandoned and are used only for some sport fishing during the tourist season.

The lack of environmental management is rapidly isolating these environments from the sea, making them prone to sedimentation. The only exception is Anafarta Tuz lagoon, on the

Gallipoli peninsula, where a Turkish company has started a project of intensive fish farming and lagoon management employing Italian expertise.

Tuzla has quite a large surface area but its output of only 4 tonnes in 1995 clearly reveals the presence of severe constraints to proper exploitation. Alibey Dalyanı is a shallow bay separated from the sea by an artificial barrier. A project for its development as a fish farm is under way. Zeytindag Dalyani, in the province of Izmir, had the same structure of embayment enclosed by fences, but it is now abandoned.

Dalyan lagoon could be an interesting – although modest-sized – lagoon environment. Unfortunately a dirt road, built right across the lagoon to reach the coastal area where very large tourist settlements are mushrooming, isolates the lagoon from any water exchange with the sea. Homa lagoon and its smaller twin Kucukkirdeniz lagoon represent a large and once productive lagoon system, which is now affected by the absence of freshwater sources.

Köyceğiz lagoon on the Aegean Sea coast, photo ©H. Deniz

Rauf Pala lagoon represents an interesting example of “artificial lagoon”, which is actually a portion of the Izmir Gulf close to its northern coast and separated by an embankment equipped with fish barriers and gates. Little can be done, however, to balance the progressive impoverishment and degradation of the gulf waters, which are heavily polluted by the nearby town.

The lagoons along the delta of the Great Menderes represent one of the most interesting wetlands of Turkey. They were included in 1993 in the National Park of the Dilek peninsula under the jurisdiction of the Ministry of Forestry, which is preparing a master plan for the entire area. Due to the area's importance for fishing and wildlife and the problems that affect the whole delta, guidelines for its rehabilitation and fishing enhancement will be developed.

The Bafa lake is a brackish landlocked lake that was once an open gulf and which gave rich catches up until recently (445 tonnes in 1987). Its current very low production (22 tonnes in 1995) is directly linked to the troubled connection with the sea via the Ancient Menderes River. Since it is currently managed to avoid saltwater inflow into the plain's irrigation network, it hampers a proper stocking of the lake with adequate numbers of seed fish from the sea. The change in ownership from private hands to the government, and the ensuing new management, is reportedly a second major cause of this dramatic fall in the fishing output.

The three southernmost lagoons of the Aegean coast – Güllük, Tuzla and Koycegiz – are all managed by fisher's co-operatives and equipped with traditional fishing installations. Koycegiz is the Turkish lagoon with the largest landings: its 350 tonnes in 1995 account for about 40 percent of total lagoon catches. Its unit production of about 64 kg/ha is also good when compared with its large surface area. The production values reported for the small Güllük lagoon appear clearly too high to be reliable and probably represent the total landings of the cooperative, including the sea catches.

Mediterranean southern coast lagoons

The Mediterranean Sea along the Turkish coasts presents a fairly stable salinity of 39 ppt and the highest surface temperatures found in the whole Mediterranean Basin. Summer temperature is around 28°C, whereas in winter it is around 18°C. There is a small increase in the temperature averages along the coast from west to east. Like the Aegean, it is a true oligotrophic sea with the lowest productivity among the Turkish marine areas

There is a small increase in the temperature averages along the coast from west to east. Like the Aegean, it is a true oligotrophic sea with the lowest productivity among the Turkish marine areas. Industrial pollution shows a peak in the Iskenderun Bay, Icel and, to a lesser extent, Antalya, due to the discharges of their industrialized areas. Other sewage inflows also come from the major tourist centres and the proliferation of large holiday housing settlements.

There are 17 lagoons (Table VIII), making up an area of approximately 11 600 ha, with an overall production of 183 tonnes in the Mediterranean southern coast.

Table VIII: Lagoons along the Mediterranean s.s. coast of Turkey

Lagoon	Surface (ha)	Province	District
Gelemiş Gölü	7	Antalya	Kaş
Beymelek Lagünü	250	Antalya	Kale
Akgol	820	Icel	Silifke
Paradeniz	590	Icel	Silifke
Dipsiz Dalyanı	50	Icel	Tarsus
Tuzla Gölü	800	Adana	Tuzla
Akyatan Gölü	5 000	Adana	Karatas
Agyatan Gölü	1 100	Adana	Karatas
Çamlı Dalyanı	1 300	Adana	Yumurtalık
Yelkoma Dalyanı	640	Adana	Yumurtalık
İkizler Kum Ocağı	13	Hatay	Erzin
Yeniyurt Gölcükleri	9	Hatay	Dörtyol
Seçil Gölcüğü	5	Hatay	Dörtyol
Tarım İl Müd. Göl.	8	Hatay	Dörtyol
Tigem Gölcüğü	24	Hatay	Dörtyol
Katipoğlu Göleti	13	Hatay	Dörtyol
Tuz Göleti	6	Hatay	Samandağ

The Mediterranean lagoons are mainly found in the delta areas of the only three major fluvial systems along this coastline: the Meric River, near Silifke, and the Rivers Seyhan and Ceyhan in the Cilician Plain (Deniz, 2004).

The delta of the Seyhan and Ceyhan Rivers is the last lagoon area before the national border with Syria. The lagoons of this area stand out as among the most important of Turkey by their size, fish production potential and naturalistic interest (STM and MARA, 1997).

Beymelek lagoon in the Mediterranean Sea coast, photo ©H. Deniz

Main typologies

The application of the management models outlined below does not include the creation of the rehabilitation works recommended to restore or protect the lagoon environment. Their implementation is largely independent of the vocational exploitation of the lagoon and is based mainly on considerations concerning its existence, both present and future (Miller *et al.*, 1990). The vocational management models for the Turkish lagoons are as follows:

a. environmental conservation;
b. environmental conservation plus traditional fishery ;
c. traditional fishing;
d. adapted valliculture (extensive and semi-intensive lagoon farming);
e. adapted integrated valliculture (extensive, semi-intensive and intensive aquaculture);
f. recreation;
g. research;
h. education; and
i. research and education.

The lagoons of Turkey have been arranged according to their potential suitability to the above-mentioned models.

Environmental conservation

This model applies to lagoons where the protection of their rich wild fauna is a priority and local inhabitants do not claim the need to exploit the environment for fishing or other uses. The waterbody is therefore managed as a wildlife reserve where the only human activities allowed should be surveillance, scientific research and education. The opportunity of giving space to ecological tourism along watched nature trails should be encouraged, provided that wildlife is not disturbed, particularly during the breeding seasons.

Environmental conservation and traditional fishery

This model applies to those lagoons where the protection of their rich wild fauna remains a priority, while at the same time there is a well-established local fishing activity that causes negligible disturbance to wildlife.

Water management should give priority to the preservation of favourable habitats for migrating and nesting birds, as well as the associated fauna and flora. The control of water level and quality of freshwater inflow requires the greatest attention to prevent alterations that would hamper the particular characteristics of these environments (Miller *et al.*, 1990).

The traditional fishing activities practiced in these lagoon systems should be maintained and upgraded by means of low impact technologies, such as increased stocking of target fish and more selective fishing equipment. Rehabilitation interventions, if necessary, should be aimed at creating or preserving favorable environmental conditions for both the target fishing species and the natural components. The lagoons that may enter this category of management model are many water bodies to which some protection status is already granted.

Traditional fishery

Where wildlife and other natural characteristics do not endorse priority and where more sophisticated fishing management forms cannot be applied for economic reasons, traditional fishing becomes the eligible choice. Generally speaking, the creation or maintenance of a lagoon environment favourable to fish also helps the conservation of its wildlife – in some well-known cases even to excess – for instance the fish-eating birds increase with the increase in the fish population. Average production figures remain in the lower limit of the production range for lagoon environments.

The present practice could be upgraded by improving the fixed capture devices and the fish juveniles stocking management. More selective fishing practices that prevent the killing of undersize fish should be adopted. The model is a sort of simplified valliculture, mainly because a proper water management system, one of the most typical features of valliculture, cannot be implemented. The greater the control over the environment, the better the final output. Specific training is also recommended for the local fishers.

Adapted valliculture

The most advanced management of Mediterranean lagoons takes its name from the Italian word *valli*, which means embanked portions of a usually brackish-water lagoon.

Since the valliculture model foresees a closer control on fish and the environment than in the case of the traditional lagoon fishing, its application requires the fulfillment of more specifications that can be summarized as follows:

- The introduction of systems for a complete management of water supply and circulation by means of sluice gates, and as a consequence the modification of certain water quality parameters;
- The close control of fish migratory movements by means of hydraulic control and the operation of the fishing installation;
- The selective fishing of sizes and species by means of the fishing installations;
- The stocking of live fish to overcome dangerous climatic conditions;
- The temporary stocking of seed fish of selected species under controlled environmental conditions; and
- The introduction of live organisms as integration to the natural diet of selected species.

The main diverging points from the “original” model, under the prevailing conditions in Turkish lagoons are:

- The control of seawater by means of sluice gates, since they are hardly economically justified;
- The control of freshwater by means of sluice gates, due the conflict involved with agriculture and their hard economic justification; and

- The optimization of lagoon water circulation by means of an internal network of ditches, since they are hardly economically justified.

The adoption of this tailored valliculture model requires first of all the modification of the applicable fishing legislation.

Integrated aquaculture

The rising running costs together with the decline of production have forced the extensive aquaculturists to look for alternative solutions aimed at increasing their landings.

The actions undertaken to complement extensive aquaculture (valliculture) production can be summarized as follows:

- Give priority to the farming of valuable species, mainly bass for climatic reasons, but also bream and eels, according to the practice of intensive farming in either concrete tanks or earth ponds placed in separate sectors;
- Introduce only hatchery-reared seed fish of selected species;
- Enhance the lagoon's natural productivity by discharging the effluent of the intensive sector into the waterbody;
- Introduce pre-grown fingerlings and yearlings of bream to avoid the risk of their wintering since they reach a marketable size already at the end of the first rearing season;
- Culture of new species for aquaculture, in particular extensive and semi-intensive shrimp farming in earth ponds, intensive fattening of salmon and sea trout, the latter two take place only during the cold season and use the facilities of the intensive sector that are not used at that time for bass and bream (which are wintering in dedicated facilities);
- Work the pond bottom by means of appropriate machinery to aerate and oxidize it and to release the nutrients trapped in the sediments;
- Improve the wintering facilities so that even the extreme climatic conditions that may take place – however rarely – can be faced; and
- Create semi-intensive ponds for a polyculture of selected species, usually breams and mullets.

These innovative practices could raise the production by well over 200 kg/ha, depending on the size of the intensive sector and that of the semi-intensive ponds.

Legal framework and constraints

The rich wildlife, with many species of animals and plants occurring either exclusively in Turkey or in extraordinarily high numbers, requires recognition as an important heritage of humankind deserving adequate protection. The Government of Turkey has signed several treaties by which the obligation to conserve the country's internationally important treasures of nature is confirmed. Among those international treaties that directly refer to the protection of lagoon systems, there are three particularly important ones:

- The Barcelona Convention for the Protection of the Mediterranean Sea against pollution was signed by the Turkish Government in 1976. This convention includes a protocol on the establishment of SPAs, which was also signed by Turkey. The government subsequently established several protected areas, one of which is the Goksu delta.
- The Bern Convention for the Protection of European Wildlife and Natural Habitats was signed by the Turkish Government in 1984. The signatories assumed the obligation to develop national policies and appropriate plans as well as to provide the necessary training and education for the protection of those plant and animal species that are in

danger of extinction. The convention compiles lists of threatened plants and animals and with the signature of the convention, Turkey agreed to protect these species and their habitats.

- The Ramsar Convention on Wetlands of international importance, especially as waterfowl habitats, aims to prevent actions that could lead to the loss of wetlands. Wetlands contribute significantly to the balance of the water regime, provide shelter for plants and animals, especially for water birds, and constitute a substantial economic, cultural, scientific and recreational resource. Turkey became a party to this convention in 1994 and subsequently designated five areas to be covered by the convention. These areas include the Goksu delta.

The Turkish Government has not only expressed its will to conserve nature by signing the above conventions, it also implements them on a national level and takes actively part in the international discussion process. In addition, the Turkish Government furthers conservation issues on other international levels, e.g. by being a party to the World Heritage Convention of Unesco. However, its signature is still lacking under the Convention on Biological Diversity, which emphasises the need for protection and utilisation of biological diversity and the equitable sharing of profits made by its utilisation.

There are six types of protection status concerning lagoons in Turkey.

National parks

- Dilek peninsula and Menderes delta national park. Park since 1966, in 1993 it includes the Menderes delta area. Main lagoons: Karina Gölü, Mavi Gölü, Kara Göl
- Gelibolu peninsula national park. One lagoon: Anafarta Gölü

Specially protected areas

- Göksu delta. It includes the lagoons of Akgol and Paradeniz; total area 4 350 ha; declared on 2/3/1990; incorporated in the list of Ramsar Treaty on l7 May 1994.
- Koycegiz lake and lagoon. It includes the lagoon of Gelemiş Gölü; total area 19 000 ha; declared on 18 January 1990.

Natural parks

- Bafa lagoon; declared on 8 July 1994.

Nature conservation areas

- Yumurtalık Gölü: declared on 8 July 1994; total protected area: 16 430 ha.
- Sarıkum Gölü: declared 30 July 1987; total protected area: 785 ha.

Wildlife conservation areas

- Kızılırmak delta (Samsun): declared Site for the Preservation and Reproduction of Waterfowl on 1979; it includes Cernek Gölü; protected area: 13 125 ha.
- Simenlik lagoon (Terme): declared Site for the Preservation and Reproduction of Waterfowl on 1975; protected area: 16 043 ha.
- Homa lagoon (Izmir): declared Site for the Preservation and Reproduction of Waterfowl on 1980; it comprises Homa lagoon and Çamaltı Salt Marshes (Çamaltı Tuzlası); protected area: 8 000 ha.
- Akyatan lagoon (Adana): declared Site for the Preservation and Reproduction of Waterfowl on 1987; protected area: 7 500 ha.
- Gökçeada (Çanakkale): declared on 1988; protected area: 28 204 ha.

- Seyhan River and Tuz lagoon (Adana): declared Site for the Preservation and Reproduction of Waterfowl on 28 December 1995; protected area: 5 796 ha.

Site Areas of the Regional Councils for the Protection and Control of Natural and Cultural Heritage

- Kızılırmak delta (Samsun): decision No.1908/21 April 1994
- Sarıkum lagoon (Sinop): decision No. 1198/21 November 1991
- Dalyan, Işık and Taşaltı lagoons, (Edirne, Enez): decision No.2232/17 March 1995
- Karagöl lagoon (Edirne, Enez), decision No.1908/7 February 1992
- Tuzla lagoon (Edirne, Keşan): decision No.1733/10 February 1994
- Poyrazlar lagoon (Sakarya, Adapazarı): decision No.2916/16 January1993
- Hoyrat Gölü (Çanakkale, Biga): decision No.2211/13 January 1995
- Çardak lagoon (Çanakkale, Çardak): decision No.2441/27 May 1995
- Çandarlı, Dalyan lagoon (İzmir, Dikli): decision No.4274/10 March 1993
- Dalyan (Muğla, Köyceğiz): decisions No.3722/27 March 1990; 2342/15 November 1994
- Gelemiş lagoon (Antalya, Kaş): decision No.719/20 June 1987; 1273/14 April 1990 and 4933/17 June 1995
- Yumurtalık lagoon (Adana, Yumurtalık): decision No.1609/19 November 1993

11.3 Living resources

Turkey is situated at the meeting point of Asia with Europe, at a short distance from Africa. Fauna and flora include, therefore, Asian and European and also African elements. The encounter and overlap of different biogeographical regions gives Turkey an outstanding importance as an area with a high number of plant and animal species including many endemic forms.

Living resources in Turkish lagoons have not been studied scientifically in detail yet. The most comprehensive studies are carried out by MoFAL under a World Bank Project concerning the Management and Development Strategies for Lagoons along the Turkish Coastline and their Rehabilitation in 1995–1997. More detailed studies were realised for four lagoons (Akyatan lagoon, Akgol-Paradeniz lagoon, Enez lagoon complex and Bafa lagoon complex) during the project.

More focus has been given to the lagoons of Homa (Alpaz and Kınacıgil, 1988; Onen and Yaramaz, 1992), Kucukcekmece (Asıkoglu, Gonenc and Basdemir, 1992; Gonenc, 1990), Köycegiz (Yerli, 1991; Erkakan and Yerli,1994), Karina (MARA, 1984; Cirik *et al.*, 1992), Homa (Cirik *et al.*, 1992), Camlik and Yelkoma (Dikel, 1990), Bafra (MARA, 1983; DSI, 1979; Uyanık and Goksel, 1991; Gonulol, 1993), Gulluk (Egemen, 2004), Yumurtalık and Akyatan (Kulan, 1984), Cardak-Burunici (MARA, 1989; MARA, 1996), Enez (MARA, 1994; Velioglu *et al.*, 2008), Karacabey (Tatar, 1987), Homa and Karina (Yaramaz *et al.,* 1992).

11.3.1 Flora

Phytoplankton: A predominance of freshwater species was reported during winter, due to the low salinity caused by precipitation and the discharge of drainage channels. A lower plankton density and composition was found in June-November due to high salinity values resulting from the high evaporation rate and absence of freshwater inflow. Marine species are present in all stations, but their relative abundance is higher in the area closer to the pass.

Diatoms (*Bacillariophyta*) are the most common group, followed by *Cyanophyta, Chlorophyta* and Dinophyta. Among diatoms, the species indicating brackish water conditions such as *Navicula, Nitzschia* closterium, *Surirella fastuosa, Striatula unipunctata, Fragilaria capucina, Campylodiscus adriaticus, Surrirella striatula, Biddulphia pulchella* were common throughout the year. Among *Cyanophyta, Lyngbia* and *Gornphosphaeria* were common in terms of geographical distribution and in all seasons, being more abundant during the hottest months. Since in *Chlorophyta* species, diversity increases with decreasing salinity, a larger number of species was observed in winter and spring.

The species composition is rather poor, being represented mainly by diatoms typical of brackish water conditions, such as *Navicula, Nitzschia closterium, Nitzschia paradoxa* and *Surirella fastuosa*, which are also the most common species together with *Pleurosignia sp*.

Aquatic vegetation: The vegetation mainly occupies the widest part of the lagoon, between the pass and the freshwater outlet of the drainage channel – about 1/3 of its total surface. In this area, an estimated 70 percent of the bottom is covered by submerged plants.

The plants form a thick mattress, which occupies the entire water column. Since the tallest plants are longer than the water depth, they remain on the surface over the submerged strata. The lower strata of this environment are therefore at risk of anoxia and do not provide favorable conditions for the fauna. Moreover, the vegetal biomass is so dense that it uses up the nutrients available in the water, reducing them to the planktonic fraction, and contributing to its depleted state. This reflects on the higher levels of the food chain as it means that less nourishment and nourishment of inferior nutritional quality is made available to those benthic organisms, which, in turn, represent an optimal feed for many fish species of commercial importance. The vegetation cover gradually disappears westward with almost none in the western corner of the lagoon.

The species consist mainly of dense meadows of *Ruppia spiralis* and *Potamogeton pectinatin*, *Potarnogeton crispus, Chary vulgaris, Myryophyllum spicatum, Ceratophyllum dernersum, Phragmites australis, Juncus acutus, Nymphaea alba occurs, Chara hispida, Phragmites comunis, Juncus litoralis* the latter more abundant in the area closer to the outlet of the drainage channel. These species are indicators of confined environment, according to the scheme of quantitative biological organization of coastal lagoons proposed by Guelorget (Perthuisot, 1983). In particular *Ruppia spiralis*, a monocotyledon with a high tolerance to salinity variation (between 1.5 and 80 ppt), indicates a zone where the influence of seawater is reduced to a minimum and corresponds to zone four of the freshwater sub-area of their classification scheme. *Potamogeton pectinatin* indicates quasi-freshwater conditions and characterizes zone five of the sub-area of the same scheme, i.e. a lagoon area closer to the continental environment than to the marine environment. Scattered patches of *Zostera marina* appear in the area near the pass. No significant presence of green algae (*Chlorophyceae*) of the genera *Ulva, Enteromorpha* and *Chaetomorpha* was observed. This is probably due to the scarce nutrient load (N and P) available, which is almost completely used by the aforementioned macrophytes.

Other plant species are *Pinus nigra, Cistus cretius, Cyclamen trochopteranthum, Hyacinthus arientalis, Iris xanthospuria, Lunipus orientalis, Lunipus angustifolius, Nerium oleander, Pinus brutia* and *Sternbergia eischeriana.*

11.3.2 Aquatic fauna

*Zooplankton: A*s for phytoplankton, the great variations in salinity create the conditions for an alternation of coastal marine species such as *Oitliana nana* and *Acartia clattsi*, and inland species such as *Brachionus plicatilis* and *Brachionus angularis*. Rotifers were abundant in winter, with prevalent freshwater conditions, whereas bivalve larvae replaced them in spring and summer.

The species composition is not rich, being represented mostly by rotifers of the genera *Brachionus, Keratella* and *Synchaeta*. *Cladocera* and *copepoda* are the other groups represented in the samples. Zooplankton plays an important role in the production dynamics of the lagoon as it represents the suitable feeding for many larval and post larval stages of commercially important fish species such as mullets, seabream, seabass and sand smelt. Other zooplanktons are *Keratella quadrata, Polyarthra vulgaris, Daphnia galeata, Bosmina longirostris, Chydorus piger, Cyclops vicinius* and *Calanipora aquaedulcis.*

Benthos: Among *Anellida*, the most common species was *Hediste diversicolor* and *Polydora ciliata*. The molluscs were represented mostly by the bivalves *Cerastoderma glaucunt* and *Abra alba* and the gastropod *Pyrenella conica*. The group of crustacea was the richest in species with *Gammarus aequicauda*, *Gantmarus subtypicus* and *Corphium orientale* the most diffused. The chironomid larvae form the third group of benthic organisms with four species identified, of which *Dicrotendipes tritonuts* was the commonest.

The benthos of lagoons is very homogenous and relatively scarce. The number of species, which is never high as less than a dozen species, were found in even the richest stations, decreases from the zone near the pass to the inner parts of the lagoon, where only chironomid larvae and the bivalve molluscs *Cerastoderma glaucum* and *Abra alba* were found (Guelorget and Perthuisot, 1983). Other important benthos species are: *Hediste diversicolor, Polydora ciliata, Cerastoderma glaucunt, Abra alba, Pyrenella conica, Gammarus aequicauda, Gantmarus subtypicus, Corphium orientale, Dicrotendipes tritonuts, Oligochaeta, Polychaeta, Nematoda, Gastropods (genus Planorbis, Gyraulus, Valvata, Physa and Radix), Bivalves (genus Unio and Anodonta, Teodoxus* sp.*, Cerastoderma glaucum, Polypedilum sp., Fleura lacustris, Theodoxus anatolica, Gyraulus albus, Potamopyrgus* sp.*, Cerastoderma glaucum, Iharix* sp.*, Heteromastus filiformis, Palaemonetes antennarius* and *Chara hispida.*

Crustacea: The Mediterranean and Aegean lagoons host a large population of the blue crab, *Callinectes sapidus*. At present, it is not exploited because demand for it collapsed after the closure of the only processing plant for crab meat, located near Karatas. Its abundance now represents a pest for the fishing industry since the crabs enter the fishing installation and damage the fish, thus lowering their commercial value. Their abundance in the catches also means that it takes a longer time to process the fish for selling. Other species observed are the common prawn *Palaemon* sp. and the crab *Carcinus mediterraneus* in the area closer to the pass. None of them are exploited by the tenant (Table IX).

Table IX: Main crustacean species in Turkish lagoons

Blue crab	*Callinectes sapidus*
Common prawn	*Palaernon* sp.
Crab	*Carcinus mediterraneus*
White claw crayfish	*Astacus leptodactylus*

Fish: The typical Mediterranean brackish water fish fauna, mainly characterized by grey mullets (several species), seabass (*Dicentrarchus labrax*), gilthead seabream (*Sparus aurata*) and eel (*Anguilla anguilla*). Some marine species such as *Diplodus sargus* and *Mullus barbatus* are also present, but confined to the area more influenced by seawater.

In the period from February to April, large numbers of fish fry and fingerlings migrate into the lagoon. During the April survey seabass, seabream, mullets and sole fry were observed. Despite the large number of migrating juvenile soles (*Solea kleini*), larger specimens appear to be absent from lagoon catches for the most part (Table X).

Table X: Main fish species in Turkish lagoons

European seabass	*Dicentrarchus labrax*
Gilthead seabream	*Sparus aurata*
European Eel	*Anguilla anguilla*
White seabream	*Diplodus sargus*
Red porgy	*Pagrus pagrus*
Red mullet	*Mullus barbatus*
Klein's sole	*Solea kleini*
Common carp	*Cyprinus carpio*
Pike-perch	*Stizostedion lucioperca*
Striped Mullet	*Mugil cephalus*
Golden grey mullet	*Liza aurata*
Thin Lipped Grey Mullet	*Liza ramada*
Redbelly Tilapia	*Tilapia zilli*

11.3.3 Wildlife

Water birds: The main breeding birds of the Turkish lagoons are marbled teal, *Marmaronetta angustirostris,* and the ducks, *Aythya nyroca, Holycon smymensis* and *Cryle rudis*, which are threatened on a global basis.

Other breeding birds which enable lagoons and its immediate surroundings to be classified as a "wetland of national importance" include the purple gallinule, *Porphyrio porphyrio*, the collared pratincole, *Glareola pratincola*, the spur-winged plover, *Hoplopterus spinosus,* the stone curlew, *Burhinus oedicnernus*, the marsh harrier ,*Circus aeruginosus,* the Kentish plover, *Charadrius alexandrinus,* the little tern, *Sterna albifrons*, the black francolin, *Francolinus francolinus, Holycon smymensis* and *C. rudis.*

The sandy beach along the seashore of the Akyatan lagoon is one of the most important nesting beaches of marine turtles in the Mediterranean. It is one of the two most important Mediterranean nesting beaches of the green turtle *Chelonia mydas,* which is classified as "threatened" on a global basis. Loggerhead turtles *Caretta caretta* (classified as "endangered") also nest, although in smaller numbers (Baran and Kasparek, 1988).

The fallow deer, *Dania damn,* live in the afforestation area between the lagoon and the sea. The population originated from three individuals that escaped from captivity in 1987/88. Today's population is 23. Although this is not a natural population, it is of great interest as fallow deer is native to Turkey and this may be a good example of re-introduction. The origin of the escapees should be revealed. The badger, *Meles meles,* is also found in the forest. Jackals *Canis aureus* are found particularly in the dune areas. The long-tailed mongoose *Herpestes ichneumon* is relatively common along the Akyatan shores.

Koycegiz is a location where the Nile turtle (*Trionyx triunguis*) can be spotted. It is a turtle with a soft shell, thence also called African soft-shell turtle, which is about one meter in size. It is a protected, thermophile species. Consequently, it is often seen near the thermal springs along the fault line. The species occurs near the sea, in lagoons, lakes, rivers and canals, both in fresh and brackish waters. The Nile turtle is mainly aquatic and will only leave the water for short periods to rest in the sun. In the Köyceğiz-Dalyan SEPA, oviposition takes place at the brackish waterside of İztuzu Beach.

11.4 Land and water management

Most lagoons along the Turkish coastline would benefit from some rehabilitation intervention. For a large number of lagoons (51, covering 56 percent of the total surface) the pace of their environmental degradation and the importance of preserving the existing activities, as well as their rich wildlife, suggest that rehabilitation measures are not only necessary, but indeed pressing.

However, in recent years, due to the development of touristic facilities, unconscious and uncontrolled utilization, disposal of industrial and domestic wastes into the lagoons and siltation, many lagoons are not utilizable. The majority of irrigation systems which were and are being constructed are in the productive deltas where there are large lagoons as well. Besides this, for the lack of environmental awareness, lagoons have become discharge places for waste and polluted waters.

The enhancement of traditional fishing and the introduction of sustainable aquaculture practices is one of the most powerful means for preserving the lagoon environment from major damage while making a renewable use of the available resources.

Turkey has 72 lagoons along the 8 333 km long coastline. The main activity is traditional fishing, which is carried out in 43 lagoons, representing 64 percent of the total surface. Different types of nature and wildlife protection have been declared for an outstanding 83 percent of the lagoon surface, amounting to 23 water bodies. However, the ban of traditional fishing in protected areas is not fully enforced.

The Turkish Government is giving a preference to protect and rehabilitate the lagoons. For this reason, most of the lagoons are under the Government's protection. At the same time, the Government would like to increase lagoon fisheries production by using the best lagoon management models.

11.5 Lagoon exploitation

Turkish lagoons are used for many purposes and the following criteria were established for classification by MoFAL (1997): fishing, aquaculture, recreational, tourism, hunting, wildlife protection, reed harvesting, cattle grazing, leech collection, research and training, none, previously exploited, and "but currently abandoned" (Table XI).

Table XI: Main activities performed in the Turkish lagoons (Source: MoFAL)

Activity	Number of Lagoon	%	Surface (ha)	%
fishing	43	60	23 085	64
aquaculture	3	4	5 650	16
recreation/tourism	14	19	6 730	19
hunting	32	44	19 522	54
wildlife protection	23	32	30 289	83
reed harvesting	5	7	12 619	35
cattle grazing	6	8	2 559	7
other catches	5	7	2 559	7
research and training	4	6	3 100	9
none	23	32	1 815	5
of which abandoned	16	22	1 674	5

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11.5.1 Aquaculture and capture fisheries

Facilities

Fishing gear: The most common fishing gear is trammel net, longlines, fyke nets, knots and fish barriers. In Table XII are given the most common fishing gear used in the Akyatan lagoon.

Table XII: Characteristics of the most common fishing gear used in Akyatan lagoon

Net type	Period (from – to)	Mesh size (mm)	Material length (m)	Material	Knot or knotless
Trammel net (fanyalı ağ)	Nov.-Jan	30-34	100	nylon	knotless
Longlines (paraketa)	Sept.-Feb.	-	500	nylon	-
Fyke nets (pinter)	Sept.-Feb.	20 -22	7	nylon	knots
Fish barriers (kuzuluk)	Jun.-Feb	10-20	138	-	mixed*

* Framework: wooden paling; wall screens: iron; catching chambers fences: marsh reed

Boats: Boats in Turkish lagoons are mainly fiberglass-lined wooden barges. No engines are allowed during the fish catch, but sometimes motor-boats are used to tow the barges to the fishing areas when they are too far from the landing site. Distribution of boats is done according to the gear on board: the "*kucuk mavna*" are used for all kind of fishery into the lagoon whilst the "*buyuk mavna*" are used only for fish collection from the fish barrier and its transport to the landing site.

Other facilities: There is only one hatchery in the Beymelek lagoon, operated by the Ministry of Food, Agriculture and Livestock.

Work force, establishments and institution

Fishers come from the villages surrounding the lagoon.

In addition to fishery co-operatives, fishery cooperative associations, the Central Associations of Fishery Cooperatives (SUR-KOOP) and Central and Regional Fishery Advisory Committees have an important role to play as representative stakeholder organizations. Currently there are 490 fisheries cooperatives as recognised under the Fisheries Cooperative Law 1163, with a total membership of 24 920; note that a coop can be established as long as there are at least seven signatories to the memorandum of incorporation.

A minimum of seven or more cooperatives that have the same objectives can establish a central union. There are 13 regional unions of fisheries cooperatives within Turkey, comprised of reportedly 482 cooperatives and one central union in Ankara.

Lagoons are mainly operated by cooperatives, except in a few lagoons. The Turkish Fisheries Law gives priority to fisheries cooperatives in lagoons.

Aquaculture and capture fisheries management

The same model of traditional fishery management is currently adopted by almost all Turkish lagoons where this activity is still present. The only notable exceptions are the lagoons of the Kizilirmak delta, where the need to keep their freshwater characteristics does not allow the adoption of permanent passes and the use of a fixed fishing trap (STM and MARA, 1997). Lagoon fisheries are usually managed as follows: from June to January, the fishers trap the fish inside the lagoon by dosing the fishing barrier – a fixed trap usually made of a paling framework and marsh reed and fences placed at the lagoon mouths to the sea. The fishers do this when they believe that enough fish have entered the lagoon, then catching the fish trapped in commences immediately after the closure of the barrier.

Fish barrier in the Koycegiz lagoon, photo ©H. Deniz

Beside the fishing barrier, different kinds of stationary or moving nets may also be employed to make catching quicker and more complete. Inside the lagoon, fishers mainly use stationary gear such as trammel nets, longlines and fyke nets.

From an ecological point of view, the lagoon fish stock is an exclusive function of the following factors: natural recruitment and the lagoon's natural capacity to entrain and retain the colonizing stages that immigrate.

To summarize, this management scheme exploits the lagoon as a mere fishing trap, representing merely a basic level of lagoon exploitation for fishing purposes. By definition and for the considerations given below, this practice involves several constraints to the optimal use of the lagoon environment and its fish resources.

The traditional structure has several limits hampering its present functionality. As it stands, it will not be able to meet any increased fish production resulting from possible improvement measures (STM and MARA, 1997):

- The structure as a whole is poorly selective, allowing the capture of undersized fish;
- Its maintenance costs are high in terms of workforce and materials, which should be replaced every year;
- The total fish holding capacity of the standard fishing chamber is less than 10 m^2 since the largest part of it is taken up by a deep V-shaped slide entrance for fish, which frequently forces the fishers to fish in overcrowded conditions;
- The reed fences are not a suitable barrier against the blue crabs, which enter the capture chamber and eat the fish trapped inside, which cannot escape attack;
- Its home-made construction does not make the "*kuzuluk*" a suitable tool for catching eels due to their ability to escape loose barriers; and
- The walls of the capture chambers are made of reed fences and rusty iron grids with rough surfaces which may damage fish skin after prolonged stocking, thereby reducing their commercial value.

Moreover, current regulations on the use of the fishing installation do not really engender a strict control of fish flows into and out of the lagoon, for the following main reasons:

- When the barrier is open, juveniles can enter the lagoon and adult fish can return to the sea;
- There are no special side entrances to allow fingerlings to move towards the lagoon; and
- There are no enclosures for the temporary stocking of undersized fish that become trapped in the fishing installation that are not suitable for the market.

Artificial propagation

The hatchery in the Beymelek lagoon operated by the Ministry of Food, Agriculture and Livestock has a 20 million fry production capacity. The main species are seabass and seabream.

No other actions to enhance productivity (pre-fattening, artificial nursery areas, restocking, intensive aquaculture, predator control, selective fishery, wintering strategies and seaweeds control) are present in Turkish lagoons.

Productions from Turkish coastal lagoons

The total 2008 fisheries productions for Turkish coastal lagoons added up to 1 600 tonnes for the Mediterranean Sea and to 1 100 tonnes for the Black Sea (Table XIII). Single annual productions are available for Akyatan lagoon (1986–2008) and for Koycegiz lagoon (1978–2008).

Table XIII: Total fisheries production in Turkish lagoons by coastal areas in 2008 (Source: MoFAL)

Coastal areas	Number	Surface area (ha)	Production (tonnes)
Black Sea	14	3 139	1 100
Marmara Sea	12	2 650	45
Aegean Sea	29	20 000	1 125
Mediterranean s.s.	17	11 600	430
Mediterranean region (subtotal)	58	34 250	1 600
Total	72	37 389	2 700

Akyatan lagoon: According to the catch figures made available by the tenant, total catches of all species have decreased since 1978, with the exception of 2008. The blue crab, once a relatively valuable product of the lagoon, is at present of no value. A blue crab canning factory close to Karatas closed its business activities, which are otherwise highly successful, because of the excessive rent costs requested by the municipality.

Fish catches have been dominated by seabream and seabass over the past 20 years. Seabream increased its relative catch by more than 15 percent from 1978 to 1995, whilst declining in overall weight from 180 to 15 tonnes. Seabass showed a similar trend, increasing from 9 percent of the catch in 1978 to 19 percent in 2008. Eel catches have increased more than fivefold in relative importance in the same years, but total figures decreased from 8 tonnes in 1978 to 3 tonnes *Akyatan lagoon*: According to the catch figures made available by the tenant, total catches of all species have decreased since 1978, with the exception of 2008. The blue crab, once a relatively valuable product of the lagoon, is at present of no value. A blue crab canning factory close to Karatas closed its business activities, which are otherwise highly successful, because of the excessive rent costs requested by the municipality.

Mullet are commonly separated into two size groups: large grey mullet (*M. cephalus*, local name "*kefal*") and mullet lighter than 250 g (local name: "*tubara*"). In the latter, all the mullet species common in the area are included. The overall mullet catch plummeted from 110 tonnes in 1978 to 31 tonnes in 2008 (Fig. 1).

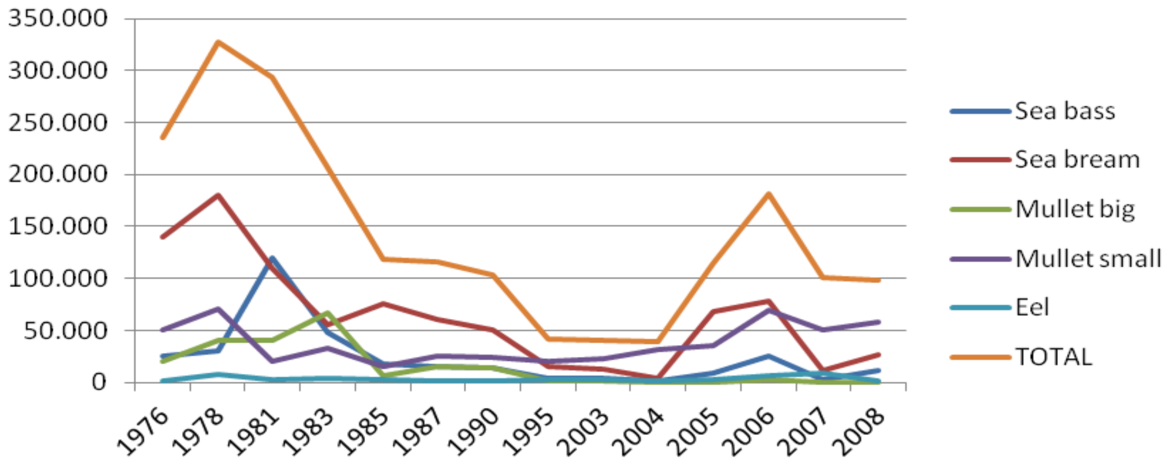

Figure 1. Fish production trend of Akyatan lagoon in 1976–2008 (tonnes) (Source: MoFAL)

To evaluate the lagoon's productivity, calculations have been made considering a permanent water-covered area of 5 000 ha. Productivity was highest in 1978 with 65 kg/ha, whilst current productivity is only 4.6 kg/ha.

Table XIV: Fish landings from Akyatan lagoon 1986–2008 (tonnes)

Year	Seabass	Seabream	Mullet (big)	Mullet (>250 g)	Eel	TOTAL
1976	25 000	140 000	20 000	50 000	1 200	236 200
1978	30 000	180 000	40 000	70 000	8 000	328 000
1981	120 000	110 000	40 000	20 000	3 000	293 000
1983	47 841	55 497	66 409	33 457	3 821	207 025
1985	17 960	76 000	6 160	15 800	3 058	118 978
1987	15 000	60 000	15 000	25 000	1 100	116 100
1990	13 500	50 600	14 100	23 800	1 250	103 250
1995	4 408	14 918	950	20 710	3 120	41 106
2003	3 720	12 850	800	22 900	2 350	40 500
2004	1 234	4 266	404	31 250	1 488	38 624
2005	8 901	67 561	550	35 129	2 654	114 795
2006	25 238	77 924	2 618	69 209	6 121	181 110
2007	2 934	11 105	660	50 322	8 841	100 271
2008	11 366	26 819	585	58 610	996	98 376

Total production has progressively decreased and shows an evident negative trend since 1978, with the only exception being the year 2008. Some figures of previous years given by the renter cast even more evidence on the fishery decline when compared with the period 1986–2008 (Table XIV).

Koycegiz lagoon: According to the catch figures made available by the tenant, total catches of all species have decreased since 1978, with the exception of 2008. Fish catches have been dominated by mullet, eel and seabass over the past 20 years. Mullet is in the front rank with 209 tonnes (78.4 percent) and carp with 23 tonnes (8.8 percent), eel with 15 tonnes (5.9 percent), seabass with 8 tonnes (3 percent) and seabream with 4 tonnes (1.6 percent) are fallow mullet in Koycegiz lagoon complex. Production of other fish amounts to 4 tonnes

(2.2 percent). The biggest portion of mullet belongs to *Mugil cephalus* with market value and egg roe.

The Koycegiz lagoon Complex has an integrated management system. There are 34 fish barriers and five fish traps with eight inner courts which are used for fishing activities. Fish production changed from 109 tonnes in the last two decades to 520 tonnes in 2008. Average production is 265 tonnes in the last 20 years. Average fish production per ha was 48 kg (20–81 kg) in the past decade (Table XV, Fig. 2).

Table XV: Fish landing from Koycegiz lagoon 1978–2008 (tonnes) (Source: MoFAL)

Species / Year	Mullet	Carp	Eel	Seabass	Seabream	Others	TOTAL
1978	304	35	23	12	6	10	390
1980	212	24	16	8	4	6	270
1982	141	16	11	5	3	4	180
1984	251	28	19	10	5	7	320
1986	126	14	10	5	2	3	160
1988	243	27	19	9	5	7	310
1990	287	32	22	11	6	7	365
1992	207	23	16	8	4	6	264
1994	350	39	26	14	7	9	445
1996	86	10	7	3	2	2	110
1999	408	46	31	16	8	11	520
2003	301	34	23	12	6	7	383
2005	275	32	21	11	5	6	350
2008	167	19	12	6	3	4	211

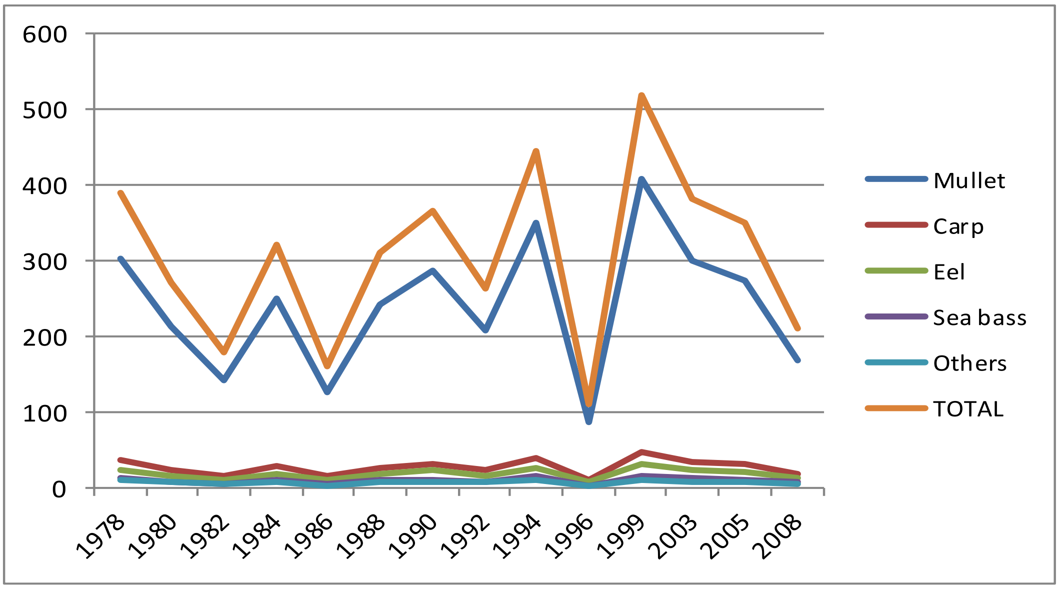

Figure 2. Fish production trend of Koycegiz lagoon in 1978–2008 (Source: MoFAL)

11.5.2 Other uses

Recreational activities

In addition to fishing activities, there are also other activities such as recreation, hunting, wildlife protection, reed harvesting etc. (Table XVI).

Table XVI: Main activities performed in the Turkish lagoons (Source: MoFAL)

Activity	Number of Lagoon	%	Surface (ha)	%
fishing	43	60	23 085	64
aquaculture	3	4	5 650	16
recreation/tourism	14	19	6 730	19
hunting	32	44	19 522	54
wildlife protection	23	32	30 289	83
reed harvesting	5	7	12 619	35
cattle grazing	6	8	2 559	7
other catches	5	7	2 559	7
research and training	4	6	3 100	9
none	23	32	1 815	5
of which abandoned	16	22	1 674	5

11.6 Interactions among aquaculture, capture fisheries and the environment in coastal lagoon management

Almost all lagoons in Turkey are owned by the State, which rents them to fishers ' cooperatives and private companies for periods from a minimum of three years, to a maximum of 15, depending on the presentation of fishery development projects. The renting fee is highly variable and indexed to the inflation rate, a mechanism which, apparently unconnected to actual production levels, results in large discrepancies among lagoons.

Cattle grazing is mainly practiced in the Black Sea lagoons and Bafra in particular, where a large wetland is currently exploited as a wet pasture for about 12 000 cattle and water buffalo during the dry season. Elsewhere in Turkey, this practice seems to have lost importance.

Reed harvesting is a locally common activity that produces for both the domestic market (building materials) and for exports (France and Germany mainly). A typical characteristic is the demand for reeds, which takes place every spring with the need to rebuild the traditional fishing installations at the lagoon mouths.

Different types of nature and wildlife protection have been declared for as much as 83 percent of the lagoon surface, amounting to 23 water bodies. However, as shown by the figures on hunting recorded in 32 lagoons, the ban on this activity in protected areas is not fully enforced. The most effective protection is given by a “national park” or “specially protected area” status, which sets rigid limits for human activities according to their subdivision in fully protected zones and buffer zones.

The unexploited lagoons account for only 5 percent of the overall surface. However, 70 percent of these – which are today abandoned – hosted a productive fishery industry until only recently, an indication of a dangerous trend threatening their conservation.

Some larger lagoons are also used by local universities for basic and applied research as well as, to a much lesser extent, for student training.

The traditional fishery is being used where wildlife and other natural characteristics do not require priority and where more sophisticated fishery management forms cannot be applied for economic reasons. In general, traditional fishery also has a limited impact on the environment and on wildlife.

The present practice could be upgraded by improving the fixed capture devices ("*kuzuluk*") and the fish juvenile stocking management. More selective fishing practices that prevent the killing of undersized fish should be adopted.

This management model is either already practiced in, or proposed for, those water bodies whose size and poor accessibility barely justify costly interventions: Ahubaba Gölleri, the Misakça lagoon complex, the Karabiga lagoons; Catal Azmak Gölleri, Kumkale lagoon, Diremli Azmağı, Alibey Dalyani, Zeytindağ Dalyani, Rauf Paşa Dalyani, Cakal Burnu Dalyani, Gebekilise Goleti, Güllük Dalyani, Tuzla lagoon and Dipsiz Dalyani.

According to the Circular of Recreational Fisheries in Sea, people who have the Amateur Fisherman Certificate can catch maximum 2 kg or 10 fish during fishing season.

There is no important conflict with commercial and recreational fishing activities.

There is no direct interaction among different fishers groups. Sometimes, fisheries cooperatives complain to seine netting fishers who fish just in front of the mouths of lagoons.

In the sea, there can be competition and conflicts between aquaculture and other coastal sectors such as tourism, urbanization, recreation, maritime and environmental protection.

Most of the lagoons are under protection, and authorities are not given permission to establish fish farms in the protected lagoons. There are a few aquaculture facilities surrounding the lagoons.

Fish and other seafood are generally consumed in the local markets and restaurants. The price is higher than aquaculture products. There is no competition and conflict between lagoon products and other aquaculture and capture fishery products because of the small amounts of lagoon production.

The Ministry of Food Agriculture and Livestock prohibited collecting juveniles in the wild for aquaculture purposes since 2000.

There are no fish farms and restocking activities in the lagoons and therefore no risk for genetic impact or escape on wild stocks and no risk for desease spreading.

Turkey is of great importance for migrating birds. Many pass the country and rest here on their way from and to their African winter quarters. In particular, river deltas with lagoons serve as first stop-over sites after a long and exhausting flight over the sea and provide undisturbed resting places for the migrants to prepare for their further journey; 441 species of birds have been recorded and 315 of them breed in the country or are supposed to breed. There is no significant impact of ichthyophagous birds on Turkish lagoons fish populations.

11.7 Environmental considerations

Lagoons are marginal environments, the full understanding of which requires large hydraulic and biological data sets. Their biological simplicity – scarce species diversity and large numbers of few species - is only apparent, since small alterations of ecological components may have a much greater effect on the ecosystem due to the coexistence of a higher number of limiting conditions when compared with more stable habitats.

Being an empirically developed human activity, managing a lagoon for fishing is a business that is a great deal more complicated and difficult than operating an intensive fish farm, to which a lagoon system is often linked (Miller, Pietrafesa and Smit, 1990).

As a rule, interventions aimed at restoring a degraded environment and improving its marketable resources require an extensive information background, a cost-benefit analysis of the proposed measures, a mathematical model to confirm the feasibility of the proposed hydraulic actions, and a serious assessment of environmental impact. Moreover, the restoration of a lagoon is a far-reaching task that involves many agents that are not always perceptible as being linked to the lagoon environment.

The following recommendations summarize the necessary steps that should be taken at various levels to assure a brighter future for the remaining Turkish lagoons. With the obvious adaptations, these proposals apply to the entire lagoon system of the Mediterranean since its populations, although different by origin and traditions, show a strikingly similar attitude towards the exploitation of coastal wet areas. There are a series of fundamental causes of wetland destruction and degradation in Turkey, as well as several other immediate factors that adversely affect wetlands.

Due to their basic importance for a real preservation of the environment over the long term, they are fully endorsed by the current studies. The effects of their possible acceptance obviously go far beyond the scope of which embraces the preservation of the lagoon system. However, it is only through such structural interventions at the level of public awareness, political will and technical issues that the environment can be preserved, and with it the quality of life, which stands as the final goal of any environmental policy.

Appropriate planning of the wetlands

The bodies in charge of land-use planning for wetlands should be improved and made more effective when addressing the task of harmonizing social growth, population increase and lagoon exploitation in a sustainable manner.

Possible solutions entail: (a) the enhancement of their technical capabilities by the upgrading of the available qualified staff and technical facilities; (b) the improvement of co-ordination and co-operation with related bodies involved in the planning process, as well as between local and central authorities; and (c) better identification of the target wetland areas and catchment basins, considered as a whole. The complexity of the approach required by an exhaustive analysis could limit the planning capacity assigned to local authorities, who may not be provided with the skills and expertise required. A multi-sectoral planning approach is recommended, as well as the involvement of local populations.

Increasing public and political awareness of wetlands value

The creation of environmental awareness among populations should be promoted at every social level, starting from the first steps by way of teaching courses through the educational system. A widespread and growing environmental consciousness attitude would have a better chance of influencing political will, thereby spurring it towards such environment-friendly decisions as to fully benefit people with the common value of wetland areas.

Harmonization and upgrading of environmental legislation

The existing legislation concerning the environment should be revised and updated to meet fully the environmental challenges faced by wetlands. Pollution control regulations should be backed up by other legal issues more specifically linked to its prevention and sustainable management of renewable resources. The legal arrangements on environmental conservation should be harmonized and amended to rectify any intrinsic contrast or repetition. By making them clearer and unequivocal, the practical difficulties for their implementation would be reduced.

Financial policies

The value of wetlands in general – and of lagoons in particular – extends well beyond the immediate economic gain from fishing and other activities such as cattle grazing, hunting or leisure, and includes indirect use through their environmental services and non-use or preservation values. Any financial policy involved in the development of lagoon areas should consider the above issues.

Legislative basis for sustainable development

A legislative basis through which a sustainable development may be carried out should be set up, in accordance with the Agenda 21 Action Plan adopted upon the 1992 Rio Environment and Development Conference, which has a binding nature for the countries.

Enforcement of the existing legislation

Greater efforts are recommended to provide the necessary means to ensure the enforcement of the restrictions provided for under the applicable legislations. This is true particularly in the case of hunting, where wardens are scarce and ill equipped to provide an effective service.

Coordination of lagoon-resource management

A coastal lagoon committee with the responsibility for central co-ordination is believed to be of great usefulness for guiding the management of wet areas. Its main targets would be of guidance, supervision and control of every action involving the lagoon heritage. It should gather and manage a constantly updated informative system, with links to other bodies at the national and international level.

An association of lagoon tenants is seen as a further step towards reaching a completely shared awareness and consciousness of the various interests involved in lagoon management. This association can favour the feasibility of common objectives through shared means, aiming at a constant improvement of the environmental and productive conditions. This association would greatly benefit from having well-established relations with professional associations of fish farmers at the national and international level.

Lagoon environment rehabilitation

Freshwater supply

An adequate supply of clean freshwater should be granted to lagoons. The amount should be tentatively based on the required salinity values acceptable for the target species, whether they be fish, waterfowl or cattle, depending on the exploitation plan designed for each lagoon. In setting the needs, the water balance, renewal rate through the pass (or passes) and ground water availability should all be taken into consideration.

If a continuous supply cannot be assured, the option of transforming part of a lagoon into a freshwater reservoir should be evaluated, taking into account the possible effects on the surrounding lowland (marsh) area. As far as possible, water should not come from agriculture drainage networks due to its load of agrochemicals and sediments. Only where adequate treatment has proved to reduce contamination to a minimum should such a freshwater source be considered. Conversely, any surplus of irrigation water exceeding the requirements for crops would be acceptable, and re-planning of existing irrigation schemes should be considered in order to gain as much clean water as possible to recover the water balance of wet areas.

Water from rivers should be analyzed prior to its use for the lagoons water renewal since it is frequently contaminated with domestic and industrial wastes and certain sediment content. Where good environmental conditions of the flowing water are found, a stable connection with the lagoon should be secured, which ideally should be governable with effective devices. At the same time, there should be a better use of the irrigation water to reduce waste and losses. Cooperation with the General Directorate of State Hydraulic Woks (DSI) in this area should be enhanced at every level.

Seawater supply

With some noticeable exceptions, a sea communication (pass) should be provided, depending on the lagoons' dimensions, their planned fishing production and the recognized need of a better colonization by marine organisms. Any action aimed at opening or restoring the existing pass should be preceded by a mathematical model that will ensure the adequate design and assess the impact on the hydro-dynamism at the sea and lagoon levels. Such studies should also be backed up by favorable cost-benefit analysis. Large lagoons, high production rates or special rehabilitation needs may justify the making of one (or more) permanent channels protected by rip-rap breakwaters at their seaward mouth. The construction of such structures, although costly and "heavy", represents the final solution to the need of a permanent opening to the sea and their additional benefits include reduced maintenance and a long effective lifetime.

Water circulation

Better water circulation should be provided if it appears limited by geomorphologic (shallowness) or biological (dense coverage of aquatic plants) factors. The excavation of a central ditch of an appropriate size, connecting the mouth of the lagoon with its inner part, would be recommendable.

The cutting of reeds and aquatic plants along an appropriate pattern of preferential waterways departing from the inflow or branching main internal channels would favour circulation without excessive investment. For interconnected water bodies, the opening or widening of communicating channels would improve overall circulation and water exchange. The orientation of the new channels should be planned depending on the prevailing wind directions.

Sedimentation

The continuous discharge of sediments into a lagoon should be halted or reduced to sustainable levels. In the absence of the recommended measures to counter soil erosion, the adoption of settling ponds could provide relief to the problem. Their maintenance has to be assured to ensure their working capacity over time. An excessive submerged plant growth due to fertilizer inflows should be controlled to reduce the amount of organic debris contributing to the sedimentation process. Boats equipped with weed mowers could be used for this purpose.

Coastal erosion

The erosion of the sandbars and dunes separating lagoons from the sea must be stopped to avoid the evolution of the lagoon in a bay. Since this usually happens when the river sediment load is reduced or cancelled by the settling action of upstream dams, actions should be taken to reintroduce these sediments in the last river tract. For the same reason, sand extraction from the riverbed has to be stopped.

The design of new dams should consider the possible effects on the shoreline up to a suitable distance from the river outlet. From this point of view, the construction of the Kayraktepe Barrage on the Göksu River, the only undammed river in this part of the Mediterranean, would probably cause the disappearance of the unique configuration of its delta over the next 40–50 years. The installation of groins to reduce beach erosion could be envisaged in the higher-risk cases.

Agrochemical pollution

Any effort to promote a more rational use of agrochemicals should be made by government authorities at national and local levels. As long as farmers follow the principle “the more water, fertilizer, pesticide we use, the better our crops will grow”, public authorities must deal with the situation by setting limits and educating people as to the benefits of more reasonable and responsible attitudes. The final success of such education will, however, depend on a reliable assessment and monitoring of the pollution situation, to which therefore a very high priority level must be allocated.

Within certain limits, the introduction of nutrients may not be a totally negative factor per se. If properly managed, the lagoon environment is highly efficient as a nutrient trap and in recycling them into biomass. However, agriculture nutrients washed out by run-off and drainage waters are associated with toxicants whose effects on the lagoon biota are clearly negative. For the same reason, the air-spraying of insecticides should be avoided in areas used for agriculture close to lagoons.

Other pollution

Industrial wastewaters and domestic sewage must be prevented from entering all lagoons, both directly and via the drainage inflow. In some parts of the Turkish coastline, sea pollution is raising growing concern. This problem should be given high priority.

Settlements

In principle, holiday housing and tourist resorts should be carefully avoided within the boundaries of the lagoon area and near connection passes. The ban does not include the central facilities for the lagoon fishing operations. To provide a true deterrent, provisions should be made for illegally constructed buildings to be pulled down and economic sanctions levied. According to the development model adopted, appropriate soft infrastructure may be allowed for eco-tourism initiatives.

Flooding

The risk of flooding from nearby rivers or drainage network, although always present, should be prevented as much as possible by the construction of embankments and other preventive facilities along the most affected water streams.

Lagoon environment monitoring

An adequate ecological monitoring of lagoons should be implemented to provide a complete assessment of the modifications likely to be caused by the proposed rehabilitation measures. Monitoring programmes should include both physico-chemical and biological aspects so that measured biological responses can be related to specific environmental parameters and/or physical modifications. They should rely on the implementation of thorough inter-calibration exercises.

Other activities in the lagoon environment

Hunting control

Illegal hunting practice in protected wetland is not admissible and must be stopped. The existing prohibitions have to be enforced and adequate means must be provided (wardens, vehicles, communication devices, etc.).

Upgrading the protection status

Since most of the protection levels granted to wetlands imply only a ban on hunting, it would be preferable to reclassify most sensitive areas by upgrading their protection status.

Ecotourism

The development of ecologically and socially sound types of tourism in more or less undisturbed natural protected lagoon areas, although complex to set up and manage, should be evaluated for selected sites. Its top priorities should include:

- minimizing negative environmental impacts; and
- preventing socio-cultural side effects and processes of cultural erosion and using its revenues to contribute to funding conservation.

Cattle grazing control

Uncontrolled grazing should be replaced by planned pasture areas exploited on a rotational system to prevent the destruction of vegetation coverage and to decrease soil erosion. Here, local authorities and cattle breeders should fully co-operate to work out feasible solutions.

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PART 3

CASE STUDIES

CASE STUDY 1: FISHERY ACTIVITIES AND MANAGEMENT PLAN IN THE VENICE LAGOON

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The Venice lagoon, located on the Adriatic coast, is the largest coastal lagoon in the Mediterranean which covers, including the islands, an area of approximately 55 000 ha. It is parallel to the coast and it extends between the mouths of the rivers Piave (North) and Brenta (South). The lagoon is separated from the Adriatic Sea by a coastal strip made of narrow parallel strands to the coast interrupted by three inlets: Lido, Malamocco and Chioggia. The lagoon is divided by three watersheds into four sub-basins: Treporti (15 000 ha) and Lido (10 000 ha) in the North, Malamocco (17 000 ha) in the center and Chioggia (13 000 ha) in the South. Each sub-basin is in communication with the sea through the inlets; deep waterways depart from these inlets and then branch into progressively smaller and less deep channels, ending with small intertidal channels (called *ghebi*). More than four-fifths of the lagoon water surface is affected by tidal excursion that is the highest in the Mediterranean Sea, with a range of about 1 m between low and high tide. About 80 percent of the entire lagoon consists of water areas; the rest is made up of land and salt marshes.

The Venice lagoon can be considered as a transitional aquatic ecosystem that interconnects the continental and marine ecosystems, which have different energy fluxes, nutrient cycles and characteristics of the biota. The total surface includes 33 000 ha of water areas and more than 9 000 ha of extensive fish farms.

There are several different fishery activities such as capture with fyke nets, Manila clam culture, mussel culture, oyster culture, fish farms, juveniles capture, and other generally seasonal fishery activities. During the period of the Serenissima Republic (1261), a specific authority (the *Magistratura della Giustizia Vecchia*) was created to regulate fisheries and to set minimum size at capture. At present, the Venice Water Authority (*Magistrato alle Acque*) and the Province of Venice and Padua legislate all the fishery activities in the Venice lagoon. There are two main fishery activities in the Venice lagoon: fyke nets fisheries and Manila clam culture.

With fyke nets, the fishers capture many different species: Boyer's sand smelts (*Atherina boyeri*), cuttlefishes (*Sepia officinalis*), brown shrimps (*Crangon crangon*), common prawns (*Palaemon* spp), grass gobies (*Zosterisessor ophiocephalus*), eels (*Anguilla anguilla*), flounders (*Platichthys flesus*), grey mullets (family Mugilidae), gilthead seambream (*Sparus aurata*), European seabass (*Dicentrarchus labrax*) and green crabs (*Carcinus aestuarii*).

Fyke nets fishery activities are practiced by 112 fishers that are divided into 7 cooperatives (two fishers are not included into any cooperative). The Cooperativa San Marco from Burano, Cooperativa Piccola Pesca from Pellestrina and Coopesca from Chioggia are the principal ones, with more than 80 percent of fishers affiliated with them. Since work is very hard and needs daily fyke nets cleaning and maintenance, young fishers prefer to work in Manila clam culture. From 1997 to 2005, the number of fyke net fishers decreased, and only since 2008 there was a little increase, probably due to the crisis in Manila clam culture and Adriatic clam fishery (Fig. 1). Average fishers age (Fig. 2) is still increasing, showing a constant aging of the category, and a low percentage of women fishers.

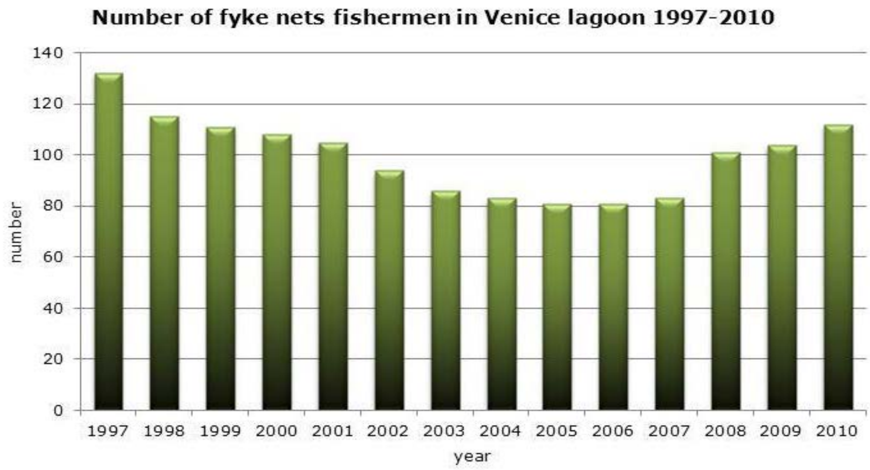

Figure 1. Evolution of number of fyke net fishers (1997–2010)

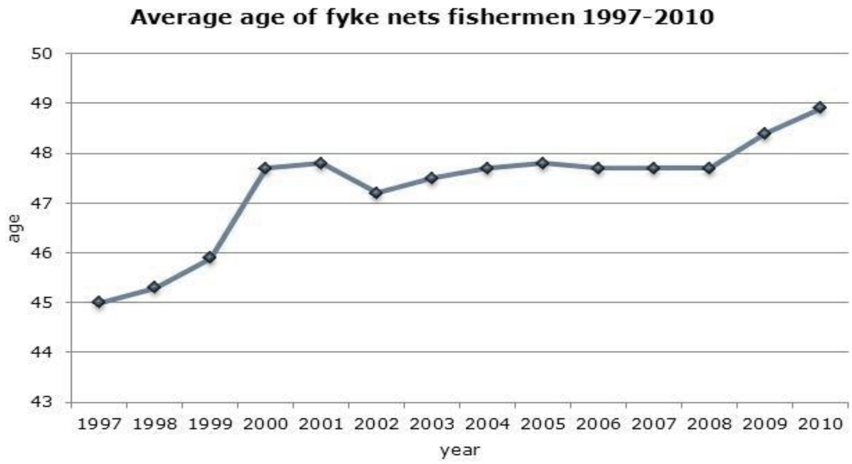

Figure 2. Average age of fishers (1997–2010)

Fyke nets are set in the lagoon in two main periods (Fig. 3): in spring (called *quaresima*) and in autumn (called *fraima*), with almost 6 000 terminal collecting bags (the traps situated at the fyke nets end). Summer and winter are the two periods where fishers usually do the maintenance and therefore there are fewer nets in the lagoon (even because in that period the Venice lagoon is really poor with fishes).

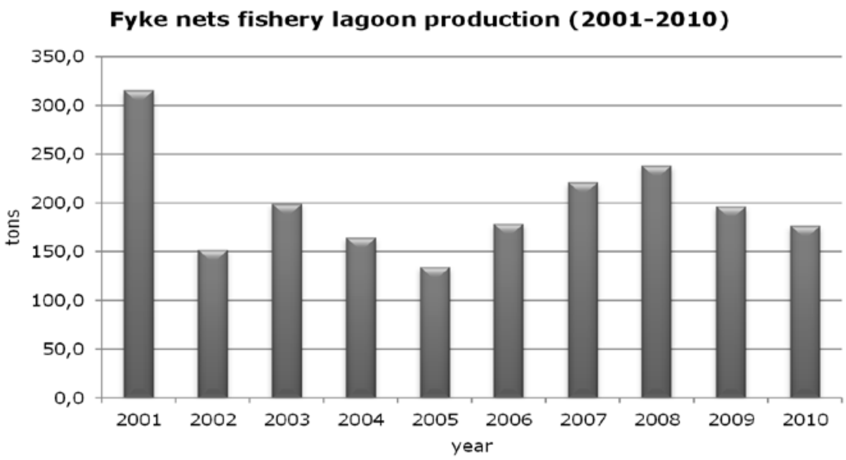

Figure 3. Seasonality of terminal collecting bags (2010)

During the 1990s, the average annual production from these traditional fishing systems was estimated at approximately 480 tonnes/year. In 2001 (Fig. 4), production started to decrease and in the recent years it ranged between 140 and 240 tonnes.

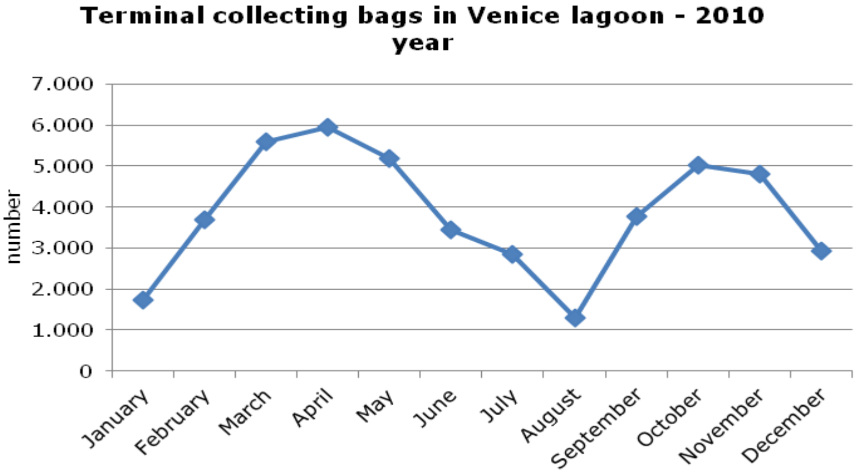

Figure 4. Production from fyke nets in the Venice lagoon (2001–2010)

One of the most important productions of the Venice lagoon is the green crab, *Carcinus mediterraneus*. The life cycle of this species allows fishers to use two different phases of its life: one is in autumn when the females undergo sexual maturity and are captured and sold as *mazenete* (Fig. 5), the second, in both spring and autumn when males and females shed their carapace to grow (Fig. 6). In this very moment, fishers take these crabs out of water to block the processes of calcification of the exoskeleton and sell the crabs without carapace; for this reason this product is called *moeca,* which means soft crabs.

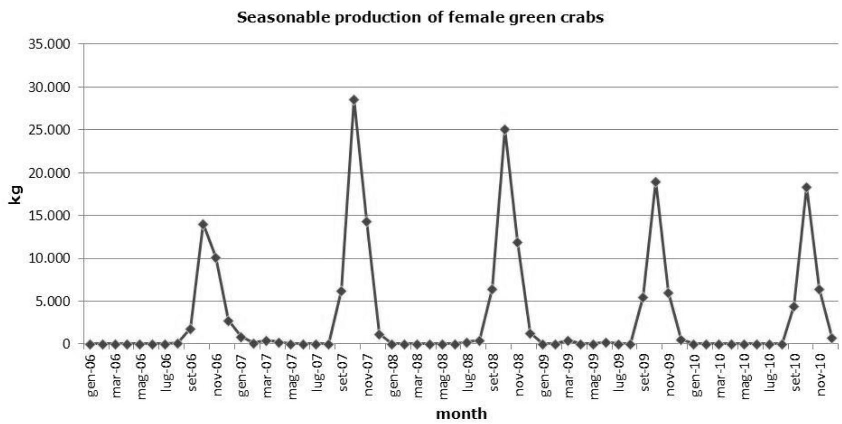

Figure 5. Production of female green crabs (2006–2010)

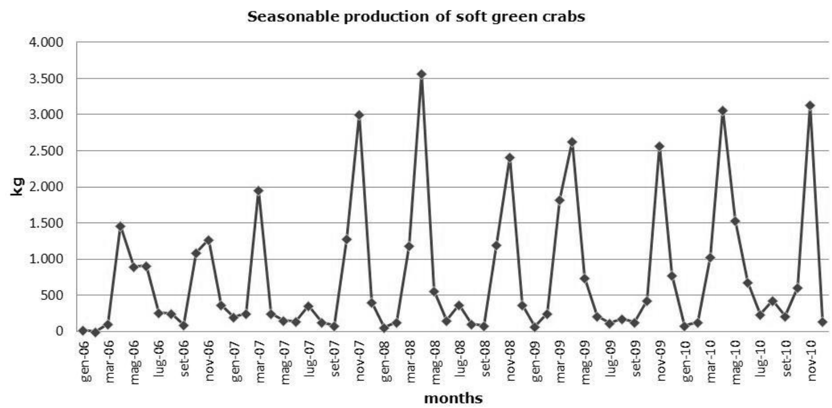

Figure 6. Production of soft green crabs (2006–2010)

This activity ranges between capture fisheries and aquaculture because fishers catch the crabs from the lagoon water and select only those that should become a soft crab; they then put them back in water in some special baskets (called *vieri*) where they wait until the carapace starts to open; they finally move them into a new basket ready for sale. This is a very peculiar and specialized delicatessen from the Venice lagoon that could reach the price of more than 80.00 €/kg, because nowadays there are so few fishers who carry out this activity and know how to select a good crab that will become a soft crab, from a 'crazy crab' (as fishers call it) that will not turn soft in that period.

Another important fishery activity in the Venice lagoon is the farming of Manila clams. In 1983, a new species of clam, *Tapes philippinarum*, was introduced in the Venice lagoon as an experimental trial to evaluate the possibility of diversifying shellfish production, until then limited mainly to mussels. In a few years, this species colonized large areas of the lagoon due to a high growth rate and to the ability to adapt to a wide range of environmental conditions (salinity, temperature, sediment type, etc.). The exploitation of natural beds started with the use of highly mechanized fishing systems such as hydraulic dredges (up to the mid-1990s and then forbidden), or small boats with a dredge without teeth (*rusca*) and harvesting machines (*vibrante*) (from the mid-1990s onwards). The *rusca,* drawn by an out-board engine, is a fishing tool used in the lagoon of Venice since 1994–95; it was modified by the professional experience of fishers, improving its efficiency and capture capability. This tool is formed by a steel box (*cassa*); parallelepipe-shaped, with a pentagonal mouth 0.7 m wide, 0.4 m high and 30 kg of weight. The *cassa* has two lateral sled-runners that prevent its ditching into the sediment. The *rusca* is used at a maximum depth of 1.5 m and it is attached with chains to the stern of the boat. The boat used for this type of fishing is provided with two engines: one used during normal sailing and an auxiliary one (15-25 hp) used only during fishing operations. The auxiliary engine operates only in the fishing zone and it is used to move sediment and clams and direct them into the net.

The harvesting machines "*vibrante*" is formed by a parallelepipe-shaped cage, tapering in the side of the mouth. The mouth is about 2 m wide (blade length) and 30 cm high; the length of the cage is 1.45–1.80 m and its weight is 600 kg. On the cage, there are one or two electric or hydraulic vibrating engines and an electric or hydraulic cable. There is also one anterior or two lateral sled-runners. The fishing operations of this tool are very similar to the ones of the hydraulic dredge. When the vessel reaches a suitable fishing place, the speed is slowed down and the stern anchor is dropped. The vessel goes on for 200–300 m, and when it is almost stationary, the steel cage is lowered on the bottom to begin dredging operations. Dredging takes place drawing the cage with the stern winch, which rewinds the steel cable of the anchor. The vibrating system of the cage allows the removal of sediment and a first selection of the catch. When the fishing operation is finished, the steel cage is taken on the stem and the catch is conveyed to a sieve.

In 1995, by decision N° 4752, the Venice Water Authority (*Magistrato alle Acque)* authorized the use of six lagoon water spaces for a total of 270 ha to be used as edible shellfish farming. The surface dedicated to the Manila clam farm increased until 2002 with more than 3 500 ha; in 2005–2007 the extension decreased to more or less 3 000 ha and at present only 2 577 ha are authorized for Manila clam farming. This reduction was due to a general review of the areas by the Venice Water Authority (*Magistrato alle Acque)* to discover if some fishers who had an area really used it to farm *Tapes philippinarum*.

Nowadays clam farming involves more than 700 fishers who are affiliated to 73 local entities; compared with fyke net fishers these are (more or less 5 years) younger and with a little female presence (almost 6 percent).There are approximately 400 fishing boats divided into more or less 70 harvesting machines and 330 *rusca*. In 2006, they were more than 550 with 450 *rusca* and around 100 harvesting machines; this decrease demonstrates the crisis that this fishery activity is undergoing.

Production soared in the middle of the 1990s (Fig. 7) and remained over 35 000 tonnes/year until 2000, when it dropped to less than 20 000 tonnes/year. From 2008 to 2010, there was a big a crisis of this activity (no official data are available for 2010 at the time of writing, though it is possible to believe that production is still decreasing) and a parallel problem: even though the official or weighted production is always lower, informal communications and press articles report different data. With a substantial chaos in the management of juvenile and commercial size clams, many illegal actions can occur even because it seems very difficult to monitor the whole activity. Due to the absence of control, the real problem is the lack of traceability of the product, in order to guarantee the healthiness of the product by the local veterinary service.

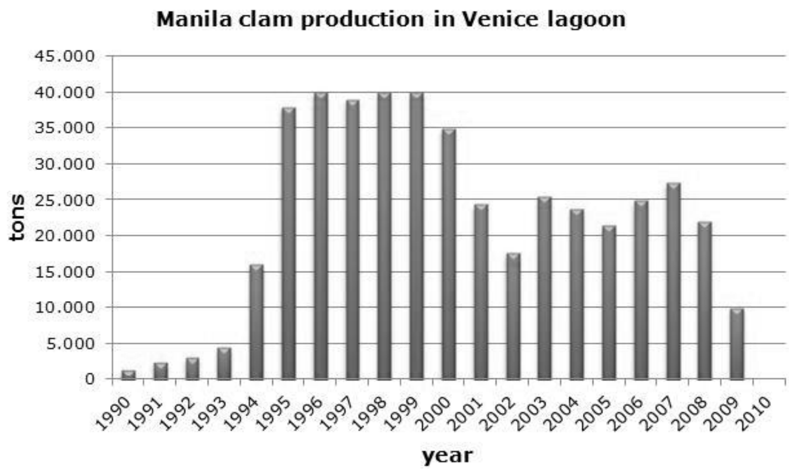

Figure 7. Manila clam production in the Venice lagoon (1990–2010)

Other important fishery activities in the Venice lagoon are mussel cultures and extensive fish farms. Already around the sixteenth century, there was evidence of mussel culture in the Venice lagoon, but the real explosion could be marked during the 1960s with more than 50 ha of productive surface and a production of more than 30 000 tonnes. Along the following decades, there was a progressive decline of mussel culture in the Venice lagoon: 21 000 tonnes in the 1980s, 9 000 tonnes in the 1990s and 4 000 tonnes at the beginning of the new millennium; this is mainly due to the better economic performance that longline mussel farms produced. Now there are only 2–2.5 ha of mussel farms in the Venice lagoon with a production of 2 000–2 500 tonnes/year and this fishery activity appears not to have a future in the Venice lagoon.

Extensive fish farms are one of the oldest farming activities in the Venice lagoon; there is evidence of this even in the eleventh century with some part of lagoon closed by piles of wood or marsh reeds. The development of these partially enclosed areas generated a new system of completely closed fish farms communicating with the lagoon only through sewers. During the evolution of fish farms, there were many laws and prohibitions regarding their role in water circulation and landfill processes, and in the sixteenth and seventeenth centuries there were almost 60 fish farms; by the beginning of the eighteenth century, only 19 were active. The total surface interested by fish farms was 13 820 ha in the early twentieth century, 12 505 ha in 1926, 10 075 ha in 1939 and from 1985 the whole surface covered about 9 000 ha. The average production is 350 tonnes/year and the principal species are grey mullets (with more than 65 percent of total production); gilthead seabreams and European seabasses are the other species with higher production and with a better economic value; eels represent a minor production because at present eel juveniles are very difficult to find.

There is a tradition in Venice of fishers specialized in the capture of mullets, seabreams and seabass fry and juveniles. The juveniles of these species enter the lagoons after a period of larval life at sea; this migration is known locally as *mount* or *remount*. Juveniles are captured in the wild, kept alive for a different period (from a few hours to ten days or more), and finally sold to fish farms, where they are used for the annual stocking of extensive wetlands. This activity (as fyke net fishers) is always losing momentum, in 1995 there were more than 70 people doing it, in 2010 only 15 are left and the average age is still increasing because young fishers prefer other activities and those who are still working at this are getting old (even because this activity needs a peculiar knowledge of the lagoon dynamics, of shallow water morphology and obviously of target species behaviour).

In the Venice lagoon there are some other particular activities such as an oyster farm, some floating cages producing European sea bass, gillnets and lift nets fisheries; these are fixed equipments with a square net, tied down in the four corners with ropes and pulleys. In the past these were only used by professionals but today they are mainly used by amateurs. In a recent census (2007), there were 31 structures with an average production of 200–300 kg/year for each structure. All this information shall be used to produce the Management plan of Natura 2000 site in the Venice lagoon; this could be a useful instrument to help competent agencies in making decisions. This plan is an agreement among the Veneto Region, the Venice Water Authority (*Magistrato alle Acque)* and the *Consorzio Venezia Nuova* that proposes a new way to manage not only the lagoon areas (not ideal for human life), but also the area around the Venice lagoon, the coasts, the drainage areas including river mouths and those areas not directly connected (but in some way linked) with the Venice lagoon. Impacts that have most influenced the structure and habitats should be searched in the urbanization that developed along the lagoon boundaries.

With the Council Directive 92/42/EEC, also called the Habitat Directive, the European ecological network "Natura 2000" was established: this is a list of sites characterized by the presence of habitats and species, both plants and animals, with a community interest, whose function is to ensure long-term survival of biodiversity on the European continent.

The ecological network is constituted by Special Protection Zones (SPZs) established under the Birds Directive (2009/147/EC), and Special Zones of Conservation (SZCs) established under the Habitat Directive. Starting from 2005, the Veneto Region has approved the revisions of SPZs to complete those areas in accordance with the European study regarding the Important Bird Areas in the lagoon of Venice (IBA 034). The new SPZ is "IT3250046 – Laguna di Venezia" and replaces the previously sites. To develop this management plan, it is important to know the current state of the habitat and its evolution with constant monitoring of species diffusion and all the pressure agents (first of all the anthropogenic ones).

The aim of this plan is the preservation and enhancement of biodiversity and the reduction of impacts, to obtain an environmentally sustainable development of the territory. To be able to give a value to the various pressure agents and then understand how to intervene on them, a risk assessment model was created. The model is organized in three successive phases of assessment (Fig. 8), to define the three axes used to calculate the risks and identification of threats: the first is the intensity of the pressure factor (hazard, in the classical model), the second is the influence (value, in the classical model, the possibility that the pressure factor involves habitats, species and habitats of species) and the third is the vulnerability of the object of protection (as in the classical model). The use of the terms *intensity* and *influence* descends directly from the Habitat Directive definitions.

Figure 8. Scheme to obtain the risk matrix into the management plan

This approach method allows working at the scale of the whole site or individual GIS polygon (habitat, species habitat, species distribution). By overmapping one of the pressure agents to the habitat map, it is possible to define the value of threats creating a first matrix to quantify the effects of the pressure factors. The combination between the pressure value and the value of vulnerability is an assessment of the risk to habitats, species and habitats of species and results in potential or actual threats in place according to the cases reported in the risk matrix (Fig. 9).

		VULNERABILITY		
PRESSURE		*1*	*2*	*3*
	1	1	2	3
	2	2	4	6
	3	3	6	9

Figure 9. Risk matrix

The interpretation of this final matrix allows to better determine the actions to perform: a null risk should correspond to a simple, but constant, monitoring effort; if the risk grows higher, some pre- determined actions should be undertaken to reduce it; ending, in the worst case scenario, with urgent priority actions of regulation and active management.

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CASE STUDY 2. SUSTAINABLE AQUACULTURE FOR THE ECOLOGICAL AND ECONOMIC IMPROVEMENT OF MEDITERRANEAN COASTAL WETLANDS: THE CASE OF DOÑANA (SW SPAIN)

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Introduction

The International Union for Conservation of Nature (IUCN), through its Marine Programme, and the Federation of European Aquaculture Producers (FEAP) signed in 2005 a common agreement to cooperate in the development of sustainable aquaculture, promoting best practices in the sector. In addition, GFCM and its subsidiary CAQ have agreed on the importance of identifying positive interactions between aquaculture/fishing practices and coastal biodiversity conservation along the Mediterranean Region, taking into account the existing successful initiatives.

In Mediterranean countries where extensive/semi-extensive aquaculture and traditional fishery systems are still practiced, managed wetlands and lagoons constitute habitats for numerous threatened species of fish, amphibians, reptiles and birds. These activities effectively contribute to both the environmental conservation and the development of local economies, and could provide a sustainable future for the coastal wetlands of the entire Mediterranean Region. This is the case of Veta la Palma farm, an extensive aquaculture operation located in the Doñana wetland, Southern Spain, where economic benefits result from the application of innovative production methods involving a wide environmental concern. This fish farm has not only been managed to supply top-quality aquaculture products, but also to minimize its ecological footprint and enhance natural ecology and biodiversity of a formerly degraded wetland area. Veta la Palma has become internationally recognized for its role in conservation and was awarded in 2003 by the Anders Wall Foundation in cooperation with the Directorate-General for the Environment of the EC (Otero and Bailey, 2003).

This document presents the activity of the Veta la Palma fish farm as a good practice in the management of lagoons. The document is part of a longer work prepared for the Regional Activity Centre for Specially Protected Areas (RAC/SPA) of the UNEP Mediterranean Action Plan, in the framework of a regional project currently under elaboration, which aims at promoting the use of sustainable aquaculture/capture fishery as a base for wetland conservation and management, within the Strategic Action Programme for the Conservation of Biological Diversity (SAP BIO) in the Mediterranean region (UNEP-MAP-RAC/SPA, 2003).

Veta la Palma: brief overview of its natural history

Doñana has been designated a Wetland of International Importance under the Ramsar Convention and a Biosphere Reserve under the Unesco Man and Biosphere Programme. The area currently devoted to aquaculture in the area extends over 3 200 ha in the privately ruled Veta la Palma estate, occupying the formerly degraded Isla Mayor del Guadalquivir.

Doñana climate is Mediterranean, moderated by the ocean, with warm dry summers and cool wet winters. The mean annual temperature is 17˚C, while average annual precipitation reaches 525 mm (Llamas, 1988). Geographically, Isla Mayor lies at the centre of the Guadalquivir river delta, and is bound on the east by this river and on the west by Doñana National Park.

After a long history of natural evolution by silting-up (Bayán Jardín, 2006), first attempts to transform Isla Mayor into farmland date back to the nineteenth century. In 1923, major channelling works were undertaken to prevent annual flooding, in order to transform the area for cereal agriculture. Rice was introduced as an alternative crop for the poor soils of the marshes in 1937. In the 1940s and 1950s of the twentieth century, rice culture became the main activity in the Guadalquivir river marshes, including the North of Isla Mayor. In 1966, 11 300 ha of the Southern Isla Mayor (the present Veta la Palma estate) were sold to the company Agropecuaria del Guadalquivir, which improved the flood defenses and used this traditionally grazing land for cattle breeding. In 1978, part of the estate (approximately 8 000 ha) was declared a protected area by National Administration. In 1982, Agropecuaria del Guadalquivir was bought by Hisparroz, S.A. and renamed as Pesquerías Isla Mayor, S.A. (PIMSA), which is the present owner of Veta la Palma estate. The former drainage network was improved and used in a reverse way, that is as irrigation canals, to create shallow lagoons for aquaculture purposes.

Considering the favorable results obtained in some preliminary experiences undertaken between 1982 and 1984 (García Novo, 1988), in 1990 PIMSA decided to initiate an ambitious aquaculture project in Veta la Palma, under approval by local Fishing Administrators, according to the Plan for the Use and Management of Doñana National Park (PRUG) regulations; 3 200 ha of the estate were flooded with first-rate water from the Guadalquivir river delta. The result was a carefully managed wetland supporting a rich and nourished flora and fauna, particularly dense communities of invertebrate species, which are the basis for a vast range of extensive aquaculture products. Farmed species are typical of the delta, including European seabass (*Dicentrarchus labrax*), gilthead seabream (*Sparus aurata*), meagre (*Argyrosomus regius*), soles (*Solea solea, S. senegalensis*), white shrimp (*Palaemonetes varians*), eel (*Anguilla anguilla*) and grey mullets (flat head grey mullet *Mugil cephalus* and thin-lipped grey mullet *Liza ramada*). Some 4 600 ha of Veta la Palma extension is marshland pasture for extensive livestock, producing horses and livestock; on the remaining 3 500 ha rice and dry cereal are grown on a rotational basis.

An innovative land-based aquaculture system

The Veta la Palma fish farming area is divided into 45 rectangular, 70 ha ponds, connected to each other and with the Guadalquivir and *Brazo de la Torre* rivers by means of a complex 300 km irrigation and drainage canal network. To maintain oxygenation and water quality, one million cubic meters of water are pumped daily from the river delta through the whole system, which is designed to work both in open and close circuit, depending on environmental and operational circumstances (Fig. 1).

Satellite image of Veta la Palma estate (centre). Images illustrate current activities, photos ©Veta la Palma, H. Muñiz, A. Liébana and J. Ramos.

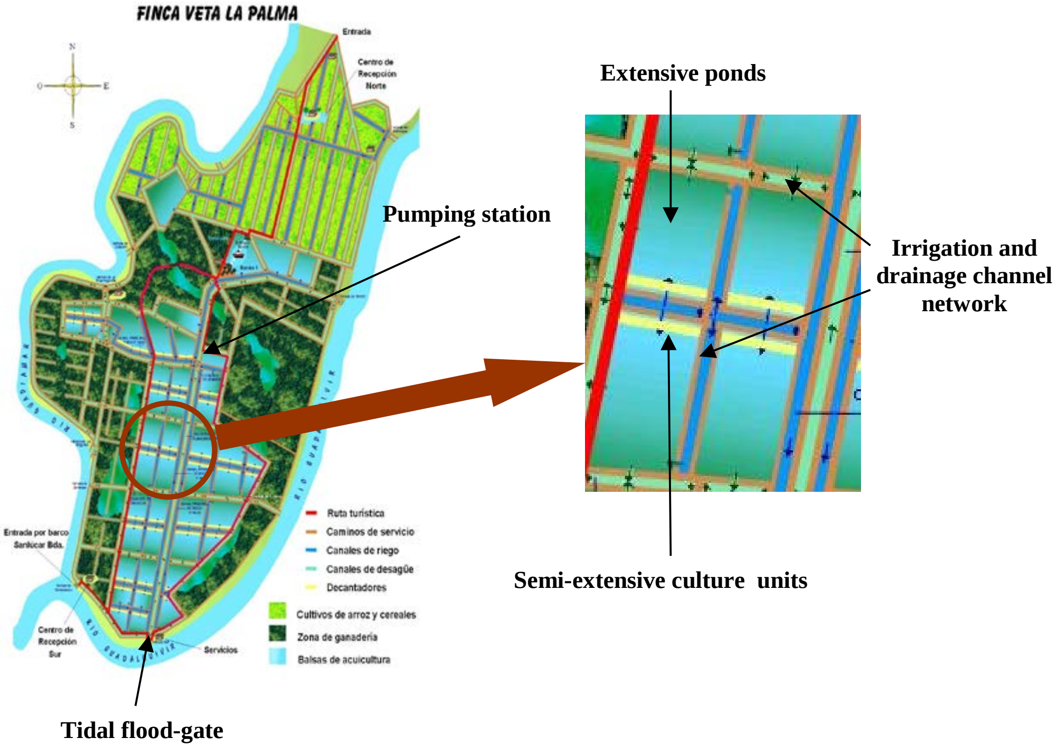

Figure 1. Operational scheme of Veta la Palma fish farm (Source: PIMSA, 2000)

Extensive fish farming ponds are characterized by their stability regarding flooded surface (3 200 ha), average depth (40-50 cm), water flow rate (up to 1 hm^3/day in summer) and salinity, although salt content may fluctuate according to the season and the amount of rain (6-15 g/l in wet periods and 15-25 g/l during driest episodes). This stability allows to buffer changes in the salinity, water flow and nutrient concentration values of the Guadalquivir delta, promoting a massive development of microalgae that efficiently assimilates excess of organic matter in the water, particularly nitrogen and phosphorus produced as waste, avoiding harmful algal blooms (PIMSA, 1995). Microalgae, as well as sediment-linked algae and bacteria taking part in decomposition, are predated by a varied aquatic microfauna composed of worms, insects, crustaceans and small fishes that ultimately constitutes the natural diet of cultured fish (Medialdea, 2009).

Extensive ponds act like huge water treatment plants where potential contamination of biological origin is removed from the water and transformed into living biomass that is finally extracted from the system via commercial fishing and predation by birds. Thus, the hydrologic system operating *in Veta la Palma avoids* eutrophication and assures that the water pumped daily from the Guadalquivir is returned to the delta with an improved microbiological, physical and chemical quality (Medialdea, 2009).

Aquaculture as a base for a sustainable wetland management

Restoration of lost ecosystem functionality

Veta la Palma aquaculture ponds and surrounding marshland pastures effectively support a number of environmental services for the hydrology and ecology of the Doñana wetland. The aquaculture operation has been managed to restore the damage produced in the original wetland by silting-up and land misuses, minimizing its own ecological footprint and combining the economic benefits of aquaculture with conservation objectives.

The ecological and functional mosaic created in the Veta la Palma estate by PIMSA, inundating the formerly dried up marshland for aquaculture and preserving the surrounding high-marsh areas for extensive livestock grazing, has improved the natural landscape of the area. Since 1990, the estate´s ownership has also invested important material and human resources to further improve Veta la Palma's ecology, through initiatives involving the construction of more than a 100 islands inside the fish farming ponds to serve as bird sanctuaries and nesting sites for waterfowls (PIMSA, 2000); total re-vegetation of 150 km of pond shores and embankments; and creation of two 300 ha and 500 ha Bird Protection Areas, including shallow lagoons with islands and areas with different ecological types of marshland (PIMSA, IIMA and Euroduck, 1992), for research purposes. Islands are composed mainly of slime and clay coming from the Guadalquivir estuary, which contain plant seeds and can be used as substrate for revegetation. In just a short time, new islands get covered by a rich carpet of halophytes and marshland shrubs, offering a new and heterogeneous habitat to aquatic birds.

The Doñana wetland exhibits a hydrologic regime that includes a high water table and extensive flooding from October to May-June, followed by a strong summer drying. Every year at the beginning of the summer season, thousands of waterfowl and coot broods leave Doñana and seek for flooded areas in surrounding sites, massively arriving to Veta la Palma. Similarly, at the end of summer and the beginning of fall, the marshes of Doñana National Park are still dry, and the clean, oxygenated and food rich water of Veta la Palma offers shelter for thousands of early migratory birds. Therefore, the Veta la Palma aquaculture operation plays a fundamental role as buffer zone for the whole area and provides food and water for the birds during moulting time, breeding season and post-breeding annual migration, as well as during particularly dry interannual periods (Quirós Herruzo and Maneiro Márquez, 1996; EBD, 2000).

Wintering ground for visiting northern birds (e.g. 70 000 greylag geese) and nesting sanctuary for spring-migrating species from Africa (e.g. 500 purple herons), Veta la Palma has become the lungs, larder and hospital for European aquatic birds. From some 30 000 birds recorded in 1984 (Fernández-Cruz e*t al.*, 1989), the population has exponentially increased to a total of 600 000 in fall months (Fig. 2), attracted by the abundance of fish and shrimps (Rodríguez Pérez and Green, 2003). More than 250 species of birds can currently be recorded in Veta la Palma, almost 50 of them included in the IUCN Red List of Threatened Species (IUCN, 2011). Kentish plover (*Charadrius alexandrinus*), slender-billed gull (*Larus genei*), osprey (*Pandion haliaetus*), greater flamingo (*Phoenicopterus ruber*), little tern (*Sterna albifrons*) and gull-billed tern (*Sterna nilotica*) are also included as threatened species in Annex II of the Protocol concerning SPAs and Biological Diversity (SPA/BD) of the Barcelona Convention. The total bird population size reaches the maximum between August and October. Census data by the Doñana Biological Station recorded a total of 600 000 birds in Veta la Palma in October 2002, which represented 80 percent of all birds of Doñana by that time (EBD, 2000; 2004). The estate is currently regarded as the most important area of private land for aquatic birds throughout Europe (Otero AND Bailey, 2003).

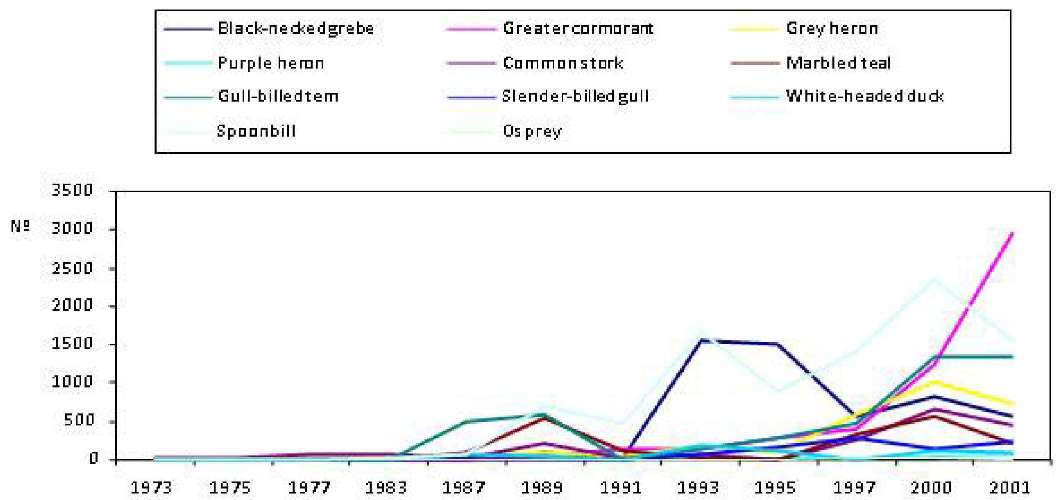

Figure 2. Evolution of the population of some relevant species of birds in the aquaculture ponds of Veta la Palma, for the period 1973–2001 (marshes still dried for cattle grazing, before aquaculture project started) (Source: PIMSA, 2000; EBD, 2004)

The first-rate water layer dedicated to extensive/semi-extensive aquaculture in Doñana also contributes to the protection and eventual recovering of the Guadalquivir delta-associated fish fauna (Table I). The highly structured trophic web of Veta la Palma fish ponds plays an important role in the protection of relevant species as the Spanish toohcarp *Aphanius iberus* (included in Annex II of the Protocol concerning SPAs and Biological Diversity – SPA/BD – of the Barcelona Convention), Allis shad, *Alosa alosa* and twaite shad, *Alosa fallax* (included in the Annex III of the Barcelona Convention), sand goby *Pomatoschistus microps*, big-scaled sand smelt *Atherina boyeri*, and other species that spend part of their natural cycle in the delta (spotted seabass *Dicentrarchus punctatus* or the farmed soles, seabream, meagre, eel and seabass). Some marine species, such as the European anchovy *Engraulis encrasicholus*, the wedge sole *Dicologoglossa cuneata* or the sand steenbras *Lithognathus mormyrus* have also been recorded during dry periods, when water salt content increases. Apart from juveniles of cultured species which are bought in commercial hatcheries and released in the ponds, larval stages and juveniles of most mentioned fish species are usually found in Veta la Palma.

Contribution to climate change mitigation

The Doñana wetland is located in a crucial point in terms of exposure to climate change, with desertification, erosion and sea level rise as major forces that may affect both the biodiversity and the economy of the local community. All climate changes scenarios in the area indicate marked increases in temperatures and a significant decrease in annual rainfall (Viner and Sayer, 2006) that will surely affect soil salinity, making agriculture even harder on this region of Spain.

Under these changing conditions, aquaculture may become a serious alternative to ensure future water availability and control for the entire wetland ecosystem. Extensive/semi-extensive aquaculture in Veta la Palma is based on a complex system of canals that allows to regulate the water across the Estate and surrounding areas, taking into consideration both productivity and biodiversity. The 300 km of channels of Veta la Palma, the rivers bordering the estate where fish farming develops, and the huge patch of protected lagoons and marshland pastures surrounding the extensive fish ponds allow the whole Doñana ecosystem to mitigate the effect of a decrease in precipitation by adapting the water control scheme and pumping operation from the river delta. Water, salt, food and vegetation cover combine themselves to provide excellent opportunities for animal breeding and feeding, transforming this area in an oasis for many species that have to face changes in climate and habitats occurring in both Europe and Africa. Regarding carbon balance, growing emissions from livestock and rice (76 percent of all emissions; Viner and Sayer, 2006) in the area may be compensated by carbon sequestration through photosynthesis in the aquaculture operation.

Conclusion: Eco-friendly aquaculture may guarantee the protection of Mediterranean coastal wetlands, promoting the balance between biodiversity conservation and development

The sustainable aquaculture system currently operating in Doñana is a highly successful model of integrated management in an extremely sensitive Mediterranean coastal wetland (Abend, 2009). The areas of extensive aquaculture ponds, natural marshlands and cereal farming constitute an ecosystem of great wealth, where balanced human management has recovered a former wetland that had been largely disturbed, increasing natural gradients of hydrographic and topographic heterogeneity (Ecoagriculture Snapshot, 2010). Fish farming activities maintain the Guadalquivir river delta in a favourable conservation state and become a very valuable support for Doñana, representing a compromise with the future of conservation and development in the area (Otero & Bailey, 2003).

The Veta la Palma aquaculture operation in the heart of Doñana has the recognition and support of a number of international institutions such as WWF, the Royal Society for the Protection of Birds and Wildlife Trust, Euroduck Internacional, the European Landowners Organization, the Spanish MAB (Man and Biosphere) Committee (Unesco) and the European Commission. In addition, the production methodologies applied in the farm are included in what the Directorate-General for Fisheries and Maritime Affairs, European Commission, called aqua-environmental measures. As defined in the European Fisheries Fund (EFF), aqua-environmental measures aim to promote aquaculture techniques that help to protect and improve the environment and to conserve nature (EU, 2007). Such technologies have to be ecologically efficient and respectful, under hard environmental exigencies within the framework of Natura 2000.

This model of eco-friendly aquaculture constitutes an interesting and efficient case study in relation to the modern safekeeping of the territory, in which collaboration between private and public initiatives based on investment in eco-friendly productivity solutions makes an enormous contribution to the conservation of coastal wetland natural resources, generating both economic and ecological outcomes (Cranbrook, 2002; Durá and Castroviejo, 2007).

Table I. Vertebrate species recorded in Doñana aquaculture operation, considered under threat according to IUCN List of Threatened Species (Source: IUCN, 2011)

Mammals		Black Tern *Chlidonias niger*	LC
Otter *Lutra lutra*	NT	Roller *Coracias garrulous*	NT
Lesser mouse-eared Myotis *Myotis blythii*	LC	Little Egret *Egretta garzetta*	LC
Greater horseshoe Bat *Rhinolophus ferrumequinum*	LC	Peregrine Falcon *Falco peregrinus*	LC
Mehely´s horseshoe Bat *Rhinolophus mehelyi*	VU	Red-knobbed Coot *Fulica cristata*	LC
Fish		Gull-billed Tern *Sterna nilotica*	LC
Alis Shad *Alosa alosa*	LC	Collared Pratincole *Glareola pratincola*	LC
Twaite Shad *Alosa fallax*	LC	Common Crane *Grus grus*	LC
Spanish Toohtcarp *Aphanius iberus*	EN	Black-winged Stilt *Himantopus himantopus*	LC
Pseudochondrostoma willkommii	VU	Slender-billed Gull *Larus genei*	LC
Cobitis paludica	VU	Marbled Teal *Marmaronetta angustirostris*	V
Iberochondrostoma lemmingii	VU	Rufous-tailed Rock-thrush *Montinola saxatilis*	LC
Amphibians		Egyptian Vulture *Neophron percnopterus*	EN
Southern marbled Newt *Triturus pygmaeus*	NT	Red-crested Pochard *Netta rufina*	LC
Birds		Eurasian Curlew *Numenius arquata*	NT
Common Kingfisher *Alcedo atthis*	LC	Black-crowned Night-heron *Nycticorax nycticorax*	LC
Garganey *Anas querquedula*	LC	White-headed *Duck Oxyura leucocephala*	EN
White-rumped Swift *Apus caffer*	LC	Osprey *Pandion haliaetus*	LC
Spanish imperial Eagle *Aquila adalberti*	VU	Greater Flamingo *Phoenicopterus roseus*	LC
Purple Heron *Ardea purpurea*	LC	Common Redstart *Phoenicurus phoenicurus*	LC
Squacco Heron *Ardeola ralloides*	LC	Purple Swamphen *Porphirio porphyrio*	LC
Short-eared Owl *Asio flammeus*	LC	Eurasian Spoonbill *Platalea leucorodia*	LC
Ferruginous Duck *Aythya nyroca*	NT	Glossy Ibis *Plegadis falcinellus*	LC
Great Bittern *Botaurus stellaris*	LC	Black-necked Grebe *Podiceps nigricollis*	LC
Rufou-taileds Scrub-robin *Eythropygia galactotes*	LC	Pin-tailed Sandgrouse *Pterocles alchata*	LC
White Stork *Ciconia ciconia*	LC	Ruddy Shelduck *Tadorna ferruginea*	LC
Black Storn *Ciconia nigra*	LC	Pied avocet *Recurvirostra avosetta*	LC
Western Marsh Harrier *Circus aeruginosus*	LC	Little Tern *Sterna albifrons*	LC
Montagu´s Harrier *Circus pygargus*	LC	Caspian Tern *Sterna caspia*	LC
Whiskered Tern *Chlidonias hybrida*	LC	European Turtle-dove *Streptopelia turtur*	LC

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CASE STUDY 3. STATE OF THE RESOURCE AND EXPLOITATION OF THE EUROPEAN EEL (*ANGUILLA ANGUILLA*, LINNEO 1758) AND ELEMENTS FOR THE PREPARATION OF A COMMON MANAGEMENT PLAN IN THE GFCM AREA

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Biology and behaviour of the European eel

The European eel is known to spawn in the Sargasso Sea and its larvae cross the Atlantic Ocean and enter the European and north-African inland waters and lagoons. Several years after, the adults backcross the Atlantic to spawn. However, neither specimen ready to spawn nor the spawning itself, which is supposed to occur at more than 2000 m depth, were ever observed. Nowadays, it is admitted that the population of this species is panmictic and that its distribution area extends from the Barentz Sea down to Mauritania and comprises the Mediterranean and the Black Sea; it is therefore a resource shared by all northern European and Mediterranean countries.

Recent works in the field of genetics reconsider the panmictic hypopthesis and recognize three different groups: the north European eels, the western European eels and the Mediterranean ones (Van Ginneken and Maes, 2005) but this theory is not accepted everywhere (Palm *et al.,* 2009). It is generally admitted that the greatest number of larvae are transported across the Atlantic ocean by the main branch of the Gulf Stream and then by the North Atlantic drift. The Azores current transports them to the Mediterranean while the northern branch of the North Atlantic drift sends them to the eastern part of the distribution area, and the southern branch transports the larvae to the central part of the European coasts (Schmidt, 1909; Kracht, 1982; Kettle, 2005).

During their journey they feed on zooplankton by making vertical migrations between 35 and 600 m deep. They reach the European coast in spring, and the northern sectors at the end of the summer at a size of 75-90 mm (Bertin, 1951; Elie, 1979). According to the authors, their transatlantic journey can last between 6 months and two years.

In the Mediterranean, the post larvae ("glass eels") are encountered along the coastline from January to December with peaks of abundance from December to April (Lefevre *et al.*, 2003). Eels continue to grow for 10–14 years until they reach a size of 60 to 80 cm; during this phase of life they are called "yellow eels" ("green eels" in the Mediterranean) because of the golden pigmentation mixed in the black pigment. The growth is variable according to the geographical zone where they live: they grow faster in the south than in the north of the species' distribution area. The growth is slower for the animals reaching the top of the streams where the individuals stay longer (more than 15 years and sometimes 20 years) and are generally females. Eels grow faster in the lagoons, which generally produce male individuals, migrating more prematurely offshore between 3 years and 7-8 years of age, according to the latitudes. These adults («silver eels») leave the coasts of European and North African coasts in autumn, and ripening, i.e. gametogenesis, takes place during the east to west transatlantic migration using the Canary islands and northern equatorial currents to reach the spawning areas of the Sargasso sea during the first half of the following year (Farrugio and Elie, 2011).

Fisheries statistics

In the Mediterranean, adult eels are mainly exploited by artisanal fisheries in inland waters (estuaries, lakes and rivers) and in the coastal lagoons of the border countries.

In most of the Mediterranean countries, eels are fished mainly using various types of traps: fixed or mobile gear like fyke nets (Figure 1) or fixed traps installed in the channels between the lagoons and the sea, which allow to manage the inputs or outputs of the fishes.

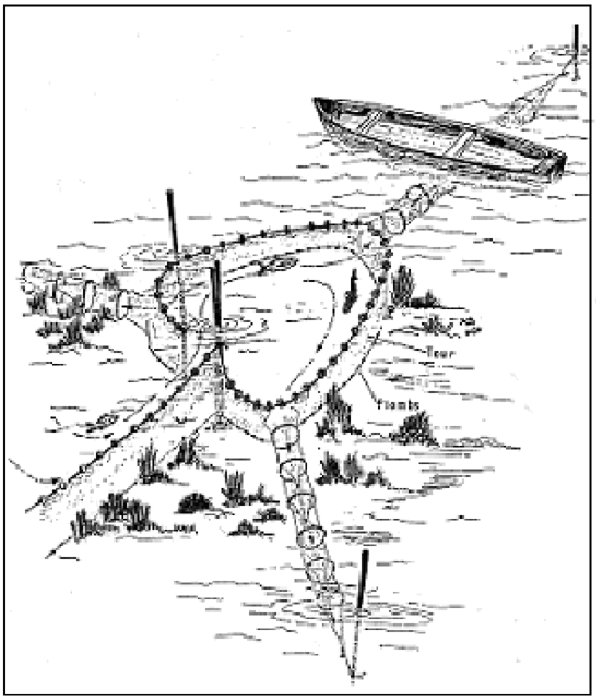

Figure 1. Fyke net for eel fishing in the Mediterranean lagoons

In most countries, the catch and effort statistics on eel are often absent or not regularly collected, however according to the FAO Fishstat database the overall production of European eel has dropped drastically since the mid-1980s.

During the first half of the twentieth century the overall production of European eel was several times greater than 50 000 tonnes, and then it has rapidly dropped starting from the 1960s. This production ranged from 10 000 to 13 000 tonnes during the 1980s and then regularly decreased down to 3 200 tonnes in 2007. A drastic decrease of more than 90 percent has been observed for the landings of glass eels along the European coasts (Fig. 2: Dekker, 1998; 2003; 2004).

In the Mediterranean, eel production comes essentially from the lagoons and there is no doubt that they represent an important economic activity, but up to now it is still very difficult to quantify it accurately. Generally, glass eel fishing is prohibited in the Mediterranean bordering countries but poaching and important illegal catches of undersized juveniles exist in some places.

In France, according to the most recent estimations, eel fishery occupies approximately 600 professionals. Eel can represent 20 to 80 percent of the total production of a lagoon according to sites. The available statistical data indicate that the total production of French lagoons, which was around 1 500 – 2 000 tonnes a year in the 1980s (Elie and Rigaud, 1984) showed a marked decline and then stabilized around 1 000 tonnes/year since the end of the 1990s.

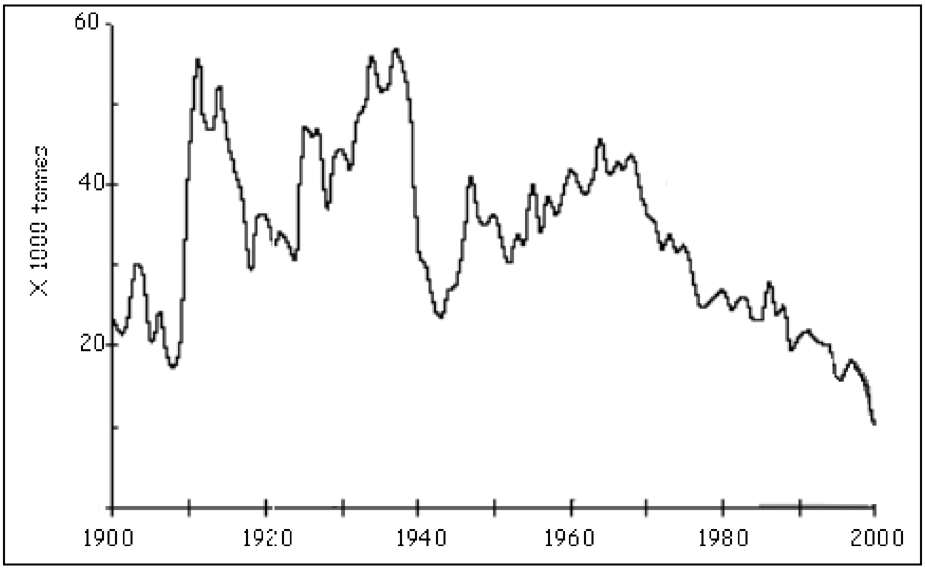

Figure 2. Evolution of the European eel catches during the 20th century
(Source: Decker, 2004)

In Italy, the most productive region is the Venetian region, which produced approximately 450 tonnes a year in 1975–1976. The total production of Italian lagoons was around 1 500–2 000 tonnes/year during the 1970–1980s. Then it decreased very strongly down to 500 tonnes in the 1990s and then around 200 tonnes in the last decade (Anon, 2002).

In Greece, production of European eel (captures plus fish farming) varied from 300 tonnes in 1980 to 1 000 tonnes in 2001. This is the result of a considerable increase of aquaculture production and of a very sensitive simultaneous decrease of the global product of the lagoon fishery, which declined from the years 1988–1998 although the individual production of some coastal lagoons and the one of inner lakes increased during the period 1990–2000 (Koutsikopoulos *et al.*, 2009).

In Spain, a study on the production of Andalusia showed that in certain sectors eel population decreased by 98 percent (Aguilar *et al.*, 2008). Also in Turkey the population of European eel decreased drastically during the last decades (Yalçın *et al.,* 2006).

In Tunisian lagoons, eel production was around 1 000 tonnes in the 1970s and 1980s and the importance of captures did not stop declining since then, down to an average of 180 tonnes/year for the period 2000–2009. In Algeria, till the beginning of the 1990s, the production of the El Mellah lagoon was dominated by eels, which represented 50 to more than 80 percent of the contributions of the fishery, then this proportion decreased by more than 80 percent. The yearly average production indicated in the region of El Kala during the last decade was of the order of 80 tonnes (Romdhane, 1985; Chaouchi, 1995).

The FAO-FISHSTAT data for the GFCM area show that the overall Mediterranean production followed the worldwide trend and decreased from yearly catches of around 4 000-5 000 tonnes in the 1980s to 1 000 tonnes in 2000 and 700 tonnes in 2007 (Fig. 3, FAO, 2009). According to these statistics, with the exception of the Egyptian data, the five main producer countries are respectively Italy (46 percent of the total), France (26 percent), Turkey (13 percent), Tunisia (9 percent) and Albania (2.6 percent).

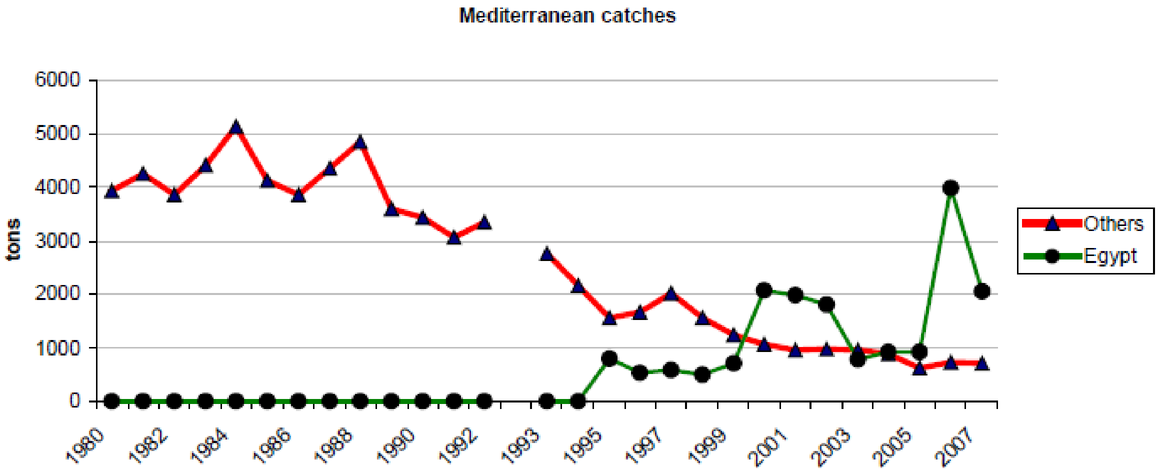

Figure 3. Recent Mediterranean catches of European eel (Source: FAO, 2009)

Factors affecting eel populations

Some results (profits) stemming from comparative studies on fish populations show that the eel is the species that accumulates the biggest quantity of organic and inorganic pollutants of various origins like PCBs (Ashley *et al.*, 2003; Tapie *et al.*, 2006; 2010), HAPs (Roche *et al.*, 2000; 2001; 2002) and heavy metals (Durrieu *et al.*, 2006; Pierron *et al.*, 2007, 2008). Furthermore, as the eel is situated at the top of food chains, it can present strong levels of contamination due to the mechanisms of bioaccumulation existing in the trophic web. It is considered that the environmental quality strongly contributed to the decrease of the species productivity. The decline of eel populations is due to several additive factors. They can be of marine origin (changes in oceanic currents, reduction of the ocean productivity, etc.) or be due to changes in the continental part of the biological cycle of the species: obstacles to migrations, degradation of large parts of the habitats, fishing activities and diseases (Elie and Rigaud, 1984; Vigier, 1990; 1997; Buslé, 1994; Moriarty and Dekker, 1997). Among the activities that have favoured the decline is the setting up of dams for the building of hydroelectric plants, which represent important obstacles to the migration as they limit the number of animals able to move upstream and downstream the rivers (Elie and Rigaud, 1984; Elie, 1997)

Parasitism is certainly one of the main causes of the decline. Since the early 1980s, 30 to 100 percent of the local eel populations are infected by *Anguillicola crassus*, a nematod blood parasite coming from Australia and southeastern Asia where it is harmless for the Japanese eel, *Anguilla japonica.* It seems that it has been introduced in the European aquaculture fattening plants with glass eels imported from Japan. It appeared in Italy in the early 1980s, in Germany in 1982 and in the French Mediterranean lagoons in 1984. In the early 1990s, it was found in the inland waters of North Africa, in Morocco, in Tunisia and in Egypt. However, the percentages of infected eels in African waters are lower than in the European ones. In 2002, *A. crassus* was observed in Turkey in the eels of the river Ceyhan.

Management objectives

It is known that the deterioration of the species habitats and the quality of its continental environment have largely decreased the productivity of the eel. According to the International Council for the Exploration of the Seas (ICES), the level of harvest of the species is unsustainable and since 2000 it has been added to the list of species of the annex II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The European eel has also been declared an endangered species by the IUCN.

Commercial trade is submitted to the setting up by exporting countries of a management plan showing, for each sector of the species distribution area, the state of the eel population, the current regulations regarding its catches and its environment and also how to manage them in order to recover the species stock

The European Union asked to each of its member countries to prepare by the end of 2008 a management plan for each catchment basin inhabited by eels. The idea is to rebuild on the long term panmictic stock to reach the main objective of increasing the escapement to the Sargasso Sea of the potential spawners from each basin. The goal is to reach a spawning stock biomass (SSB) close to the average SSB of the 1970s, a period in which the recruitment of glass eels was situated at "normal" levels (Farrugio and Elie, 2011).

Logically, this result implies that it could be possible to act on all the species mortality factors of the eel. However, a very few number of studies currently exist on the production and the rate of escapement of silver eels, in particular from the lagoons inhabited by the main sub-populations in the Mediterranean region.

To reach this goal, it is also necessary to apply methodologies enabling the escapement of silver eels from rivers and lagoons to the open sea and enabling to evaluate their impact on the exploited population. A few studies have been carried out on the evaluation of the escapement rate and on silver eel population size and its exploitation rate. These works were based on the tagging and recapture technique using non-lethal dyes which could easily be applied in many sub areas (Farrugio *et al.*, 2006; Amilhat *et al.*, 2007).

The European Union is financing a group of experts belonging to the CEFAS to elaborate a synthesis on the pilot projects aimed at evaluating the current and possible escapement of silver eels. This group intends also to realize a synthesis on the various existing mathematical models and their domain of applicability.

The EU asked for the implementation of management plans to the countries exploiting eel in order to control trade and ensure traceability. These plans have to ensure an escapement of at least 40 percent of the pristine biomass of adults. To be approved by the EU, they have to describe the means to reach this goal and the methods to be used in order to estimate the efficiency of the plans. At present, 70 management plans have been submitted to the EU, 15 of which have already been approved. Among the Mediterranean southern countries, Tunisia presented a first draft and obtained a quota of export for eels in 2009. However, to stabilize its production and its resource, this country elaborated a complete plan of management which was subjected to the EC in November 2010.

Methods of analysis

Some mathematical models already exist to evaluate eel populations dynamics; they all give pessimistic diagnosis on the state of this resource. However, up to now, no one has taken into account the spatial diversity of the population and the fact that there could be a part of this population specific of the Mediterranean and that the biological and ecological characteristics are very different between the northern and southern parts of the distribution area.

The models on the Mediterranean eel population dynamics need to be improved in order to take in account all the various anthropic pressures and to assess the enforcement of new protection measures which could be adopted by the countries exploiting this resource.

However, in the current context of the research on eel in the GFCM area, much information, though necessary, is missing: elements on the demography of the populations living in the Mediterranean hydrosystems (size structures, age and sex compositions, growth parameters, quality of the animals in terms of pollution and parasitism, etc.), knowledge on the continental habitats, human pressure other than fishing, quality of the migrating specimen, quantities of chemical pollutants in the water and along the trophic web. Currently, these data do not exist in the GFCM database so it will be important as a first step to feed it with some preliminary elements and then to complete the information after having selected the relevant factors in the frame of the activities of the GFCM Scientific Committees.

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CASE STUDY 4. TOWARDS A STOCK-WIDE ASSESSMENT OF THE EUROPEAN EEL: STATUS OF THE ADVICE AND OF THE MANAGEMENT FRAMEWORK IN EUROPE, AND EVIDENCE FOR THE NEED OF A CONTRIBUTION FROM THE MEDITERRANEAN AREA

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Introduction

Concern about the conservation of the European eel, *Anguilla anguilla*, has been growing in the course of the last two decades, and the need for conservation and management measures was clearly identified by scientists, managers, and even by the public opinion. For this species in fact major problems exist, in relation to a continent-wide decline in recruitment observed since the late 1980s, and to a contraction in adult eel capture fisheries (ICES, 2001; Dekker, 2002). If compared with other shared species or to other migratory fish, the eel shows some peculiar features. Eel exploitation occurs exclusively within national boundaries, in continental waters, without any interaction between economic zones, typical eel fisheries being mainly small-scale. The spawning process takes place in international waters, and all oceanic life stages are unexploited. Finally, the population is panmictic and the species is a shared resource by practically all European and Mediterranean countries.

The unique status of the eel was defined in 1976, when a joint International Council for the Exploration of the Sea (ICES)/EIFAC Working Party on Eels was established, which has met in alternate years since then. Within the WP, a coordinated monitoring for eel recruitment was set up, that allowed to document and follow the decline of supply following the abundance of the 1970s (Moriarty, 1990; 1996). The EC, in 1997, requested ICES to provide information about the status of the eel, in order to ensure a sustainable development of eel fisheries within the European Union, and in 1998, having acknowledged that eel stocks were outside safe biological limits, has requested to provide escapement targets and other biological reference points. The general concern by fishers, fish culturists and scientists alike on the decline in recruitment and fishery yields of the eel led to a strong debate and numerous consultations.

With specific reference to the Mediterranean, in 2002 a STECF Subgroup on Mediterranean included the eel within the species for which a scientific evaluation and critical review of the background information were performed, in consideration of the fact that this resource is shared among the majority of Mediterranean countries. Eel, in fact, is included among the shared stocks in the Community Action Plan for the conservation and sustainable exploitation of fisheries resources in the Mediterranean Sea under the Common Fisheries Policy (COM(2002)535).

In October 2002, the ICES pointed out the urgent need for a recovery plan for European eel that should include measures to reduce exploitation of all life stages and restore habitats.

Management actions

The strong need for urgent management actions has since been acknowledged, also supported by the precautionary principle, which suggests that high-risk situations need urgent protective measures. After a long process, which foresaw consultations at many levels with all stakeholders, in 2007 Regulation 1100 has been issued by the EU, aimed at the recovery of the European eel stock. In conservation terms, the main objective of eel management actions is identified in allowing an adequate escapement of silver eels. A specific level of escapement has been indicated in the Regulation, corresponding to 40 percent of the pristine escapement level. This is, therefore, the target that each EU Member State has to consider. In taking into account the possible management measures and the rebuilding plan targets, the overall approach of the document is centred on ICES advice. In many areas, the quickest and most effective measure to increase the survival of eel will prove to be a reduction in fishing, whereas environmental improvements may take some years to show results. A number of actions are identified, which are intended to develop a comprehensive basis for rebuilding eel stocks, based on locally appropriate actions and targets. Another important step for eel protection has been the inclusion in 2008 of eel in Annex IV of CITES, which regulates its trade.

In 2008, all EU Member States submitted eel management plans (EMPs), and in 2009 all plans were evaluated by the ICES, modified accordingly and approved. At present, EMPs are being implemented in all participating countries, and a first report to the EU is foreseen in 2012. The 2012 reports shall provide ICES with the tools to proceed to a stock-wide assessment for eel, to which new actions shall follow depending on the outcomes of the assessment. In fact, the Commission should present to the European Parliament and Council, not later than 31 December 2013, a report with a statistical and scientific evaluation of the outcome of the implementation of the eel management plans.

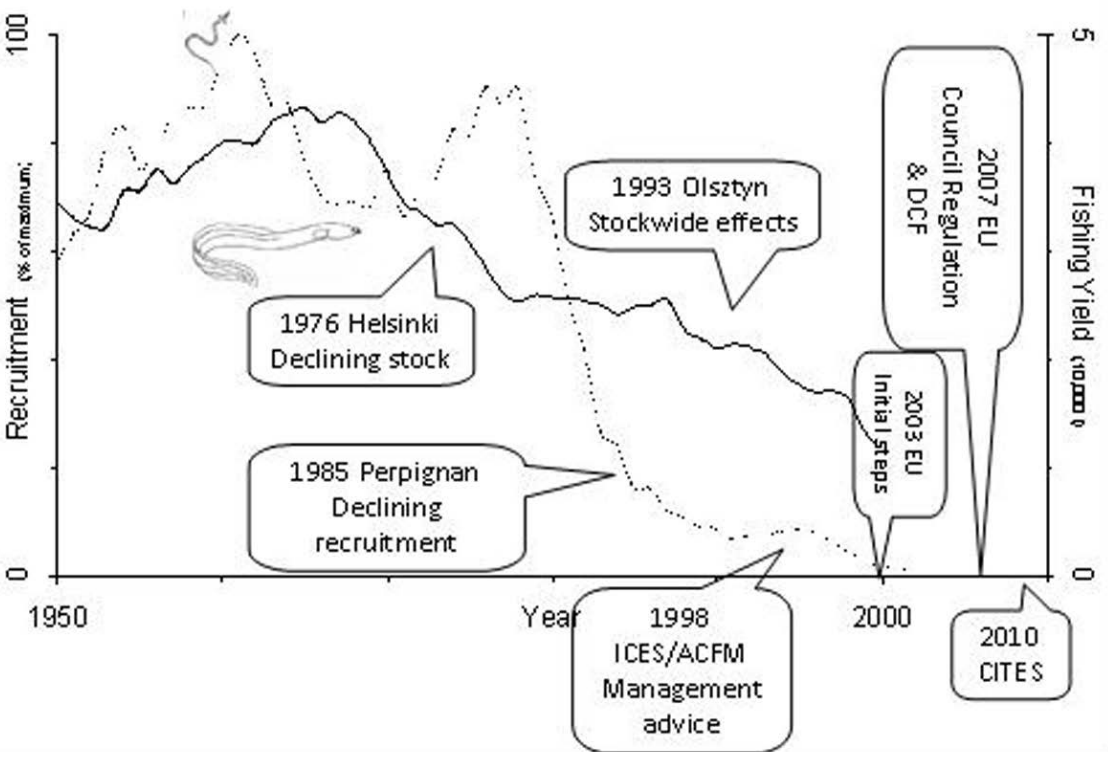

Figure 1. Timetable of evidence for eel decline from the EIFAAC/ICES WG on Eel and management actions (by courtesy of Willem Dekker)

Role of the European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC)/ICES Working Group on Eels

The EIFAAC/ICES Working Group on Eels since 1975 has had an important role in providing scientific and technical background information on eel.

The WG evolved in time from a group organising symposia on eel biology to a technical working group dealing with data collection and evaluation, assessing trends, dealing with methodological issues, stock-wide dimension, quality issues, effects of anthropogenic impacts and global changes, suggestions for a recovery plan. The Eel Working Group is now the expert group providing background for advice, and a series of thematic Workshops are taking place to evaluate data and methods that will feed into the stockwide assessment of the European eel.

In order to assess whether the measures being applied under the Regulation are adequate to halt the decline and create a recovery, it is in fact necessary to have a complete assessment of the stock over the whole geographic range.

CITES regulates the import/export of eels from EU territory and from individual non-EU countries, by means of a requirement for a so-called "non-detriment finding" (NDF). Minimal conditions for a NDF are that the import/export is "not detrimental to the survival of the species" and "that species is maintained throughout its range at a level consistent with its role in the ecosystems in which it occurs". Due to the panmixia of the eel (i.e. local silver eel production contributes an unknown fraction to the entire European eel spawning stock, which in turn generates new glass eel recruitment), the efficacy of local protective actions (e.g. single EMPs, national export regulation) cannot be post-evaluated without considering the overall efficacy of all protective measures taken throughout the distribution range.

All this requires an international post-evaluation. There are two different approaches for this, a centralised assessment, or a regional stock assessment and *post hoc* summing up of indicators for total stock assessment. The second appears to be more pragmatic and to relate more directly to the approach taken in the EU Eel Regulation and CITES procedures. For quality control, however, even a regionalised assessment will require that data are made available.

The stock-wide assessment

Among the actions propedeutical to the stock-wide evaluation of the European eel foreseen in 2012, a specific study group intended to design, test, analyse and report on a method of scientific *ex-post* evaluation at the stock-wide level of applied management measure for eel restoration was set up (ICES Study Group on International Post evaluation on Eels, SGIPEE).

The objective of eel stock assessment is to quantify the biomass of silver eel escaping, in order to assess compliance with the EU target of 40 percent of pristine biomass without anthropogenic mortality. Given that it will be impractical to directly assess silver eel biomass and mortality in many rivers, yellow eel stock assessment will also be required.

Scientific reference points have not been previously set for eel. The EU Regulation sets a long-term escapement objective for the biomass of silver eel escaping from each management area at 40 percent of the pristine biomass (B_0) or B_{lim}. However, no explicit limit on anthropogenic impacts A_{lim} was specified, even though current biomass is (far) below B_0 and B_{lim}. The biomass reference point of B_{lim} = 40 percent of B_0 corresponds to a lifetime mortality limit of ΣA_{lim} = 0.92, unless strong density-dependence applies. As an initial option, it has been recommended to set $B_{MSY-trigge}$r (value that should trigger a mortality reduction) at B_{lim}, and to reduce the mortality target below $B_{MSY-trigger}$ correspondingly. Allowing for natural variation in B_0 and for uncertainty in the estimates of status indicators and reference points, the resulting reference points (Blim, $B_{MSY-trigger}$ and A_{lim}) should be considered as somewhat optimistic or unsafe. Noting the relationship between biomass stock reference points $B_{current}$, $B_{MSY-trigger}$ and mortality reference point ΣA_{lim}, the actual value for ΣA_{lim} below $B_{MSY-trigger}$ must be determined on a country (or Eel Management Unit) basis.

On the basis of these considerations, the minimum data requirements for the post-evaluation are therefore B_0, B_{best}, B_{post} and ΣA ("3Bs&A"). All those countries that implemented EMPs in the 2009–2011 reviewed these estimates in 2012 and reported these reviews to the European Commission. Ideally for the post-evaluation of the Regulation, therefore, these B and A estimates should be provided in these reviews, and reported either at the country level and/or disaggregated at the EMU or catchment level. Furthermore, there are some countries in the EU who have not implemented EMPs, and there are a number of countries outside the EU that have an eel production but are not subject to the Eel Regulation. The potential implications of this scenario should be considered. On the whole, 38 countries are comprised within the eel distribution area including Europe, Africa and Asia and have presently (or have had in the past) eel capture fisheries production according to FAO Fishstat (2011). Of these, only 19 countries are in the EU and have produced EMPs (SGIPEE, 2011).

The European Eel Regulation recognises that cooperation between countries within and outside EU is desired, especially where management measures taken in one country might interact with measures taken in other countries. This has brought attention to the fact that the "missing" countries that are most relevant to the production assessment are the Mediterranean countries. The Mediterranean area has been neglected up to now regarding its role in the stock-wide assessment. A distinctive contribution regarding potential and actual escapement for Mediterranean areas might be envisaged, on the basis of specific growth patterns, silvering rates and sex-ratios (Bevacqua *et al.*, 2006).

The need to involve Mediterranean countries

The need for a contribution of the Mediterranean area appears therefore suitable and urgent, because a stock-wide evaluation needs to be comprehensively addressed to the whole eel distribution area. Some distinctive features of exploitation, in particular with regards to Mediterranean coastal lagoons, provide a key to the setting up of a relevant geographical management unit (Ciccotti, 2005). In this sense, the example of the Baltic area can be of interest, where a specific group has been organised to deal with this shared resource, aiming at carrying out a joint analysis and an efficient assessment of the local stock, also quantifying interactions.

The first approach is therefore to enhance knowledge and participation of Mediterranean countries, also increasing coordination and communication. An initial step was represented by the "Transversal expert meeting on European Eel" that was held in Sfax, Tunisia, September 23–24, 2010, within the GFCM meetings. This meeting dealt with the involvement of some northern African countries in eel, particularly Tunisia. The interest and urgency to be strongly involved in the restoration of resources of this species and the need to establish a regional coordination was clear.

A possible strategy could be to organise a thematic workshop by 2013. This workshops could address: *a)* initial planning, data inventory, data collation (eel and its habitat in the Mediterranean), assessments and initial analysis, *b)* recruitment, yellow eels stocks, silver eel, fisheries and other impacts (e.g. hydropower, aquaculture, cormorants), stock surveys and data collection, *c)* stock assessment, the ICES framework of 3Bs&A (as worded in the EU reporting template), the overlap and interactions between countries, *d)* dissemination and communication of the results to the managers and stakeholders, placing the results out at a local level and also in the wider stock context. This will allow for a broader group of countries to participate and collaborate with WGEEL, an important step to allow the GFCM area to participate actively to the recovery of the eel stocks

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CASE STUDY 5. INDICATORS FOR THE SUSTAINABLE MANAGEMENT OF COASTAL LAGOONS AREAS

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Introduction to sustainability

Sustainability and sustainable development are terms that are becoming very common in any kind of issues and situations. Definitions can be found from many sources, some of the most significant of which are reported below.

Our Common Future, also known as the Brundtland Report, from the United Nations World Commission on Environment and Development (WCED) was published in 1987 (WCED, 2007). Multilateralism and interdependence of nations in the search for a sustainable development path were declared as the main tasks. Special attention was set on environmental issues, to be placed firmly on the political agenda, in order to discuss environment and development as one single aspect.

From this report, Sustainable development is simply "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs"

The publication of *Our Common Future* and the work of the World Commission on Environment and Development laid the groundwork for convening the 1992 Earth Summit and the subsequent adoption of Agenda 21 and the Rio Declaration, as well as leading to the establishment of the Commission on Sustainable Development.

The UN Río Convention 1992, Conference on Environment and Development, set up the Principles of Sustainable Development, and introduced the concept of a "Global perspective for a Global problem" together with the strategy of "think globally, act locally". This was applied to Agenda 21, in which the adaptation of Principles to the local context and needs was proposed, and the three pillars of sustainable development were defined: economic growth, social justice and environmental preservation.

All this lays down an ecosystems-based view of sustainable development that focuses on the maintenance of ecosystem stability and resilience. Sustainable development recognizes the interdependencies of human economies with their environment, and highlights the need for scientific understanding of ecosystem functioning and changes, as well as the effect on society.

Dimensions of sustainability

Figure 1 represents the three pillars or dimensions of sustainability. A global perspective forces the consideration of those three aspects and their interdependence. Equilibrium must be achieved among them in order to reach sustainability.

There are other representations of the pillars as in the figures 2 and 3 below (F. Simard, based on O'Connor, M. 2006).

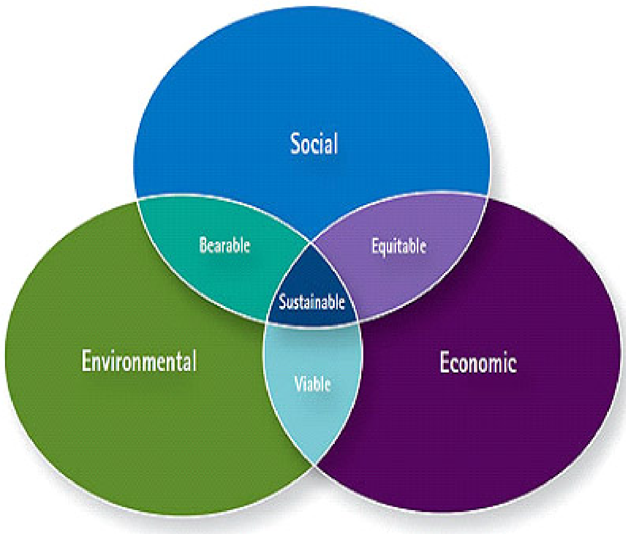

Figure 1. Pillars of sustainability

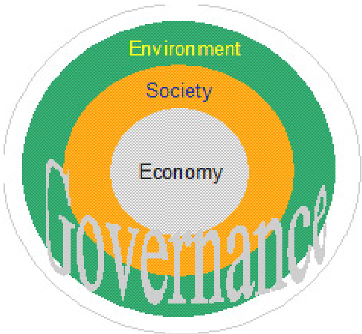

Figure 2. Equilibrium among dimensions of sustainability

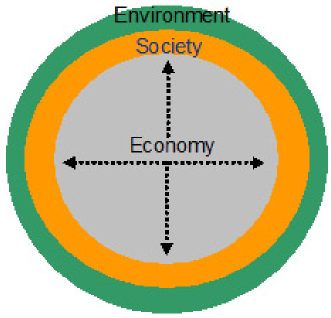

Figure 3. Extreme economic growth. Non-sustainable situation

Here, the circles are contained in each other, taking into consideration their dimensions and the pressure among them, that is: economy is generated by society taking resources from the environment; the growth of one of them will always put pressure on the others from the centre to the edges. Extreme situations, such as uncontrolled economy growth (Fig. 3), will increase the pressure of society on the environment, to reach a non-acceptable environmental situation, which is not convenient.

On the contrary, no economic growth (Fig. 4) will cause a social crisis, and only a small percentage of the population will benefit from the economy. Although the environment will benefit from this situation, it will not be economically viable and socially inequitable, therefore unsustainable.

Equilibrium must be achieved to gain sustainability. Figure 1 shows the best situation where the idea of governance is included and affects all dimensions (or pillars) of sustainability.

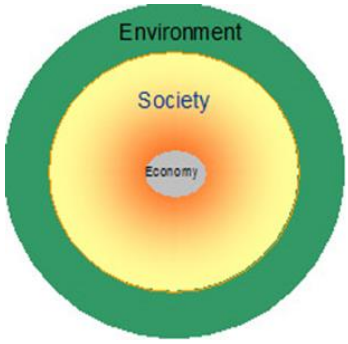

Figure 4. No economic growth

The concept of governance was developed and considered as a key issue for sustainable development at the World Summit on Sustainable Development in Johannesburg 2002. Stakeholders´ involvement and public-private partnerships were pushed forward through the evolution of the institutional system (a set of rules and methods) and the strength of the actors' capacity to participate on decision-making processes through collective learning issues and empowerment.

The principle, criteria and indicators (PCI) approach

The PCI approach for sustainable aquaculture has been defined according to a hierarchical nesting process, which makes it possible to link the indicators to the general principles of sustainable aquaculture (Rey-Valette *et al.*, 2008). According to Rey-Valette *et al.*, the process goes from a global vision to particular issues related to the four dimensions of sustainability, as reported hereunder. Following a sequential process, **principles** are defined considering the main issues related to sustainability. These principles are then expressed through **criteria**, which are the variables that explain those principles. Finally, **indicators** are developed to measure those variables in the form of indices and threshold values, which depend on available information and on the social acceptance of the standards.

Some definitions are needed to understand the process:

Principles: From Latin "*principium*" defined as "what serve as a basis", for the action to be taken towards an objective of sustainability. Principles should have a general scope and acceptance, they should be considered as a rule or habit and be formulated as short statements, with action verbs originated from management vocabulary such as contribute, ensure, adapt and strengthen.

General Principles are adapted according to the specific needs of the context and to the application scale in order to facilitate ownership and implementation.

Criteria: Considered as a second-order principle or a standard rule or test on which a judgment or decision can be based. Criteria help to break down Principles into several homogeneous elements to link with the characteristics of the system, so they help in understanding the principles. Criteria should have a more specific scope related to the issues, they should identify variables and should be formulated by expressing the degree or state of the variable i.e., level of, control of, existence of, access to and capacity of.

Indicators: They are considered as a simple way to express the information related to a variable or a process. They are "communication tools which serve to quantify and simplify information in order to make it comprehensive to a targeted audience. They are tools to assist monitoring, evaluation, forecasting and decision-making. They are defined with reference to previously-set objectives; comparing the value shown by an indicator with the corresponding objective helps to judge whether an action is effective" (Madec, 2003). Indicators illustrate the variation observed according to the available data, they help to simplify and standardise information.

PCI approach: conceptual framework

A summary of the concepts and definition of the system, when talking about the PCI approach and in the case of lagoon areas, is shown below on figure 5. From an upside down tree structure, Principles represent objectives towards sustainability, several criteria can be developed for each principle, identifying the variables that will serve as a diagnosis of the system. Criteria are described and measured by one or more indicators, based on data from the system.

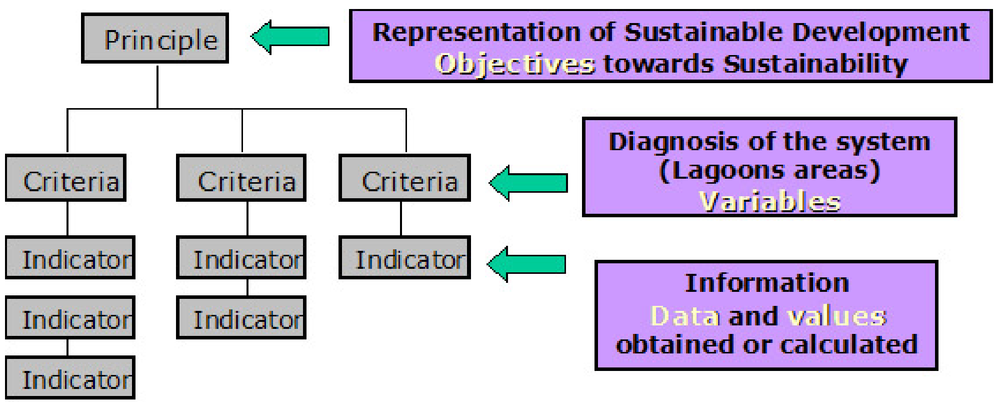

Figure 5. PCI approach: conceptual framework

Indicators for the sustainable management of coastal lagoons areas

The development of indicators for the sustainable management of lagoon areas is not an easy task, due to the complexity of the system and the numerous activities that take place in coastal lagoons and surrounding areas. Some aspects have to be considered in order to achieve sustainability not only on the aims and results, but also on the methodology itself.

A co-construction process should be implemented, in which all the inputs from stakeholders have to be taken into consideration, and which should be based on a participatory approach to gain from all possible actors directly or indirectly related to the activity and assure the acceptability of the project. Consensus among all stakeholders in the definition of objectives, methodology and expected results has to be achieved prior to the development of indicators.

In order to focus and help on the identification and definition of principles, criteria and indicators, an ecosystem-based approach should be considered to facilitate dialogue and consensus among parties. If a common interest and priority is identified for all users, the process will be easier and the success will be assured.

Methodology associated to the process

Taking into consideration the complexity of the surrounding environment of the lagoon areas, a multidisciplinary approach should be implemented, to simplify procedures and, gaining from previous experience (GFCM, 2011); the methodology could be developed in various steps or phases:

Phase I: descriptive

It is necessary to know and identify all the elements that benefit from the ecosystem. In this case there will be different categories such as:

- ***Stakeholders***: All possible users of lagoons areas, apart from aquaculture producers and fishers, should be identified, that is: researchers, ONGs, general public, administrative bodies with competences on the environment (as they are the decision makers and responsible for management). Their needs and interests in connection with the ecosystem should also be defined.
- ***Uses and activities***: All activities and uses of the ecosystem should be identified and linked to the stakeholders. Special attention should be given to capture fisheries and aquaculture; but other activities such as tourism, industry, agriculture, hunting and so on, should be described as part of the system.
- ***Environmental conditions***: All the specific biological, hydrodynamic and geomorphologic characteristics of the environment should be identified, in order to establish the ecological status of the lagoons and surrounding areas.
- ***Interactions*****:** The relationships between aquaculture producers and fishers should be identified, as well as with the rest of stakeholders and their activities. Positive and negative interactions should be described and taken into consideration.

All this information should be gathered and placed on a GIS, not only as a data base, but also as a communication tool. It has been proven by experience (Macías *et al.*, 2003; Aguilar, 2006) that GIS is useful to facilitate dialogue, offering to all stakeholders the same information in a rational way, triggering participation and common understanding of the different situations.

Phase II: co-construction, PCI approach

This is the base to build up indicators for the sustainable management of lagoon areas. As it has been mentioned, the PCI approach should be implemented taking into consideration the four pillars of sustainability and through the following steps:

- Identification of principles as objectives of sustainability. From existing sustainable management reference frameworks, such as the Rio Conference, principles should be established and agreed upon among all parties;
- Identification of Criteria as variables to describe the principles. From the database and collected by experts for the four dimensions of sustainability with direct relation to the relevant principles;
- Identification of Indicators to measure the variables. Indicators should be validated according to attributes. Existing standards and reference points should be considered for quantitative and qualitative indicators and described for those that are not identified yet.

The process of identification of indicators is not an easy issue. Prioritisation and a selection of a minimum number of indicators is needed; equilibrium among the number of indicators per dimension of sustainability is recommended.

Phase III. Indicators assessment

Indicators should be tested and performance evaluated to validate, not only the indicator itself, but also the method for calculation and the reference values. Those should be associated to either a critical or an optimal state, where the former identifies a limit to be avoided (limit values) and the latter a target to be attained by the system (target values). Assessment should be performed through specific case studies and real application of indicators in order to become quality management standards.

Phase IV. Implementation and feedback

Indicators should support the decision-making process by describing the pressures affecting the ecosystem, along with the state and evolution related to the activities. Indicators should be a communication tool for all observers. For those purposes, several methods can be implemented, but one of the most visual, simple and straightforward is the Traffic-light Approach (TLA) (Ceriola, 2008). TLA is the representation of the state of the ecosystem through the values of the indicators, directly linked to colours, that is: positive = green, intermediate/neutral = yellow, negative = red.

Based on the colour code, the variations of each indicator can be highlighted and information is translated and made available in an easy way to set up objectives and new management decisions.

Boundaries, as well as minimum and maximum values for indicators, should be previously established.

Organizational framework

The PCI approach and the development indicators are multidisciplinary issues. Working groups should be established and participation of all stakeholders should be motivated. A panel of experts on economics, biological and social sciences and governance should carry out supervision of the performance of the groups as well as of the outputs, as sustainable management relies on the four pillars of sustainability. Figure 6 shows an example of an organizational framework for the identification of indicators .

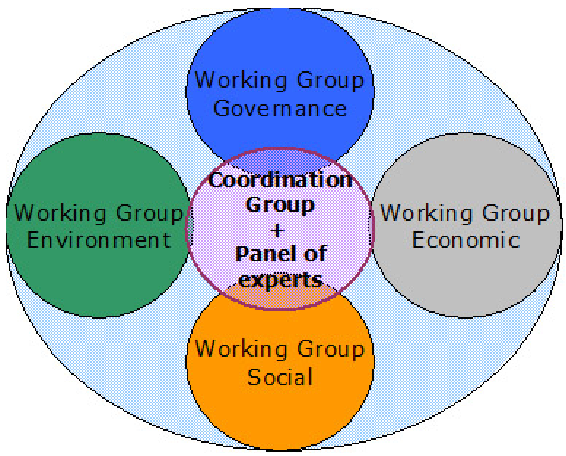

Figure 6. Organizational framework

Conclusions

Coastal lagoons areas are considered as ecosystems of high interest from the environmental, social and economic point of view. Indicators for the sustainable management of coastal lagoon areas are a tool of communication among all stakeholders and users of the system as well as a means to evaluate the performance of the activities towards sustainability.

Methods and tools to develop indicators are available, such as the PCI approach, which gives consistency to the whole process as well as the participative and co-construction approaches that ensure acceptability and allow the achievement of consensus. A panel of experts on the different dimensions of sustainability is required in order to help all participants in the understanding of the system.

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The Mediterranean region hosts around 400 coastal lagoons, covering a surface of over 641 000 ha differing in both their typology and use. Fisheries and various forms of aquaculture have been traditionally carried out in Mediterranean coastal lagoons since ancient times and are part of the cultural heritage of the region. Traditional lagoon management linked to extensive aquaculture and fish harvesting has certainly contributed, over time, to preserve these peculiar ecosystems, although much of the coastal lagoon areas have progressively disappeared due to land reclamation and other uses. Recently, coastal lagoons have become a relevant environmental concern: land claiming, pollution and the lack of management, among other factors, have strongly modified both the structure and functioning of these sensitive coastal ecosystems. In particular, the management of traditional aquaculture and capture fisheries activities has been identified as the main instrument to maintain lagoons' ecological features and to prevent the degradation of their sensitive habitats, both from an environmental and socioeconomic point of view. To guarantee the sustainability of aquaculture and capture fisheries in lagoons, proper management plans should be established so as to ensure the preservation of both biodiversity and local knowledge. This should also be considered as a fundamental pillar for any programme for the preservation and restoration of lagoons' environment.

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