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ROLE OF SCIENCE IN COASTAL LAGOON MANAGEMENT

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RESUMO

As lagoas litorais ocupam aproximadamente 13% da costa continental do mundo. São ecologicamente e economicamente muito valiosas na zona litoral ou seja sujeito às pressões antropogenicas e requerem práticas de gestão sustentavel. A relação entre a bacia hidrografica e a zona litoral, faz do ICARM a melhor prática para gestão de lagoas litorais. De acordo com o processo do planeamento de ICARM, a ciência tem um papel importante para a execução de uma gestão integrada. Usando dois casos de estudo em duas lagoas muito distintas: a lagoa dos Patos (Brasil) e a Ria Formosa (Portugal), mostra-se que a ciência é a base requerida para conseguir uma gestão sustentavel de lagoas litorais. Aplicando o procedimento detalhado OSPAR na Ria Formosa demonstra-se que é uma boa ferramenta para informar gerentes sobre a eutrofização na execução da Directiva Quadro da Agua (DQA), que é a principal base legal para um ICARM na Europa. A execução da DQA no Brasil encontraria desafios importantes e não seria possível hoje em dia. A base científica existe na lagoa dos Patos para aplicar o procedimento detalhado no futuro. Ambos estudos de caso indicaram que a monitoração observacional é um parâmetro crítico no processo integrado da gerência.

Palavra-chaves: *ICARM, DQA, gestão de lagoas costeras, avaliação da eutrofização, papel da ciência, Lagoa dos Patos (Brazil), Ria Formosa (Portugal)*

ABSTRACT

Coastal lagoons occupy about 13% of the world's continental coast. They are highly ecologically and economically valuable in the coastal zone and therefore are subject to anthropogenic pressures and require sustainable management practices. The relation between river basin and coastal zone make the ICARM the management practice fitting the best for coastal lagoons. According to the ICARM planning process science has an important role toward the implementation of integrated management. Using two study cases in two very distinctive lagoons: the Patos Lagoon (Brazil) and the Ria Formosa (Portugal); it has been pointed out that science is the required basis to achieve sustainable management of coastal lagoons. Moreover, the European Water Framework Directive being the main legal support toward an ICARM in Europe, the OSPAR comprehensive procedure has been applied in the Ria Formosa showing that it is a good tool that natural sciences can use to inform managers on eutrophication for the implementation of the WFD. Implementation of the WFD in Brazil would encounter important challenges and would not be possible nowadays. The scientific basis exists in the Patos lagoon to apply the comprehensive procedure in the future. Both study case pointed out that surveillance monitoring is a critical parameter in integrated management process.

Keywords: *ICARM, WFD, Coastal lagoon management, Eutrophication assessment, role of science, Patos lagoon (Brazil), Ria Formosa (Portugal)*

Table of Content

List of Figures

List of tables

Synopsis

Chapter 1 gives a definition on coastal lagoon natural and socio-economic characteristics.

Chapter 2: Within this chapter, the concepts of integrated coastal and river basin management (ICARM) and integration are discussed. This part also shows the role of science toward an ICARM. The integration within science is discussed through a short survey on the existing networks in Europe.

Chapter 3 discusses the water and coastal management in Brazil, and the role that science played in the management of the Patos lagoon estuary.

Chapter 4 in this chapter the eutrophication of the Ria Formosa coastal lagoon is assessed showing the role natural science can have for the management of lagoons through the OSPAR comprehensive procedure, a tool related to the water framework directive that natural scientist may use to inform managers.

Chapter 5 is a discussion on the different part, mainly on chapter 3 and 4. The relation between the comprehensive procedure and EU water policies is discussed. It is also discussed if a tool such as the comprehensive procedure might be applicable in Brazil.

Introduction

Coastal lagoons constitute a common coastal environment around the world occupying about 13% of the world's continental coast (Barnes, 1980).

They have a major ecological and economical role in the coastal zone. Indeed, in the general classification of aquatic ecosystems, lagoons have among the highest primary and secondary productivities known (Macintosh, 1994); the average natural fish production in lagoons being around 100 $kg.ha^{-1}.year^{-1}$ (Kapetsky, 1984). These ecological characteristics support fisheries, aquaculture and have an economic impact on the lagoon region. Coastal lagoons are also economically important with the development of tourism and are often used as recreational areas.

To respond to these anthropogenic pressures on the lagoons, management tools have been developed and the concept of integrated management came into force during the world summit held in Rio (1992) when the United Nations recognized the link between natural and anthropogenic processes and the need for integrated actions to reach sustainable development. Regarding the characteristics of coastal lagoons (located on the coastal zone and influenced by the river basin) two widely used integrated management approaches are related to lagoons: the Integrated River Basin Management and the Integrated Coastal Zone Management (IRBM and ICZM, respectively). At a European level, these two practices are being either supported by the commission (ICZM) or under implementation (IRBM with the Water Framework Directive). These two practices share a common objective, the sustainable use of water and coastal resources and can be merged to an Integrated Coastal Area and River Management (ICARM) toward a sustainable development of coastal lagoons. ICARM is based on a system analogy considering the natural and the human systems and therefore a good knowledge of these two systems is required to set up management boundaries and options; this knowledge being provided by natural and social science.

Considering the ***hypothesis*** that science is the required basis toward a sustainable management of coastal lagoons, this work aims to analyze the role of science in an integrated management of coastal lagoons, focusing on the natural sciences.

To realize this analysis, this work can be divided in two main part, theory and study case.

The ***Theory*** aims to characterize coastal lagoons but also to discuss the concept of ICARM and the role of science within such integrated management.

The second part consists in two ***Study Cases.*** The Patos Lagoon study case aims to illustrate and discuss the role of science in coastal lagoon management in Brazil. The Ria Formosa study case aims to assess the eutrophication of this lagoon using the OSPAR comprehensive procedure and to illustrate how natural scientist can inform managers through such tool.

Chapter 1: Characterization of coastal lagoons

1. Natural Science - A tool to define and explain coastal lagoons characteristics

Coastal lagoons are natural ecosystems with particular characteristics differentiating it from other coastal systems. The European Water Framework Directive (WFD) recognizes that the ecological character of surface waters will vary according to their different physical regimes. Therefore Article 5 of the WFD requires Member States to carry out a characterization of all water bodies. This exercise is referred to as typology and it is one of the first stages in the implementation of the WFD (WFD CIS, 2003).

The definition, characterization and the typology of coastal lagoon is done through natural sciences. This chapter aims to define the characteristics and typology of coastal lagoons.

1.1. Definition of Coastal Lagoons

The definition of coastal lagoons varies widely depending on the criteria used to classify coastal systems. However, the geomorphological approach remains the easiest way to define coastal lagoons. According to Kjerfve (1994), coastal lagoons are *"inland water bodies, usually oriented parallel to the coast, separated from the ocean by a barrier, connected to the ocean by one or more restricted inlets which remains open at least intermittently, and have water depths which seldom exceed a couple of meters. A lagoon may or may not be subject to tidal mixing, and salinity can vary from that of a coastal freshwater lake to a hypersaline lagoon, depending on the hydrologic balance"*.

Using this broad definition, coastal lagoons are found in a variety of environments ranging from arctic to equatorial, and from arid to humid (Lasserre, 1979; Guilcher, 1981) and at a variety of scales from over 10000 km^2 (Fig.2 - Patos Lagoon, Brazil) down to less than 1 hectare (Bird, 1994).

The size of the connection with the open sea is the characteristic most used to classify coastal lagoons. As described by Bird (1982), the term coastal lagoon is applied when the width of the marine entrances at high tide is less than one fifth (20%) of the total length of the enclosing barrier.

1.2. Geomorphology

The definition given by Bird covers the main features of coastal lagoons. However, like estuaries, they display a great variety of physical types and characteristics and several authors proposed classification of lagoons. The most common approach was to link morphology (barrier spit and the amount of entrances) together with dynamic factors responsible of their formation (tide, swell, fluvial flow and wind circulation).

Kjerfve (1986) thus sub-divided coastal lagoons into three geomorphic types according to water exchange with the coastal ocean (Fig.1).

Figure 1: Coastal lagoon subdivisions (Kjerfve, 1994)

Choked lagoons (e.g. Fig.2) usually consist of a series of connected elliptical cells, connected by a simple long, narrow entrance channel, along coasts with high wave energy and significant littoral drift. Choked coastal lagoons are characterized by long flushing times, dominant wind forcing, and intermittent stratification events due to intense solar radiation or runoff events. Choked lagoons are mostly oriented shore parallel but are sometimes also found associated with river deltas and then occasionally oriented shore-normal.

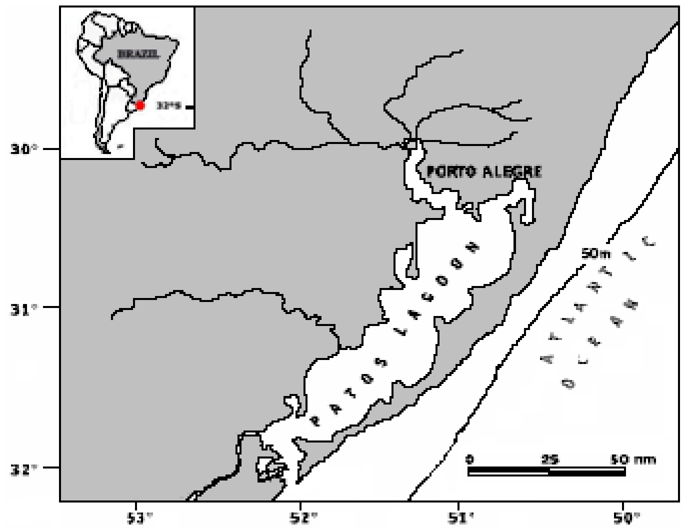

Figure 2: The Patos lagoon (Brazil), a choked lagoon (After Windom et al., 1999)

Restricted lagoons (e.g. Fig.3) consist of a large and wide water body, usually oriented shore-parallel, and exhibit two or more entrance channels or inlets. As a result, restricted coastal lagoons have a well defined tidal circulation, are influenced by winds, are mostly vertically well mixed, and exhibit salinities from brackish water to oceanic salinities. Flushing times are usually considerably shorter than for choked coastal lagoons.

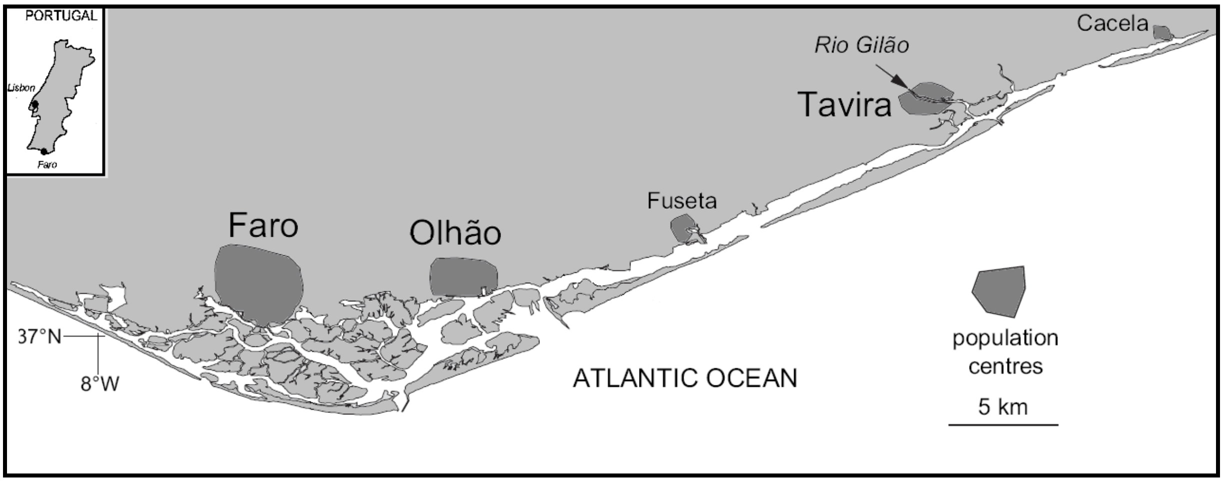

Figure 3: The Ria Formosa (Portugal), a restricted lagoon (modified, Mudge & Duce, 2005)

Leaky lagoons (e.g. Fig.4) are elongated shore-parallel water bodies with many ocean entrance channels along coasts where tidal currents are sufficiently strong to overcome the tendencies by wave action and littoral drift to close the channel entrances. Leaky lagoons are characterized by numerous wide tidal passes, unimpaired water exchange with the ocean on wave, tidal, and no longer time scales, strong tidal currents, and salinities close to that of coastal ocean. However, like estuaries (with which they have often been erroneously classified), they display a great variety of physical types and characteristics. Kjerfve (1994) also notes that coastal lagoons can span the range of salinities from hypersaline to completely fresh.

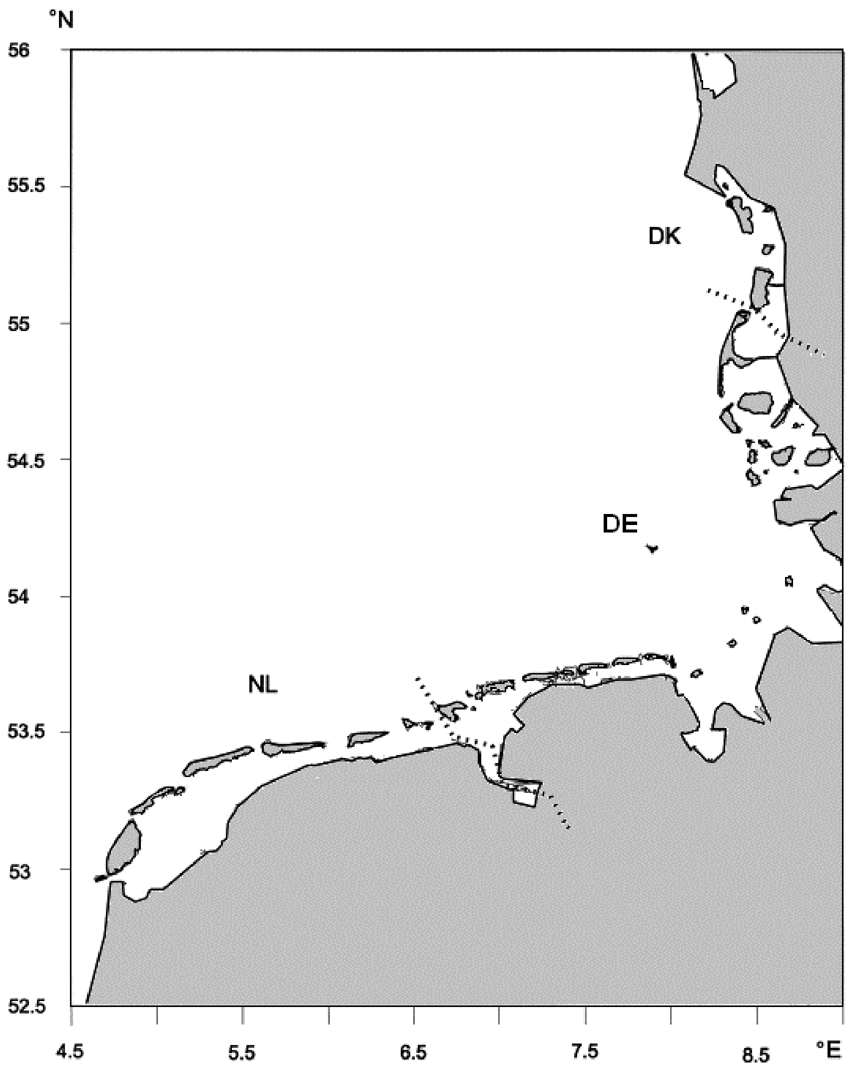

Figure 4: The Wadden Sea (Netherlands, Germany and Denmark), a leaky lagoon (Ries et al., 1999).

1.3. Distribution and dynamics of coastal lagoons

Coastal lagoons are found all over the world, however, the distribution and the dynamics of coastal lagoons are influenced by several factors summarized by Bird (1994) and presented in figure 5.

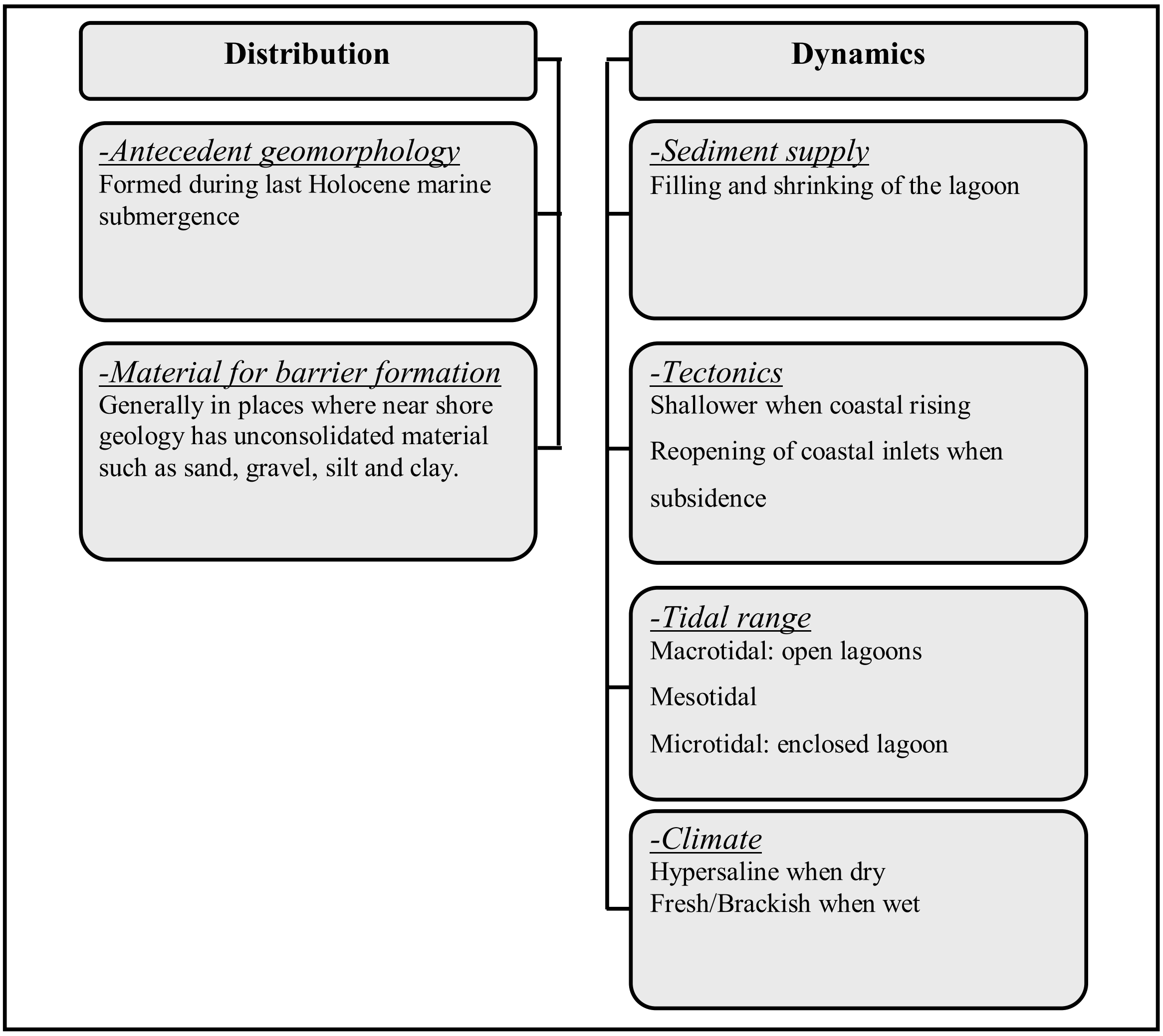

Figure 5: Factors influencing the distribution and dynamics of coastal lagoons (after Bird, 1994)

1.4. Water circulation

Circulation is an important parameter for both hydrography and water quality in coastal lagoon. By definition, coastal lagoons are enclosed by barrier islands and generally found in microtidal coasts (e.g. Baltic, Mediterranean and Black seas). This means that waves and currents in coastal lagoons are typically generated by winds blowing over their waters (strength, direction and fetch).

The circulation in coastal lagoons can be divided in several ways (Smith, 1994):

A basic distinction consists in separating the tidal and the non-tidal transports. Non-tidal transport can further be subdivided by distinguishing between barotropic and baroclinic forcing. A barotropic pressure gradient arises from a slope in the surface of the lagoon. Such a slope may be created by created by the wind driven setup or setdown of water levels or it may occur in response to surface runoff entering the lagoon at some point. A baroclinic pressure gradient arises most commonly from longitudinal salinity gradients and the resulting density gradients. Baroclinic pressure gradients may be created in subsurface layers at the inclined interface between salt water and brackish water near an inlet.

The circulation within a coastal lagoon can also be thought of as arising in response to local and non-local, or “remote” forcing. Local forcing is dominated by wind stress which creates currents, waves and setup and setdown (Fig.6). Non local forcing of the lagoon circulation is the result of tidal and low frequency variation in coastal sea level and swell.

Inlet morphology plays a central role in the lagoon-shelf exchange process (Smith, 1994), the entrance channels can actually serves as a dynamic filter and may largely eliminates tidal currents and water-level fluctuations inside coastal lagoons (Kjerfve, 1986; Kjerfve et al., 1990; Kjerfve & Knoppers, 1991).

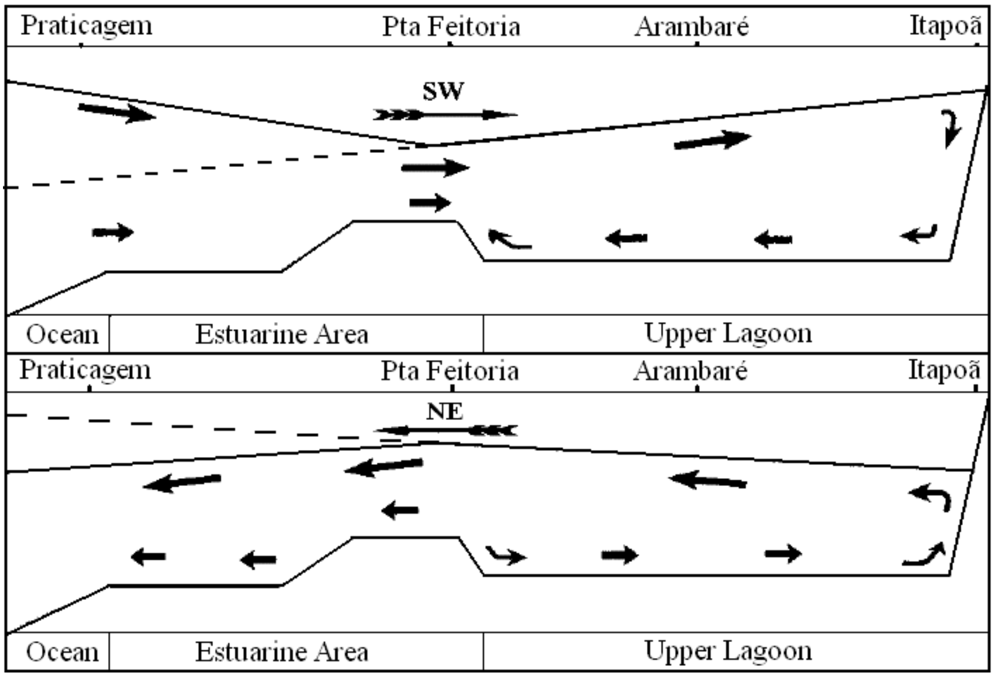

Figure 6: Schematic representation of Patos lagoon dynamical behavior when forced with Southwest (A) and Northeast (B) winds. The dotted line represents the wind set-up if the lagoon was closed at both extremities. No proportion in arrows denoting current (Moller *et al.*, 2001)

1.5. Coastal lagoons typology according to WFD

The WFD differentiates four kinds of surface water bodies: rivers, lakes, transitional waters and coastal waters.

Coastal lagoons may be either coastal waters or transitional waters, depending on whether the lagoon fits the definition of transitional waters in the Directive *"in the vicinity of river mouths*" and "*substantially influenced by freshwater flows"* (Article 2(6)).

1.6. Comparison between Patos lagoon and Ria Formosa

Morphologically, the Patos Lagoon and the Ria Formosa are different; the Patos L. being choked whereas the Ria Formosa is restricted according to the definition of coastal lagoons. Patos L. is mainly freshwater except the estuarine area whereas the Ria Formosa is mainly saline. According to WFD typology the estuarine area of the Patos lagoon would be classified as transitional water whereas Ria Formosa is classified as coastal water (MONAE, 2005). A comparison between the two systems is summarized in Table 1.

Table 1: Comparison between the Patos Lagoon (Brazil) and the Ria Formosa (Portugal)

Characteristic	Patos lagoon		Ria Formosa
	Lagoon	*Estuary*	
Latitude	30°55' – 32°30' S	-	36°58' – 37°03' N
Longitude	50°55' – 52°20' W	-	7°32' – 8°02 W
Typology	Choked	-	Restricted
Drainage Area	201 626 km²	100 km²	860 km²
Lagoon Area	9 300 km²	971 km²	14.5 km²
Tidal range	0 m	0.1 m	0.7 – 3.5 m
Average Depth	5 m	3 m	3 m
Typical Salinity	0	18	>32
Average temperature	20	20	12 (winter) – 27 (summer)
Average Rainfall	1.75 $m.yr^{-1}$	1.20 $m.yr^{-1}$	0.8 $m.yr^{-1}$

Size is an important factor differentiating the two systems. The estuarine area of Patos lagoon is for instance bigger than the entire river basin of the Ria Formosa. The Ria Formosa presents more or less homogenous environmental and biological conditions whereas Patos L. can be divided into five biological units as described by Asmus (1997).

In term of management such a difference in size has several consequences. Management boundaries for the Ria Formosa can consider the Lagoon as a whole but the Patos lagoon should be divided into several units with different management responses. This can be illustrated in the Patos L. estuarine area where the Mangueira embayment is subject to a weak water circulation whereas the canal of the estuary is highly dynamic with important water circulation (Tyrrell, 2005). Moreover, the application of the WFD typology to the Patos L. would divide the lagoon into at least two water bodies, one as river water body (inner lagoon) and one as transitional water body (estuary).

2. Socio-Economics of Coastal Lagoons

2.1. Coastal lagoons economics

Coastal lagoons are highly valuable ecosystem (Table 2) and must be managed carefully to sustain the "goods and services" that human benefit from it.

Table 2: Economic of a coastal leaky lagoon, the Dutch Wadden sea, the Netherlands (WWF, 2004)

Economic Benefit	Economic Value per year (converted to 2003 US$)
Flood prevention	189,000,000
Storage and recycling of organic matter	756,000,000
Storage and recycling of nutrients	945,000,000
Habitat and nursery	45,360,000
Nature protection	5,670,000
Aquaculture	8,316,000
Recreation	189,000,000
Food	170,100,000
Raw materials for construction	9,450,000
Spiritual / historical information	5,670,000
Education and scientific information	6,048,000
TOTAL ECONOMIC VALUE	**2,329,614,000**

Costanza *et al.* (1997) stated: "*Ecosystem services provide an important portion of the total contribution to human welfare on this planet. We must begin to give the natural capital stock that produces these services adequate weight in the decision making process, otherwise current and continued future human welfare may drastically suffer*".

This quotation actually shows the importance of ecosystems to human being, providing goods and services. To be sustainable, coastal lagoon management should thus take into account the "value" of these ecosystem services. However, ecosystem goods and services are the products of processes operative over long temporal scales and broad spatial scales and are therefore difficult to evaluate. The better the knowledge of the ecosystem processes, its function and the linked human activities, the better will be the evaluation of the goods and services it can produce. Sustainable management of coastal lagoons requires therefore good knowledge in natural and social science to justify the actions to be taken.

2.2. Ecosystem goods and services of coastal lagoons

"Ecosystem services" is a general term and consequently many definition and interpretation can be found in the literature. From a very restricted definition where ecosystem services are seen just as "components of nature, directly enjoyed, consumed, or used to yield human well-being" (Boyd and Banzhaf, 2007) to a wider definition from Heina *et al.* (2006) where it can be "goods and services produced in the ecosystem (production services), biological process (regulation services) and benefits people obtain through the ecosystem (cultural services)".

Ecosystems are managed in a human perspective, which means that management actions are done in order to directly or indirectly benefit to human beings. As a result, managers must understand the ecological basis of ecosystem sustainability and the inextricable interconnectedness of the human well-being (Miller, 2003).

The aim of this part is thus to illustrate the connection between lagoon ecosystem and human well-being and show the importance of coastal lagoons for human being.

From this point of view, there is no particular need to clearly distinguish ecosystem goods and ecosystem services of coastal lagoons. The ecosystem goods and services (including system function and processes) can be summarized in Table 3.

Table 3: Ecosystem goods and services of coastal lagoons (non exhaustive, after WWF, 2004; Costanza *et al.*, 1997; Seixas & Troutt, 2004 ; Miller, 2003; Heina *et al.*, 2006)

Ecosystem goods and Services	Description
Food, wildlife, marine life	Fish, clams…
Erosion control and sediment retention	Plants such as seagrasses retain sediments, and protect the shore from erosion, formation of land.
Biological control	Trophic-dynamic regulations of populations. Keystone predator control of prey species, reduction of herbivore by top predators.
Biological productivity	Rich in nutrient, high primary productivity
Habitat and nursery for plant and animal species	Rich in nutrients, high primary production, good conditions for nurseries and migratory species (birds, fish…)
Biological nitrogen fixation (BNF)	Seagrasses absorb and fix nutrients such as nitrogen
Storage and recycling of nutrients and gases	Sustain biogeochemical flux, mineral and gaseous cycling, storage
Genetic resources	Maintain the genetic diversity, Sources of unique biological materials and products
Medicinal resources	Plants and algae can be used for medical purposes
Provide energy	Use of tidal mill
Research, education and monitoring	Provide scientific and educational information. e.g. many research activities from the University of the Algarve are linked to the Ria Formosa lagoon,
Raw materials for building, construction and industrial use	Sand extraction for construction purposes
Uniqueness, rarity or naturalness and role in cultural heritage	
Disturbance regulation	Capacitance, damping and integrity of ecosystem response to environmental fluctuations - Storm protection and other aspects of habitat response to environmental variability mainly controlled by vegetation structure
Absorbing and detoxifying pollutants, provides for waste treatment	
Recreation and tourism	Provide natural beauty, inspiration. Eco-tourism, sport fishing, and other outdoor recreational activities (boating, swimming…)
Provision of cultural, historical and religious heritage (e.g., a historical landscape or a sacred forests)	
Provision of other information (e.g., cultural or artistic inspiration)	
Carbon sequestration	

3. The DPSIR Framework – A link between social and natural sciences in Coastal lagoons

3.1. DPSIR Framework definition

Environmental management is based on the knowledge of the system and the state of the environment. A set of physical, biological or chemical indicators are generally used to reflect a system analysis view of the relation between the environmental system and human system.

At a European level, the DPSIR approach (Driving forces, Pressure, State, Impact, and Response) is widely used to organize the information about the state of the environment; this framework being used by the European Environment Agency in its reporting activities (EEA, 1999).

According to this systems analysis view, social and economic developments (as Driving forces, e.g. industries) create a set of Pressures on the environment (e.g. by producing effluent discharges). Consequently, the State Change of the environment (e.g. to the benthic or water column system) undergoes Impacts affecting human uses (e.g. degraded habitats, human health problems or barriers to fish migration). The latter then requires to be addressed by a human Response (e.g. legal control and administrative arrangements) that feeds back to the driving forces, the state or the impacts (Audry & Elliot, 2006).

This framework can be schematized as Figure 7:

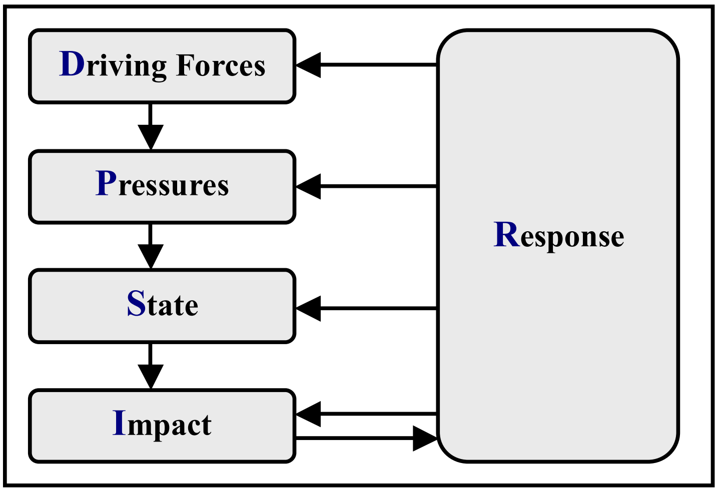

Figure 7: The DPSIR framework (modified. EEA, 1999)

3.2. DPSIR for coastal lagoons

Lagoons are located in the coastal zone and receive its freshwater from the river basin further inland. Human activities located in the costal zone (fisheries, aquaculture, salt marshes…) and in the river basin (agriculture, industries…) influence thus directly or indirectly the natural system of a lagoon. Human and environmental systems are interrelated in lagoon management.

To respond to environmental problems in coastal lagoons, a cause-effect analysis can be done using the DPSIR framework in order to report its environmental status and define the management issues. This analysis links social science (driving forces and Response) with natural sciences (Pressure, State and Impact).

The DPSIR have for instance been applied, in the two main Portuguese lagoonal system (PLANET, 2007) to determine the environmental status regarding Mercury pollution in one hand, and eutrophication in the other hand. Indeed, Duarte *et al.* (2007) applied the DPSIR framework for mercury pollution in the Ria de Aveiro whereas Newton *et al.* (2003) applied this framework for the eutrophication of the Ria Formosa.

The results of the DPSIR approach in these two study cases have been summarized in Table 4.

Table 4: The DPSIR approach in coastal lagoons – 2 examples: Eutrophication in Ria Formosa (Newton *et al.*, 2003) and Mercury pollution in Ria de Aveiro (Duarte *et al.*, 2007); Portugal

	Mercury Pollution (Ria de Aveiro)	Eutrophication (Ria Formosa)
D	▪ Industry (Historical pollution) ▪ Agricultural activities ▪ Households-waste water treatment	▪ Agricultural activities ▪ Industry wastewater ▪ Households wastewater ▪ Soil erosion ▪ Aquaculture
P	▪ Discharges from industrial point source (main source) ▪ Release of Hg from historical contaminated sediments ▪ Solid waste management (disposal) ▪ Loads to surface waters by diffuse sources (drainage, transport, accidental spills) ▪ Leaching from agricultural areas ▪ Atmospheric deposition	▪ Increase in intensive farming (chicken and pig farms, greenhouses) ▪ Increase of urbanization ▪
S	Bioaccumulation of Hg and organic Hg in biota: ▪ Macroalgae (*Fucus*, *Gracilaria* and *Enteromorpha*) ▪ Macrofauna (*Scrobicularia plana* and *Carcinus maenas*) ▪ Salt marshes plants (*Halimione portulacoides*)	▪ ''poor'' to ''bad'' quality status of winter ▪ Nutrient concentrations (eastern lagoon) ▪ Eutrophic conditions in areas receiving a greater freshwater input from urban and, especially, agricultural catchments. ▪ Events of oxygen depletion
I	▪ Contamination problems in Ria de Aveiro are confined to the Laranjo Basin. ▪ Macroalgal harvesting for human uses and human consumption of mussels and crabs from the Laranjo -Basin may constitute a risk for human health.	▪ Decline in bivalve harvest ▪ Increase in the mortality in clam stock farms, with mass mortalities in some areas of the lagoon ▪ Increase of harmful algal blooms incidences ▪ Fish kills with increasing frequency in the summer months. ▪ decrease in seagrasses ▪ Large increase in algal mats and Ulva.
R	▪ Development of Analytical Methods ▪ Development of decontamination technologies ▪ Water Framework Directive (2000/60/EC) ▪ Urban Waste Water Treatment Directive (91/271/EEC) ▪ Bathing Water Directive (76/160/EEC) ▪ Integrated Pollution Prevention and Control Directive (96/61/EC) ▪ Studies focused in developing skills for ecosystem restoration	▪ Development of monitoring network to monitor: ▪ Ecological end chemical status ▪ Nutrients, Chlorophyll a, oxygen concentration and saturation, primary and secondary symptoms (algal & macroalgae abundance), phytoplankton composition, macrobenthos & macrophytes biomass ▪ Report to database eutrophication data under UE directives ▪ Assure quality of data ▪ Study contribution of sediments ▪ Include nutrients and organic matter from aquaculture ▪ Use of remote sensing, aerial photography & GIS for modeling ▪ Test TRIX, EUTRIX, PSA and equation indices to Ria Formosa ▪ Evaluate effect of seasonal population change ▪ Evaluate impact of rainfall and climate

Chapter 2: Management of Coastal Lagoons

1. Integrated Coastal Area and River Basin Management

Coastal lagoons are coastal ecosystems influenced by both tides and freshwater input from the watershed. They are located in the coastal area and have a direct relation to the watershed (Fig.8-9). Indeed, approximately 70% of the Earth's non-frozen land surface ultimately drains into coastal waters and oceans (Sorensen, 2002).

Figure 8: Freshwater runoff from the watershed (201,626 km2) into the Patos-Mirim Lagoon system reaches continental shelf waters of the southwestern Atlantic through the Patos Lagoon estuary, with flow rates varying from 4,000 to 10,000 $m^3.s^{-1}$. (Modified, Hartmann & Schettini, 1991)

Therefore coastal and river basin management can no longer be considered independent sciences or management areas and the best management practice for coastal lagoon would be the Integrated Coastal Area and River basin Management (ICARM) which came up in the 1990s (UNEP, 1999).

1.1. Definition of ICARM

"ICARM is the adoption of goals, objectives and policies and the establishment of governance mechanisms which recognize the interrelationships between the [coastal and river basin] *systems with a view for environmental protection and socio-economic development"* (Coccossis, 2004).

During the world summit held in Rio (1992), the United Nations recognized the link between natural and anthropogenic processes and the need for integrated actions to reach sustainable development. The features of the coastal zone (ecologically important and strong development of human activities) make the coast an area of big concern for sustainable development. One of the tools developed to ensure the sustainable development is the Integrated Coastal Zone Management. However, coastal zone manager observed that an integrated management of the coastal zone "only" was not sufficient to truly well manage the coast because of the strong relationship between river basin and coastal area (Fig.8-9). A good example of how decision making in river basin can strongly affect the coastal zone is the construction of the Aswan dam in Egypt which lead to the erosion of the Nile river delta.

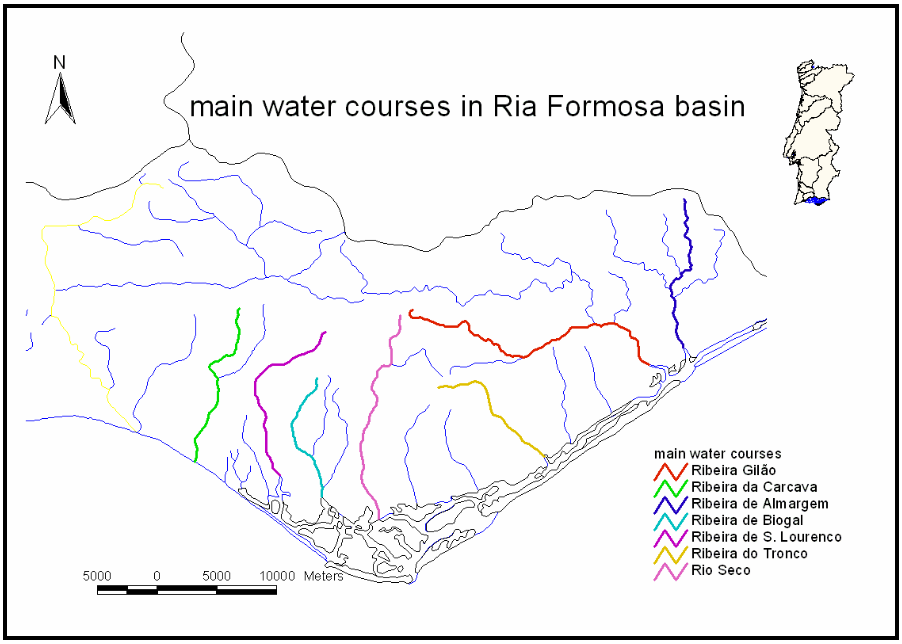

Figure 9: The Ria Formosa basin has an area of approximately 860 km2, a maximum altitude of 522 m and an average slope of 11%. (Guerreiro, 2007, not published yet)

The *goals* of integrated coastal area and river basin management fall within the framework of sustainable development according to which environmental conservation is of equal importance to economic efficiency and social equity, all sought in a long-term perspective on the basis of intergenerational equity (Coccossis, 2004).

According to UNEP (1999), the ICARM *principles* of sustainable development involve: (1) respecting the integrity of the river basin or coastal ecosystem; (2) accepting the limits on the use of resources and the strategic importance of renewable resources for socio-economic development; (3) allowing for the use of resources integrating complementary activities and regulating/separating conflicting ones; (4) ensuring multi-sectoral and multi-level integration in decision-making; (5) linking broad scale management to local level interventions; and (6) allowing for the participation of all actors and stakeholders, particularly local populations, in the planning process to assure good management.

1.2. The concept of integration

Integration is a key concept in framing the role of research in decision-making. Indeed, a survey-based study done by Steel *et al.* (2004) revealed that the 90% of the environmental managers surveyed (n = 167) agreed with the statement that: ''Scientists should work closely with managers and others to integrate scientific findings in management decisions'' (Table 5).

Table 5: Attitudes toward scientific advocacy (from Steel *et al.*, 2004)

Statements	Scientists: % agree[a], mean (S.D.)	Managers: % agree, mean (S.D.)
Scientists should report scientific results for others involved in natural resource management decisions: F-test = 3.696**	87%, 4.18 (0.85)	78%, 3.92 (0.86)
Scientists should work closely with managers and others to integrate scientific results in management decisions: F-test = 1.867	77%, 4.09 (0.94)	90%, 4.30 (0.76)
n	154	167

Scale used: 1: strongly disagree, 2: disagree, 3: neutral, 4: agree, and 5: strongly agree.
[a]Percent agree and strongly agree.
***Significance level P≤0.001.

In a general sense, integration can be defined as the act of combining or coordinating several parts or elements into an entire whole. In science, the concept of integration has become a catch phrase over the recent years (van Kerkhoff, 2005) and plenty of articles actually deal with integration in the recent literature. The development of integrated project in research has been promoted in Europe through the European Commission's sixth Framework Program (FP6). Most of the projects funded by the FP6 actually deal with integration (European Commission, 2002 - 2007). Examples of integrated projects for the coastal zone (EU DG for research, 2007) include ENCORA[1] (European Network on Coastal Research), SPICOSA[2] (Science and Policy Integration for Coastal System Assessment), EUROWET[3] (Integration of

[1] ENCORA website. URL: http://www.encora.eu/ (accessed on May 15, 2007).
[2] SPICOSA website. URL: http://www.spicosa.eu/ (accessed on May 15, 2007).
[3] EUROWET website. URL: http://eurowet.brgm.fr/ (accessed on May 15, 2007).

European Wetland research in a sustainable management of water cycle) and CONSCIENCE[1] (Concepts and Science for Coastal Erosion Management). Another FP5 European funded integrated project for coastal lagoons in particular is the DITTY project[2] (Development of an information technology tool for the management of Southern European lagoons under the influence of river-basin runoff). More details about these projects can be founded on the references.

Reviewing the different concepts of integration and according to different study examples, van Kerkhoff (2005) could distinguish 12 uses of the term integration ranging from integration across disciplines to integration across resources such as funding.

Van Kerkhoff (2005) also designed a framework (Fig.10) that can be use to analyze which form of integration is the most appropriate to achieve a particular goal and to see how the different uses of the term integration relate to each other.

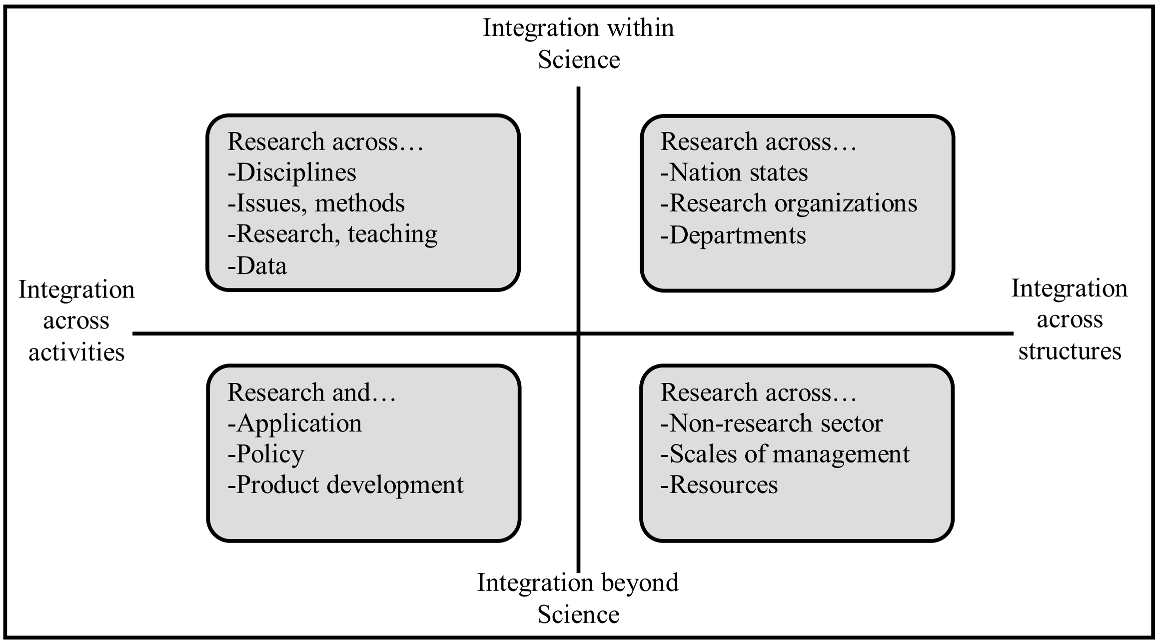

Figure 10: A framework for analyzing integration (van Kerkhoff, 2005)

[1] CONSCIENCE website. URL: http://www.conscience-eu.net/ (accessed on May 15, 2007).
[2] DITTY Project website. URL: http://www.dittyproject.org (accessed on May 15, 2007).

1.3. Integration in coastal zone management

The determination of the different levels of integration that have to be taken into account in Integrated Coastal Zone Management (ICZM) varies depending on the literature. For instance, according to RAMSAR (2002), there are nine dimensions of integration that ICZM needs to address whereas the Intergovernmental Oceanographic Commission (IOC) from the UNESCO (van Kerkhoff, 2005) draws only five (Table 6).

Table 6: The different dimensions of integration according to RAMSAR and UNESCO (after RAMSAR, 2002 and van Kerkhoff, 2005)

RAMSAR	UNSECO-IOC
▪ Vertical integration	▪ Intersectoral integration
▪ Horizontal integration	▪ Intergovernmental integration
▪ Systemic integration	▪ Spatial integration
▪ Functional integration	▪ International integration
▪ Science-Management integration	▪ Science-Management integration
▪ Policy integration	
▪ Spatial integration	
▪ Planning integration	
▪ Temporal integration	

However, some of the dimensions can be grouped and the ones that are recurrent in the literature have been well summarized by Coastlearn (2007). Indeed, the distinction is generally made between several types management integration (Tab.7).

Table 7: The different dimensions of integration according to Coastlearn (2007)

Type of Integration	Example/Description
Intergovernmental integration or "Vertical Integration"	Local, provincial and national government levels. This integration has the objective to harmonize policy development by national and the final implementation by the local governments.
Intersectoral integration or "horizontal integration"	The Ministry of Public Works, the Ministry of spatial planning and the Ministry of Tourism. A specific type is called integration in space, as the land and sea side of the coastal zone are traditionally governed by different sectors (e.g. tourism vs. fishery), but activities at either side influences the other.
Integration of governmental and non-governmental organizations	local government, local nature organizations and small industries
Integration of science and management	Clearly, social, nature and engineering sciences have the task to inform coastal and ocean managers. However, their communication is often not optimal
International integration	It may occur that problem areas are cut in two by international borders. As the effects of use of natural resources don't know these boundaries, international co-ordination is a prerequisite. Though, the problem might have a regional character, the national governments play a leading role in such cases.

1.4. Integrated science and management

The different characterizations of integration from RAMSAR (2002), Coastlearn (2007) and IOC (van Kerkhoff, 2005) include science into their framework. This shows both the need for disciplinary integration within science and better integration of science with coastal management. A well conducted ICARM requires good knowledge of the system which is usually obtained through scientific input.

There are important functional relationships between river basins and coastal areas and one may influence the other (Coccossis, 2004). The two systems are linked through natural processes (water flow, sediment transport, energy) and human activities (urban development, rural activities, technical infrastructures, waste and pollution). Because of this relationship, integration within science (natural sciences, social sciences, engineering) and between science and coastal/ocean manager is of major importance to achieve a good ICARM process. This integration is mainly done through communication between the different parties and developing methods integrating the information (database, website, models, networks…) as presented in Figure 11.

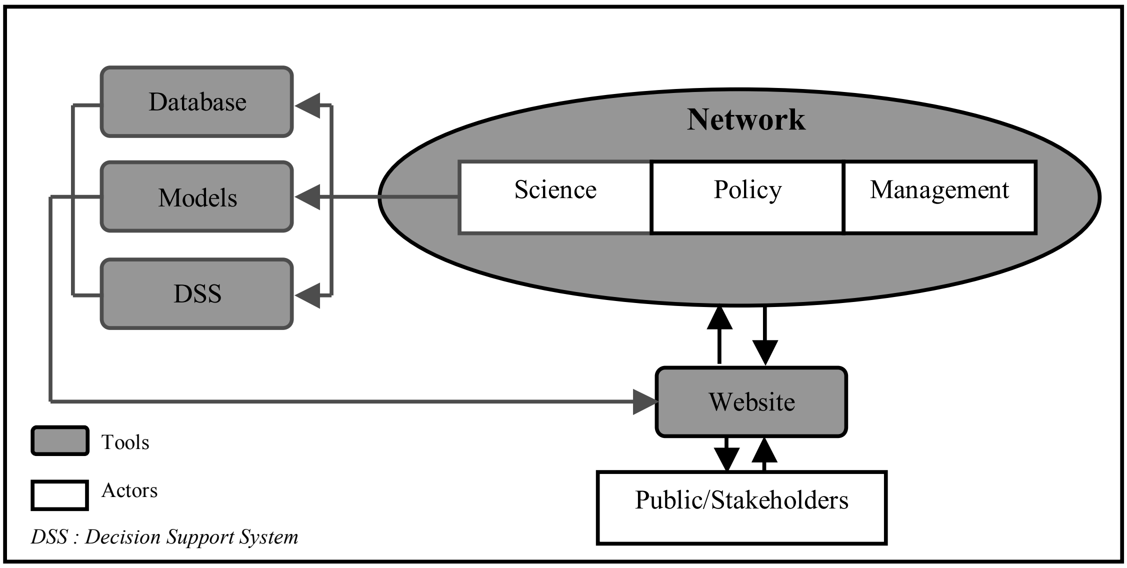

Figure 11: Example of integration tools and interrelation between the different actors in ICARM

2. Role of science in ICARM

ICARM extended the range of management for coastal and river basin areas to natural resource management, environmental management and land-use planning combining ICZM with Integrated River Basin Management (IRBM) practices.

As coastal and riverine environments are complex ecosystems there is a need to develop a simple analogy which scientists and managers can use to describe the essential features of these ecosystems and their interaction with human usage (UNEP, 1999). ICARM is based on a system analogy described in the UNEP planning guidelines for ICARM (UNEP, 1999). This analogy is made of the two main components which interact in river basin and coastal areas: the natural system and the human system. The description and understanding of these two systems can be done through natural and social science.

According to the UNEP/MAP/PAP (United Nations Environment Programme/Mediterranean Action Plan/Priority Action Programme) planning guidelines for ICARM (UNEP, 1999), the planning process of ICARM is divided into seven "steps":

1. Initiation
2. Analysis of existing situation
3. Identification of conflicts/opportunities
4. Identification of goals and alternatives courses for action
5. Strategy formulation
6. Implementation
7. Monitoring and evaluation

Good management practices are based on the available knowledge on the system we actually want to manage. Generally, the best way to solve a problem is by having the highest knowledge on the possible causes of this problem. How could eutrophication be solved in coastal waters if we do not know that it is actually linked with anthropogenic nutrient input? Science in river basin and coastal management has therefore a role from the early start of the ICARM (providing information analyzing the system and developing a simple analogy) to the reviewing process of the different issues through monitoring.

In order to illustrate the role of science in the planning process of ICARM, steps 2 and 3 can be merged as well as steps 5 and 6. A modified planning process with four steps is thus defined (Fig.12).

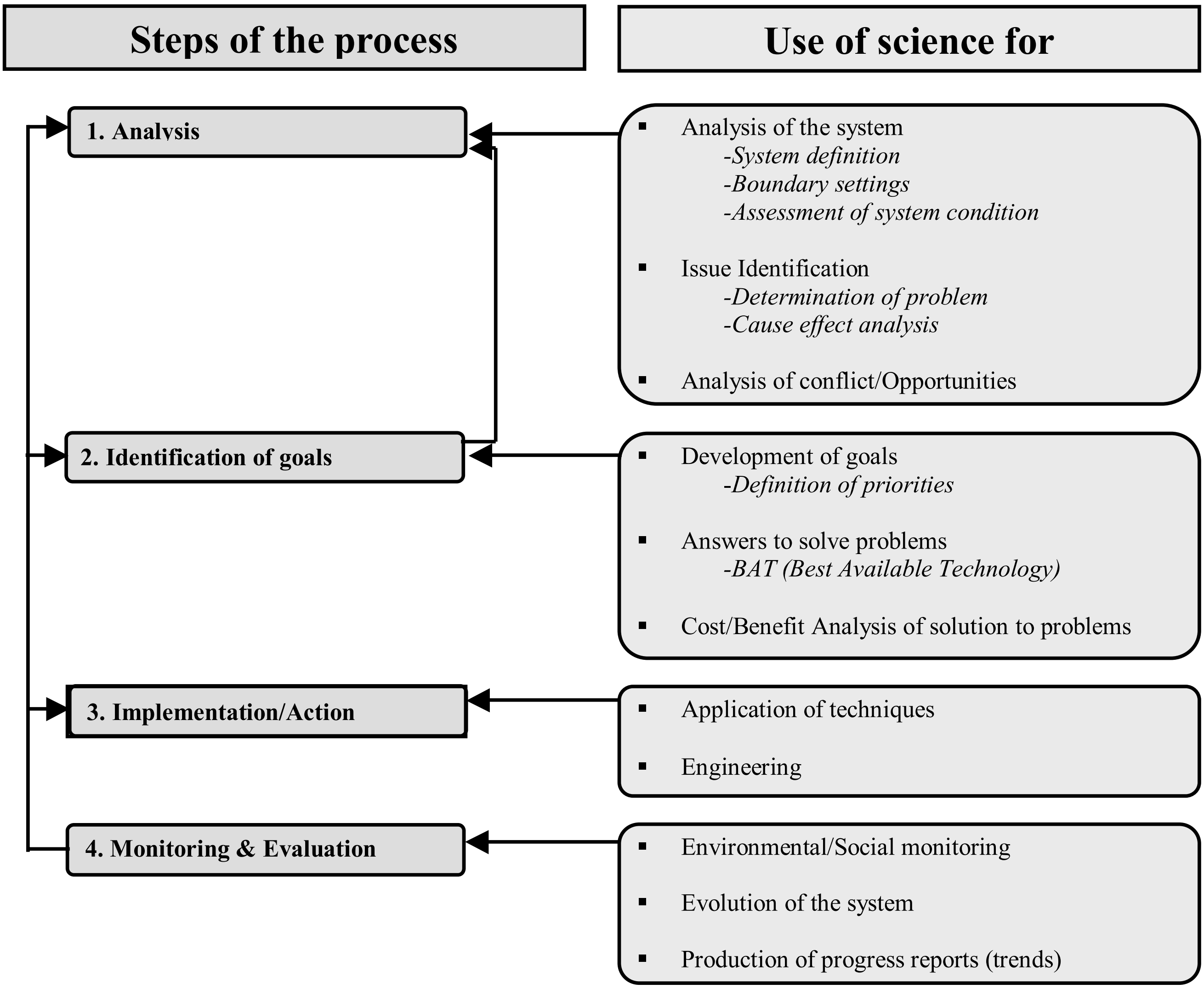

Figure 12: The use of science in the different step of ICARM planning process (after UNEP, 1999; Coccossis, 2004 and GESAMP, 1996)

Figure 12 gives an overview of the science input in the ICARM planning process. This figure outline that science has an important role in almost all the steps of the process.

In its report "*The contributions of science to coastal zone management*", the GESAMP (1996) actually recognize that science plays a major role in all the steps of ICZM:
"Collaboration between managers and scientists at all stages of the formulation of management policy and programmes, and in the design, conduct, interpretation and application of research and monitoring" being a pre-requisite for a successful ICZM.
This report outline the contribution of science in ICZM process through a general description illustrated with four study case from different countries.

The basic principles of ICARM are the same as those for ICZM (RAMSAR, 2006); therefore, the contribution of science in ICARM can be considered the same as those developed by GESAMP.
According to this GESAMP report, managers should base their decision through trends rather than states, precautionary principle and priorities. To support these decisions, three main key role of the science can be summarized from the report:

1. Definition of the management issues
2. Isolation of the problems causes and helps to eradicate misconceptions
3. Monitor results to adapt management (trend analysis to support management decision)

However the success of ICARM does not only rely on the data availability and science knowledge but also in the cooperation between scientists and managers. For instance, a successful management program can be realized only if there is community support and therefore scientists and managers must work together to achieve this support.

To achieve good management GESAMP also recommend that:

- Science in support of ICARM must be undertaken within a structure for solving problems.
- Scientists and managers must work together continuously if science is to be relevant and applied to management decisions.
- Having nearby scientific institutions involved is helpful to achieving these objectives.
- There must be realistic and specific research objectives and time-frames to support a research effort that will successfully answer management questions.
- Response to scientific knowledge varies among nations and cultures. The presentation and application of such knowledge must be sensitive to the local culture.
- As ICARM programmes mature, the role of science evolves from issue identification into helping to develop the needed technologies, and to understanding results of research and monitoring, feedback loops and other interrelationships.

From all the integrated projects funded through the European FP6, SPICOSA which started in February 2007 is maybe the best illustration of the effort that EU members are realizing to integrate science and policy/decision making in coastal areas. Indeed, the overall objective of SPICOSA is "*to develop a self-evolving, holistic research approach for integrated assessment of Coastal Systems so that the best available scientific knowledge can be mobilized to support deliberative and decision-making processes aimed at improving the sustainability of Coastal Systems by implementing Integrated Coastal Zone Management (ICZM) policies*" (SPICOSA, 2006). These goals being planned to be achieved within four years and with the collaboration of 54 partner institutes from 22 countries and a critical mass of researchers, stakeholders and policy operatives.

The characteristics and objectives of such an ambitious project does not only illustrate that EU encourages science-policy integration, but also that scientific community realizes that there is a need of such approach to achieve good ICZM practices in European coastal areas.

3. Network survey

Integration in the scientific community can be done through the creation of networks. Networks are actually essential to allow people from different countries, institutions and research themes to be able to communicate and to be up to date with experiences from other places. Analyzing the existing European networks on coastal lagoons through their webpage, it is possible to have an idea how integrated is the science in coastal lagoon management.

Eight national and/or international networks/projects about coastal lagoons in Europe exist (Table 8).

Table 8: European networks/projects working on integrated research for coastal lagoons

Name of the Network/Project		Participating countries
Networks	Planet[1]	Portugal (National network)
	Elnet[2]	Greece (National network)
	Lagunet[3]	Italy (National network)
	PNEC[4]/RSL[5]	France (National network)
	Red Marismas[6]	Spain (National network)
	CORILA[7]	Italy (Venice lagoon only)
	Balloon[8]	Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russian federation and Sweden
Projects	TWreferenceNET[9]	Italy, Greece, Albania, Romania and Bulgaria
	DITTY project[10]	Portugal, Spain, France, Italy and Greece

Remark: Planet, Elnet, Lagunet, PNEC/RSL, TW reference network form the NetSEA (Networks of Southern European Arc) – LOICZ, 2006.

[1] Planet website. URL: http://www2.ufp.pt/~pduarte/PLANET%20web/_private/Welkome.htm (accessed March 12, 2007)

[2] Elnet website. URL: http://www.elnet-net.gr/engl_index.htm (accessed March 12, 2007)

[3] Lagunet website. URL: http://www.dsa.unipr.it/lagunet/english/index.htm (accessed March 12, 2007)

[4] PNEC website. URL: http://www.programme-pnec.org/ (accessed March 12, 2007)

[5] RSL website. URL: http://rsl.cepralmar.com/ (accessed March 12, 2007)

[6] Redmarismas website. URL: http://www.irta.es/redmarismas/ (accessed March 12, 2007)

[7] Corila website. URL: http://www.corila.it (accessed March 12, 2007)

[8] Balloon website. URL: http://www.balticlagoons.net/ (accessed March 12, 2007)

[9] TWreferenceNet website. URL: http://www.twreferencenet.com/ (accessed March 12, 2007)

[10] DITTY project website. URL: http://www.dittyproject.org/ (accessed March 12, 2007)

Although they are classified as “projects” in Table 8, DITTY and TWreferenceNET can also be considered as networks because they have international partners studying several lagoon systems and scientists sharing knowledge. CORILA is in fact a consortium promoting and coordinating research on the Venice lagoon. It can be considered thus as a “network” because it brings together scientists from different disciplines (natural and social sciences) to improve and share the knowledge on Venice lagoon.

These networks have different specific objectives but they share the same main objectives which are:

- Enhance cooperation between research groups through creation of forum for discussion for instance
- Increase and share knowledge on coastal lagoons
- Develop common approaches on the study of coastal lagoons
- Provide scientific support for the implementation of EU and national directives

From the webpage based survey, the main objectives/functions for each network have been summarized (Table 9).

Table 9: General characteristics of the European Coastal lagoon Networks/Projects (non exhaustive)

Network/Project	Main objectives/functions	Integration between
Elnet	▪ Scientific cooperation ▪ Exchange of experience (data, methodologies and management) ▪ Establish common monitoring projects and water quality assessment schemes	NSc
Lagunet	▪ Forum for researchers ▪ Evaluate available information on biogeochemistry ▪ Study feasibility of the application of the LOICZ Biogeochemical Model ▪ Promote common approach	NSc
Planet	▪ Biogeochemical processes ▪ Geological records and sedimentary profiles ▪ Plio-pleistocene evolution of the coastal lagoons ▪ Effects of global change ▪ Ecological modeling of watersheds/lagoons/sea relationships; ▪ Impacts and interactions that affect lagoon environments ▪ Ecosystem functions ▪ Conservation problems and conflicts	NSc
PNEC	▪ Develop knowledge & Provide knowledge for ICZM ▪ Modeling of physical & ecological processes – interaction between river basin & coastal waters	NSc
RSL	▪ Monitoring eutrophication and biogeochemistry ▪ Production of reports for public	NSc
Redmarismas	▪ Operate as a ‘committee of experts’ on coastal lagoons and wetlands	NSc
Balloon	▪ Data sharing, develop joint project ▪ Dissemination of scientific results ▪ Forum ▪ Represent Baltic lagoons at international level ▪ Support implementation of EU policies	NSc, SSc
CORILA	▪ Economics and social aspects ▪ Architecture and cultural heritage ▪ Environmental processes ▪ Data management and diffusion	NSc, SSc, P
TWreferenceNET	▪ Analyze anthropogenic pressures ▪ Develop methodological tools for monitoring and conservation ▪ Legislative integration ▪ Sustainable development strategies ▪ e-center	NSc, SSc, P
DITTY project	▪ Develop scientific and operational bases for sustainable management ▪ Develop IT tools (GIS, DSS…)	NSc, SSc, DM, P

NSc=Natural Sciences *DM=Decision Makers*
SSc=Social Sciences *P=Policy*

Integration within natural science is achieved through these networks (all of them dealing with natural sciences) and help to increase a common knowledge on lagoon systems. However, social science is poorly represented with only 4 out of 10 networks including social science. Only the DITTY project seems to work closely with management developing tools for sustainable management. Comparing these observations with the steps of the planning process of ICARM previously defined, is seems that coastal lagoon management in Europe is in the initiation and analysis of existing situation phase.

Considering that science in water and coastal management is nowadays mainly working on the implementation of the WFD, this result is not surprising. Indeed, the WFD is the legal framework in Europe on which ICARM is based. According to the planning process and agenda of the directive (Tab.10), the WFD is still in the initiation and analysis phase of the planning before its implementation. At this stage of the directive, most of the scientific input comes from natural science.

Table 10: Water Framework Directive agenda (MONAE, 2005)

		Year															
WFD agenda	**Source**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
WFD approval		■															
Draft register of intercalibration sites	Ann.V				■												
Final register of intercalibration sites	Ann.V					■											
Final typology in GIS maps	COAST					■											
Reference conditions for the intercalibration exercise	COAST					■											
Characterization of River Basin Districts water bodies	Art. 5					■											
Review pressures and impacts	COAST					■											
Identify sites at risk of not achieving ‘good status’	COAST					■											
Undertake economic analysis of water use	COAST					■											
Intercalibration exercise (application of the monitoring system)	Ann.V							■									
Comprehensive monitoring programs operational	Art. 8							■									
First draft of the classification of water bodies (in RBMP draft)	COAST									■							
Publish the River Basin Management Plans (RBMP) to include:	Art. 13										■						
- Designation of Artificial and Heavily Modified Bodies of Water	Art. 4										■						
- Final classification of the ecological status of water bodies	COAST										■						
Program of measures to achieve WFD objectives	Art. 11										■						
Implement water pricing policies	Art. 9											■					
Achieve non-eutrophic status in marine environment	OSPAR/COAST											■					
To make measures of the program operational	Art. 11													■			
The combined approach for point and diffuse sources	Art. 10													■			
Update of reference conditions	COAST														■		
Update characterization of the River Basin Districts	Art. 5														■		
Achieve Good surface water status	Art. 4																■
Revision of the program of measures	Art. 11																■

Chapter 3: Legislative and scientific basis toward and integrated management of the Patos Lagoon (Brazil)

1. Description of the area

The Patos lagoon (30°55’-32°30’ South and 50°55-52°20’ West) is the world largest choked coastal lagoon located in the coastal plain of Rio Grande do Sul state. Its typical dimensions are approximately the following: 250 km long, 40 km wide and 5 meters deep (Moller and Castaing, 1999).

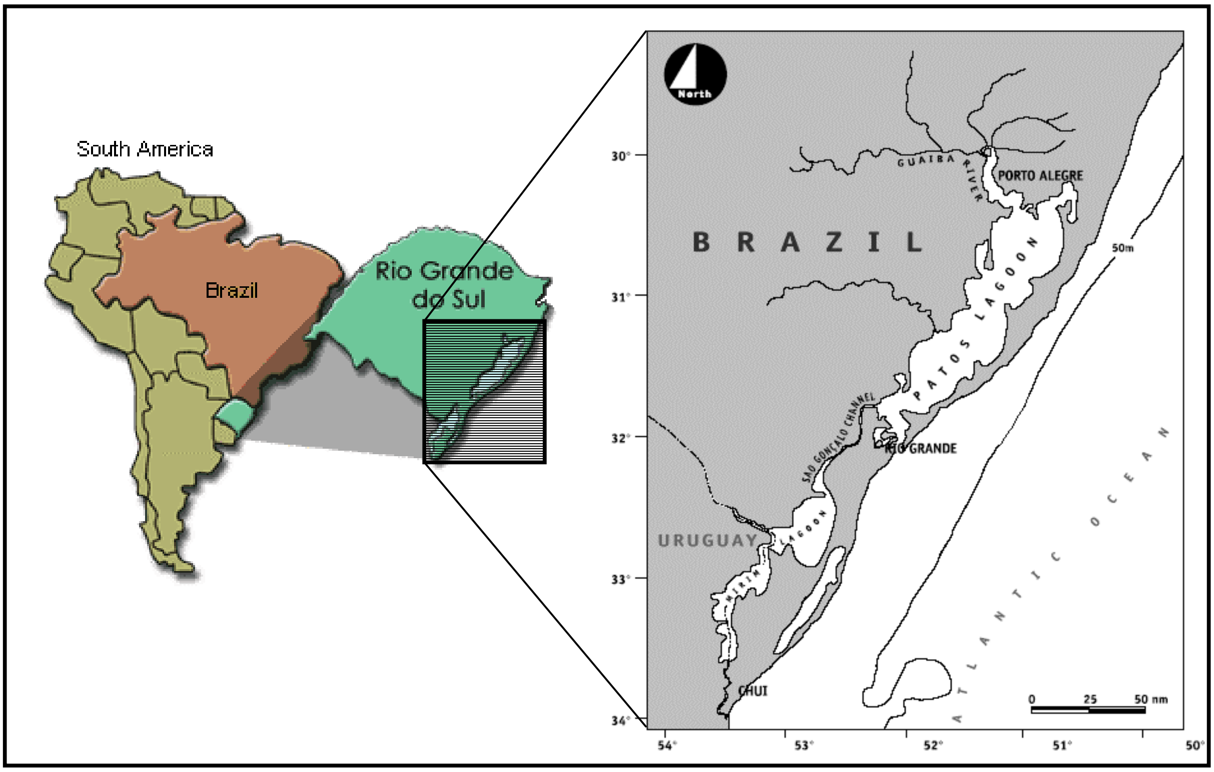

Figure 13: Location of the Patos-Mirim Lagoon System (Map of Río Grande do Sul from www.tce.rs.gov.br and map of Patos-Mirim lagoon from Windom *et al.* (1999)

The lagoon receives water from a 201 626 km² drainage basin (Asmus, 1997), either directly from tributaries (Guaíba and Camaquã Rivers) or through the São Gonçalo Channel from the Mirim Lagoon watershed (Fig.13-15). Elevated precipitation and complex river flow patterns in the drainage basin result in highly dynamic and rapidly changing hydrographic processes.

Moller and Castaing (1999) differentiated two geomorphological units that can be distinguished along the lagoon: the lower/estuarine (southern) and inner (northern) areas.

There are 971 km^2 of *estuarine area* (~10% of the lagoon) in the south which exchanges waters with the Atlantic Ocean through a 20 km long and 0.5-3 km wide inlet.

Considering the agriculture, industry and services activities as the 3 economical sectors of the Rio Grande state, they are respectively responsible for 19, 40 and 41% of the GDP (IBGE 2002).

Patos L. is a choked lagoon (Fig.2-13) with estuarine and freshwater ecosystems resulting in an important biodiversity. Moreover, it is composed of tidal marshes, wetlands and shallow waters which presents a variety of habitats and provide an abundant food supply and protection against predators for many species (Sinque and Muelbert, 1997).

Ecological aspects and the biodiversity of the estuarine area (tidal marshes and wetland plants, benthic macroalgae, microalgae, zooplankton, benthic invertebrates, ichthyofauna, bird fauna and marine mammals) have been discussed by Seeliger *et al.* (1997).

Patos L. river basin is mainly urbanized with more than 80% of Rio Grande do Sul population living in urban areas (Table 11). The Guaíba River Basin (Fig.14-15) is the most anthropogenically affected with about 65% of the Rio Grande do Sul population living in this area (DRH/SEMA, 2006).

Table 11: Main Urban areas of Rio Grande do Sul State – Fig.14 – (after IBGE)

Agglomeration/Urbanization	Population	% Total Urban Population	
Rio Grande do Sul	8 317 984	100%	
		NE included	*NE excluded*
Nordeste	605 749	59%	52%
Do Sul	557 216		
Litoral Norte	231 753		
Metropolitana	3 551 672		

Total population of Rio Grande do Sul: 10 187 798

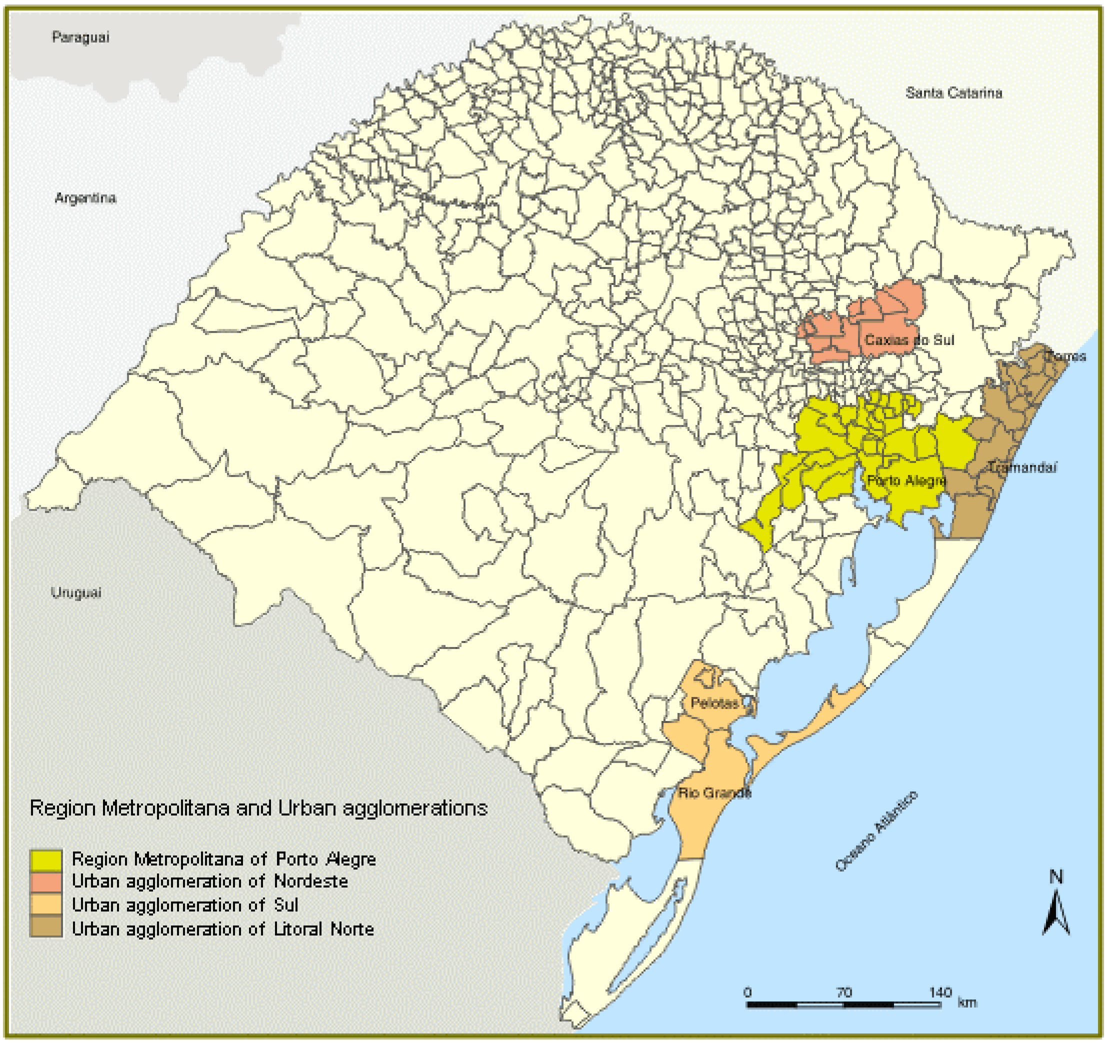

Figure 14: Localization of the 4 main Urban agglomeration of Rio Grande do Sul State (from METROPLAN, SCP/DEPLAN, 2004)

Patos L. is the most prominent lagoon in Brazil affected by shore erosion, local rise or relative sea-level, uncontrolled land use and drainage basin fertilization, deforestation, and urban-industrial expansion (Knoppers and Kjervfe, 1999). The natural and human impacts on the estuarine area have been discussed by Seeliger and Costa (1997).

There are several policies and institutions that affect coastal and water management of the Patos Lagoon which are discussed in this part. This part also aims to see how science can be used in the management of the Patos L. estuary through three example of science input to management.

2. Water and coastal management in Brazil – Management affecting the Patos Lagoon

2.1. Water resources management in Brazil

The actual water resources management date from 1997 when Brazil started to implement the Water Resources National Plan (PNRH) and the Water Resources Management System (SGRH), created from the Federal Law 9.433 as know as the "Water Law". Brazilian water resources system is based on the French river basin management system. However, unlike the centralized French system, administrative organization in Brazil is composed of three institutional levels: Federal, State and municipal (Rosso, 2005). Legislation on the water resources in Brazil is provided by the Brazilian Ministry of Environment (MMA, 2006a).

The water resource management principles, instruments and institutional framework have been discussed by Garrido (2000) and can be summarized as follow:

Water resources management is based on the following principles:

1. River basin as the territorial unit for the implementation of the National Water Resources Policy
2. Management of water resources should allow for multiple uses of water
3. Water is a limited resource, which has economic value
4. Management of water resources should be decentralized and should involve participation by the Government, the users and the community
5. When there is a shortage of water, priority is given to human consumption and watering of animals.

The main water resources management instruments are the following:

Water Resources Plans are the program documents for action at the river basin level, the state level, or even at the national level. They are master plans that provide a basis and orientation for the management of water resources, and the implementation of the National Water Resources Policy.

Classification of Bodies of Water

Water bodies are classified and regulated in eight different classes by Resolution n°20 of 1986 of the Environment National Council (CONAMA).

Water Permits system aims at ensuring the qualitative and quantitative control of water according to its use, as well as ensuring water use rights. The water uses requiring a water use permit are defined by the Federal Law no 9.433/97.

Water Tariffs *(polluter pays)*

Water uses subject to tariffs are the same as those which are subject to water permits.

The National Water Resources institutional framework consists of:

• The National Council on Water Resources[1]
• The State and Federal District Councils on Water Resources[2]
• The River Basin Committees (Fig.15)
• The Water Agencies
• The organizations at the federal, state, and municipal levels whose respective areas of competence are related to the management of water resources

The role of these different institutions/organisms is given in details by Garrido (2000).

[1] http://www.cnrh-srh.gov.br/

[2] Rio Grande State Secretary of Environment. URL: http://www.sema.rs.gov.br/sema/jsp/rechidro.jsp

In Rio Grande do Sul State, management of water resources follows the principle of integrated river basin management with division into hydrographic regions and river basins (Fig.15).

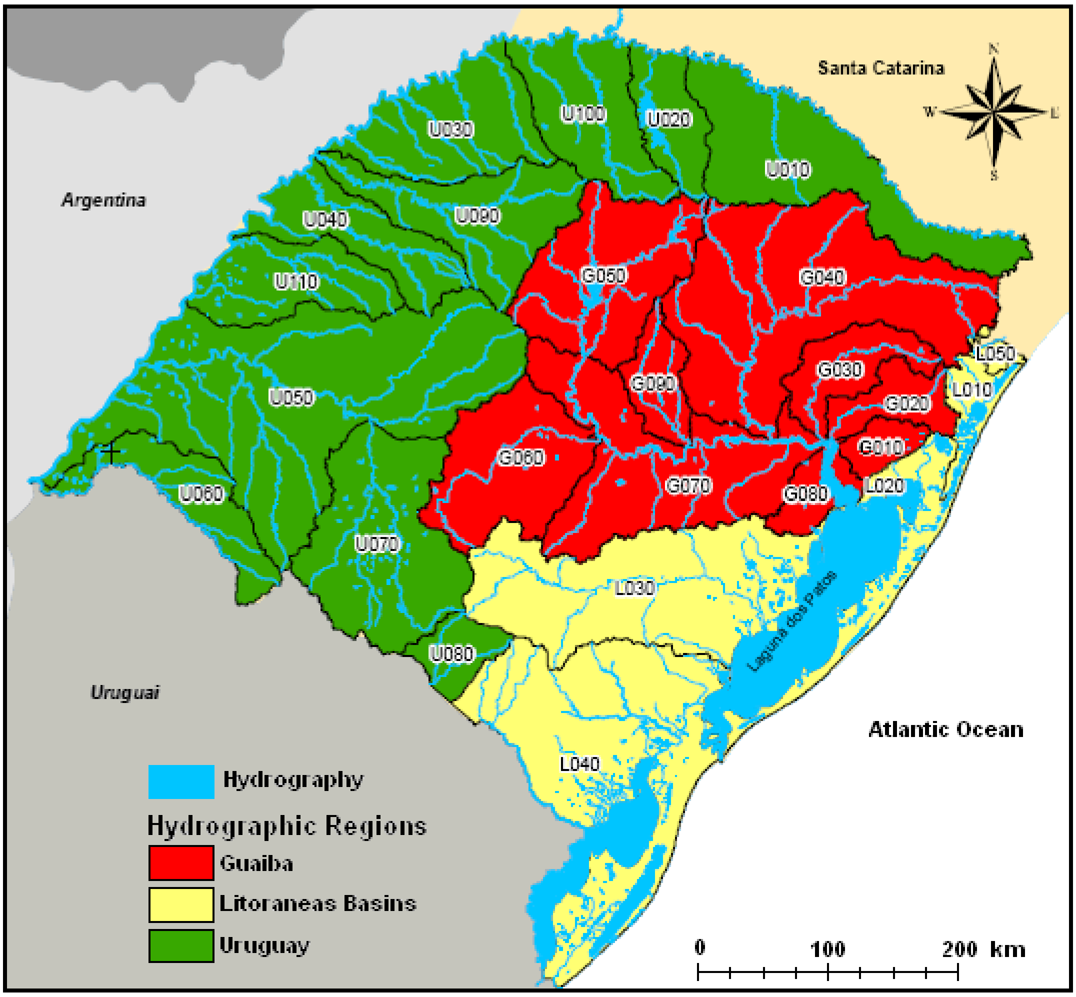

Figure 15: Hydrographic regions and the different river basins in Rio Grande do Sul State (FEPAM, 2007)

2.2. Coastal management

Coastal management in Brazil is based on the National coastal management policy (PNGC), the National environmental policy, the national water resources policy, the national patrimonial policy and the actions related to national defense and commercial and tourist navigation (Rosso, 2005). The two main policies being the National environmental Policy (PNMA) instituted by the Law nº 6.938 of August 31st, 1981 and the National coastal management policy (PNGC) instituted by the Law nº 7.661 of May 16th, 1988.

The PNGC is aimed at the rational use of natural resources in the coastal area in order increase social welfare and to protect its natural, historic, ethnic and cultural patrimony.

Many organisms and institution are linked with coastal management in Brazil (Rosso, 2005):

- Interministerial Commission for Sea Resources (CIRM)
- Ministry of Environment (MMA)
- National Water Agencies (ANA)
- State water resources institutions
- Secretary of the Union Patrimony (SPU)
- Brazilian Marine Forces
- Special secretary of the republic presidency on aquaculture and fishing (SEAP/PR)
- Brazilian Institute of environment and natural renewable resources (IBAMA)
- Environmental state and municipal institutions

The main scientific, legal and institutional initiatives towards an ICZM in Patos Lagoon Estuary have been discussed by Tagliani *et al.* (2003).

3. The role of science in the management of the Patos lagoon estuary

Brazilian legislation is very careful in dealing with the participation principle. In this respect, the role played by civil organizations (including scientific community) in the decision-making process is significant. There is a law which establishes that these organizations should be represented on the National Water Resources Council, besides taking part in river basin committees (Garrido, 2000).

With the FURG (Rio Grande University Foundation) located in the city of Rio Grande, the estuary of the Patos L. is a well studied area. A general description of this ecosystem has been published by Seeliger *et al.* (1997). A significant scientific knowledge about the Patos L. estuarine ecosystem exists and many information can be found in the literature:

1. Nutrient and organic matter cycles, role of sediments (Niencheski *et al.*, 1999; Niencheski & Windom, 1994), Chlorophyll a and phytoplankton (Jesus & Odebrecht, 1999; Abreu *et al.,* 1994; Persich et al., 1996), material transport (Windom et al., 1999).
2. Sources of contamination (Almeida *et al.*, 1993, Abreu *et al.*, 2006, Niencheski & Windom, 1994, Baumgarten *et al.*, 1998) and eutrophication (Persich *et al.*, 1996, Baumgarten *et al.*, 1995, Abreu *et al.*, 2006).
3. Metal (Niencheski *et al.*, 1994 ; Niencheski & Baumgarten, 2000 ; Mirlean *et al.*, 2003a, 2003b ; Niencheski *et al.*, 2001) and organic (Medeirosa *et al.*, 2005) contamination.
4. Pressures on the morphology (Schiller *et al.*, 2004); Santos *et al.*, 2004; Seeliger & Costa, 1997, 2002; Calliari, 1980).
5. Habitat loss (Burns *et al.*, 2006; Machado, 1976; Seeliger *et al.*, 2000; Seeliger, 2003; Seeliger & Costa, 2003; Marangoni and Costa, 2006) and introduction of alien species (Silva *et al.*, 2002; Seeliger and Costa, 2003).
6. Hydrodynamics (Monteiro *et al.*, 2005; Costa, 2005; Schiller, 2004; Schiller *et al.*, 2004; Castelão & Möller, 2003; Fernandes *et al.*, 2002, 2004ab; Fernandes, 2001 ; Möller *et al.*, 1996; Almeida, 2000) and biological (Silva and Asmus, 2001 Cunha *et al.*, 2005; Teixeira da Silva, 1995) modeling.

Brazilian legislation gives legal power to scientific institutions to participate in the River Basin and Coastal Zone Management. The role of science in ICARM has been previously discussed. However, this part aims to show the role that science can play in the management of the Patos lagoon estuary through a selection of three examples/projects accomplished where science was used for the management of this area:

1. Development of an ICZM in the Patos lagoon estuary
2. The Patos Lagoon Forum – Integration of science for fishery management
3. Environmental Impact Assessment of the Rio Grande harbor

3.1. Development of an ICZM in the Patos lagoon estuary

Tagliani *et al.* (2003) presented the main actions that have been taken at different levels (national, regional and local from government and academic origin) in the last 30 years. During that period, the most significant inputs from science towards an ICZM were:

1. To publish scientific information attesting environmental degradation of Mangueira Embayment.
2. Establish scientific basis to the management of the Patos L. estuary (Identification and mapping of the different environments of the estuary, recommendation of the different level of management according to resilience and environmental functions).
3. Identify, classify and map the aquatic sources of contamination.
4. Classification of acceptable water quality levels for all water bodies of the low estuary and its micro-watershed, according to the prevailing uses and the resolution n°20 of CONAMA.
5. Participation in the Forum of Patos Lagoon for a better fishery management.
6. Establish the scientific basis for the recuperation of the Mangueira Embayment ("Integrated Management of Patos Lagoon Estuary with emphasis on the Mangueira Embayment" project).

ICZM of the Patos lagoon estuary is under planning process where science will be used in four distinctive components and activities with science inputs (Tagliani *et al.*, 2003):

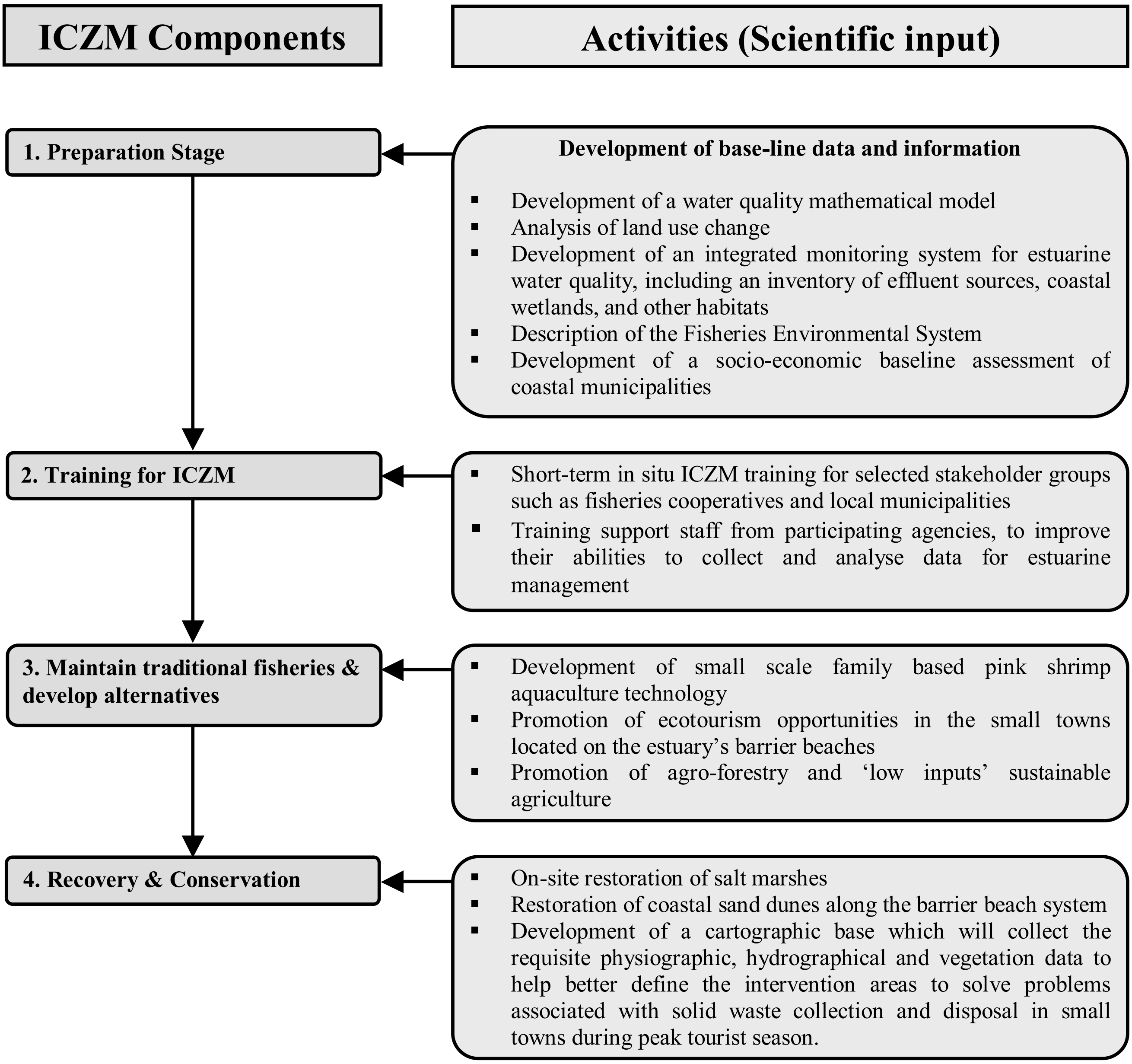

Figure 16: Components and activities included in the ICZM of the Patos Lagoon estuary (After Taglinani *et al.*, 2003)

3.2. The Patos Lagoon Forum – Integration of science for fishery management

The Forum of Patos Lagoon is a co-management arrangement composed of 21 stakeholders with the purpose to (1) discuss and develop alternative actions to mitigate and/or resolve the problems of the fishers and the crisis in the artisanal fisheries sector, (2) to recover the important artisanal fisheries and (3) to share decisions to address problems more effectively (Kalikoski *et al.*, 2002).

The scientific community is represented in this Forum through the FURG (University Foundation of Rio Grande) and the IBAMA's Rio Grande Research Unit.

Science has several roles in the Forum such as providing scientific information to the fishermen and analyzing the community-based management system (Table 12)

Table 12: The role of sciences in a community based fishery management, the Forum of Patos Lagoon (non exhaustive)

Role Of Science in the Forum of Patos Lagoon	Source
▪ Provide fishing community with information about environment, biology, legal support and co-operative work (e.g. establishment of mesh sizes and closed seasons)	Reis & D'Incao (2000)
▪ Develop research projects to provide supporting information for regulation propositions (e.g. alternatives to regulate the shrimp fishing activity)	D'Incao & Reis (2002).
▪ Analyze how congruent are the environmental institutions to the conservation of the fisheries common-pool resources (CPR) and the maintenance of artisanal fisheries over time in the estuary of Patos Lagoon ▪ Analyze historical changes in legislation, and in the local socio-ecological system (e.g. monitoring and enforcement effort ▪ Analysis of management and fishing boundaries. ▪ Analyze the factors behind the institutional misfits	Kalikoski *et al.* (2002)
▪ Assess the processes that are influencing the Forum's approach toward participatory management. ▪ Analyze the key characteristics of co-management in reference to their contribution (or not) to forwarding a more sustainable fishery. ▪ Analyze the process of implementing a local fisheries co-management regime of fisheries.	Kalikoski & Satterfield (2004)

3.3. Environmental Impact Assessment of the Rio Grande harbor

The harbor of Rio Grande is naturally well located and therefore has known a rapid development to become the most important port in the state and the second in Brazil (Mirlean *et al.,* 2003a). The FURG conducted an Environmental Impact Assessment of the port activities and the city of Rio Grande (Tagliani & Asmus, 1997). This EIA aimed to characterize the Patos lagoon estuarine area ecological and environmental system, environmental impacts of the harbor activities and their causes. It also aimed to give recommendations to decrease the impact of the port activities (e.g. mitigation measures).

During this impact assessment studies have been conduct on the estuarine:

- **Biota** (Plankton, benthos, fish community, emergent and submerged vegetation)
- **Geology and geomorphology** (e.g. environmental impact assessment of dredging in the Rio Grande harbor on the estuarine morphology)
- **Geochemistry** (organic matter, nutrients, metal trace elements in sediments and particulate sediments) to determine the origin of contamination, the most contaminated sites etc…
- **Hydrochemistry** (salinity, nutrients, suspended matter, dissolved oxygen, total fraction of metals, oil and phenols in the water column)
- **Ecotoxicology** (laboratory toxicity test on the misidacea *Metamysidopsis elongata atlantica* and the amphipod *Hyalella azteca*) to determine impact of contaminants on living animals.

The input of science in the EIA of the Rio Grande harbor can be grouped into 3 main categories (Table 13).

Table 13: Scientific input for the Environmental Impact Assessment of the port of Rio Grande (non exhaustive)

Category	Scientific input
Analysis	▪ Analysis of the ecological and environmental system (previous page) ▪ Analysis of the possible social impacts ▪ Mapping of the different zones in the estuarine area ▪ Mapping of the different shared responsibilities regarding the environmental impacts ▪ Creation of impact matrix (positive and negative impact of the different activities ▪ Risk Analysis ▪ Classification of impacts into four categories: Aesthetic, socio-cultural, economic and ecological. ▪ Use of modeling for management purposes (water quality, impact of the extension of jetties and increase of the channel depth on the hydrodynamic)
Planning	▪ Develop strategic plan and norms for dredging activities and dredged material dumping ▪ Develop environmental management plans ▪ Develop directives and planning for monitoring
Recommendation	▪ Mitigation (plan environmental actions, plan zoning of the different port areas, classification of the risk activities of the port, propose several alternatives for least effects of dredging activities) ▪ Directives ▪ Implementation

4. Discussion

The first part of this study case shows that the legislative basis exist in Brazil for an integrative management of the Patos Lagoon. The analysis of the three different roles that science had for the management of the estuary also pointed out that scientific knowledge exists for the implementation of an integrated management of the estuarine system.

Moreover, the case of the Forum of the Patos Lagoon not only show that science is used to support managers but also to participate actively with the fishermen community in order to set up solution to fisheries problems and implement new directives. Therefore, it is a good example of how science can be integrated with management, policy and stakeholders such as fishermen.

Legislative and scientific basis in the Patos Lagoon exist toward an integrated management. In theory, an ICARM in Brazil for the sustainable management of the Patos Lagoon might be possible to set up. However, in practice there are several recurrent problems in Brazil making difficult to set up such approach; the institutional fragility being the biggest challenge (Tagliani *et al.,* 2003).

Brazilian coastal zone has an important physico-environmental diversity associated with multiple competencies and a lack of articulation between the various management entities. It can be for instance observed in the articles 22 and 23 of the federal constitution, a legislative superposition where the competencies to legislate environmental questions are not clear (Rosso, 2005). Many organizations are participating in the management of the water basin and coastal zone in Brazil, from federal to local level increasing the possible conflicts and the difficulties for an integrated management.

For instance Tagliani & Asmus (1997) observed a lack of vertical integration during the EIA of the port of Rio Grande concerning the legislation on air quality. Indeed, the FEPAM (Rio Grande do Sul State Environmental Protection Agency) set a maximum acceptable total particle concentration of 150 mg/m^3 (**milligrams** per cubic meter) whereas the CONAMA (National Environment Council) Resolution 03 from 28/06/1990 set a maximum concentration of 80 $\mu g/m^3$ (**micrograms** per cubic meter).

It can also be observed from Figure 15 that Rio Grande do Sul state is divided into 3 main hydrographical regions, Patos lagoon being "located" in the "Litoraneas basins" region. However, drainage basin of the lagoon comprise also the Guaíba hydrographical region and Guaíba river is actually the most important water input of the Patos lagoon. Moreover a part of the drainage basin is situated in Uruguay and no transboundary agreements exist concerning river basin management between Brazil and Uruguay.

Considering the ICARM requirements, geographical boundaries for the management of the Patos lagoon should be the entire drainage basin but the actual administrative structure is not favorable to set up such boundaries.

Chapter 4: Eutrophication assessment of the Ria Formosa using the OSPAR comprehensive procedure

1. Introduction on the Comprehensive procedure

1.1. Background

According to Article 2.(11) of the Directive 91/271/EEC concerning urban waste water treatment (the UWWT Directive), eutrophication means "*the enrichment of water by nutrients especially compounds of nitrogen or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned*".

Eutrophication naturally occurs in some water environment (e.g. upwelling). However, the development of human activities in river basin and coastal areas increased the nutrient input in the water ecosystem (agricultural runoff, urban runoff, sewage discharge…). This increase of nutrient input and the associated eutrophication can create conditions that interfere with the natural ecosystem reducing its health and diversity.

Eutrophication of marine waters caused by excess load with nitrogen and phosphorus nutrients from human activities is a major problem in many European coastal areas (EEA, 2001). As a response of the European water quality problems, the European Commission developed several directives where eutrophication is one of the great topics.

Indeed, through the EU urban wastewater treatment directive (91/271/EEC), the nitrate directive (91/676/EEC), the more recent water framework directive (2000/60/EC) and the OSPAR convention, European states are both identifying the eutrophication sensitive areas and trying to reduce eutrophication in European waters.

Identification of problem or non-problem areas regarding eutrophication, is important to be able to decide whether the water system quality must by improved or not and to have good management response. This identification can be done through an assessment of the trophic status.

To assess the eutrophic status in water bodies, several methods have been developed (Painting *et al.*, 2007; Newton *et al.*, 2003; Bricker *et al.*, 2003).

Painting *et al.* (2007) described briefly the main methods used as follow:

For freshwater, the OECD (1982) proposed a simple system of thresholds for assessing eutrophic status. This approach was extended to coastal water (CSTT, 1994 and 1997) and to estuaries, coastal and offshore waters (OSPAR, 2001). In Europe, ongoing development of assessment tools has been undertaken by OSPAR and under EU directives such as the Water Framework Directive (WFD). These include the development of Ecological Quality elements and objectives for monitoring nutrient enrichment and potential eutrophication effects in coastal waters (OSPAR Commission, 2005 and Painting *et al.*, 2005). In the US, the national eutrophication model includes primary and secondary symptoms of eutrophication (Bricker *et al.*, 1999).

In this study case, the link between science, policy and management (Fig.17), can be clearly seen. Indeed, the aim of the WFD is to reach by 2015 a good ecological quality of European waters, eutrophication being a critical parameter in ecological quality assessment.

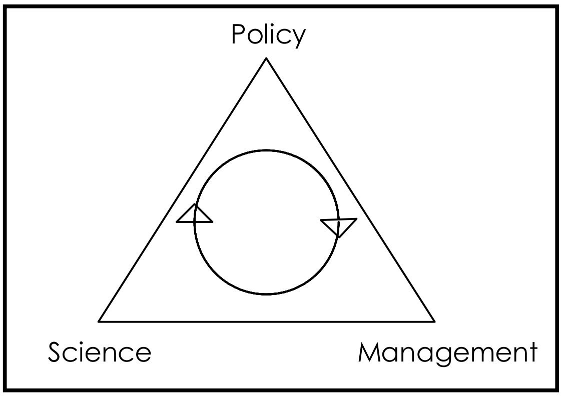

Figure 17: The Science-Policy-Management interrelation triad

One of the steps to reach the objectives of this policy is to determine which areas in Europe are actually in good ecological status or not. Thanks to this status the appropriate management option can be used. The EU has identified eutrophication as major problem in surface waters and eutrophication is a good water quality indicator. Therefore, the assessment of its trophic status allows to determine if an area has a good ecological status or not (regarding eutrophication). ***Science*** is used to perform the assessment and define the water quality status, which lead to the appropriate ***management*** of the water system and then reach the ***policy***'s objectives.

From the different methodologies summarized by Painting *et al.* (2005), the two most up to date are the European OSPAR comprehensive procedure (OSPAR, 2001) and the American National Estuarine Eutrophication Assessment – NEEA – (Bricker *et al.*, 1999).

Both methodologies can have the ambition to be selected in order to support the WFD. However, because the OSPAR comprehensive procedure has been developed by European countries, this methodology might be preferred to support the WFD instead of the NEEA.

The trophic status of the Ria Formosa has been assessed using the NEEA methodology but not the OSPAR procedure. The aim of this study consists in assessing the trophic status of the Ria Formosa using the OSPAR comprehensive procedure in order to be able to compare the results with the assessments which have been done using other methods (NEEA, DPSIR…).

1.2. The OSPAR comprehensive procedure – General methodology

The OSPAR comprehensive procedure is actually the second part of a two step "*common procedure*". The first step called the *"screening procedure"* have been completed in 2000 and basically consisted in a broad brush process, performed only one time, to identify obvious Non-Problem Areas with regard to eutrophication.

The comprehensive procedure basically consists in the classification of the maritime/coastal systems into areas which are considered to be Problem Areas (PA), Potential Problem Areas (PPA), or Non-Problem Areas (NPA) with regard to eutrophication (OSPAR Commission, 2003).

The comprehensive procedure assessment is divided in 3 main steps which are briefly described here:

1. Determination/classification of the assessment parameters
2. Integration of the categorized assessment parameters (initial classification)
3. Appraisal of all relevant information (final classification)

STEP 1 – Categorization of the assessment parameters

The biological, chemical and physical assessment criteria are organized into four categories of information (www.eutro.org):

- **Category I:** Causative Factors including sources of nutrients
- **Category II:** Direct Effects of nutrient
- **Category III:** Indirect Effects of nutrient enrichment
- **Category IV:** Other Possible Effects of nutrient enrichment

More details on the methodology are given in Appendix A.

STEP 2 – Integration of the categorized assessment parameters - Initial Classification

The aim of the second step of the process is to integrate the assessment parameters from Step 1 to obtain a coherent classification (see Appendix B). From this integration, it will result the so called "initial classification" which consists in defining the area as Problem Area (PA), Potential Problem Area (PPA) and Non-Problem Area (NPA).

STEP 3 - Appraisal of all relevant information - Final Classification

The goal of the last step is to provide a transparent and sound account of the reasons for establishing a particular status for the area given by the initial classification (see Appendix C). In this so called final classification, the supporting environmental factors and region specific characteristics such as physical and hydrodynamical aspects, and weather/climate conditions should be taken into account. These region specific characteristics actually play a role in explaining the results of the classification.

2. Description of the Area

The Ria Formosa mesotidal lagoon is located on the southern Portuguese coast (36°58′ to 37°03′N and 7°32′ to 8°02′W) (Aníbal *et al.,* 2007). It is the largest lagoon in Europe (Mudge & Duce, 2005) and extends for 55 km along the coast and is 6 km at its widest point (Fig.18). The lagoon comprises 14,522 ha of wetlands which includes saltwater, salt marsh, exposed sands and mud banks. In addition, it includes a further 2478 ha of sand dunes, farmland, forest and urban land (Bebianno, 1995). The intertidal zone is separated from the sea by two peninsular sand spits, as well as a string of barrier islands. There are six inlets, two of which have been artificially consolidated, that allow exchanges of water with the Atlantic Ocean.

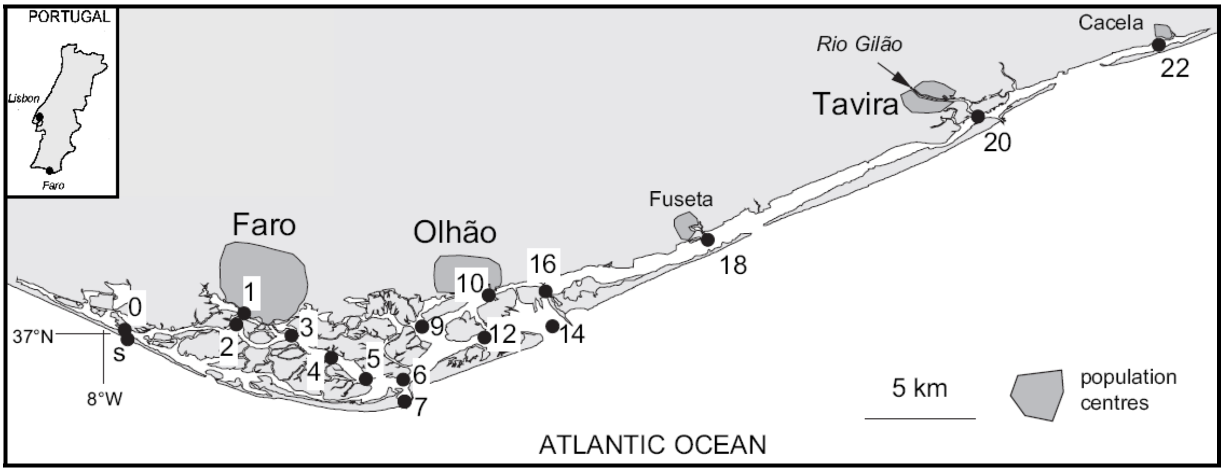

Figure 18: The Ria Formosa Coastal lagoon - Location of some sampling stations (Newton & Mudge, 2003)

The entire water body is sheltered, with an average depth of 3 m. Only a small fraction (14%) of the lagoon is permanently immersed and approximately 80% of the total area is uncovered during spring tides. The tides are semi-diurnal with amplitudes that range from about 0.7 m (neaps) to about 3.5 m (springs). Daily, in the outer regions of the Ria Formosa, 50 to 75% of the water is exchanged between the lagoon and the ocean (Coelho *et al.,* 2002).

Water temperature in the channels of the Ria Formosa range from 12°C in winter to 27°C in summer and salinity from 13 to 36.5 (Newton & Mudge, 2003).

The Ria Formosa river basin has an annual mean precipitation ranging from 600 to 800 mm/y and an annual mean evapotranspiration varying between 820 to 880 mm/y (DITTY, 2007). Most of the rainfall occurs during the winter, often concentrated into only a few days. Although salinity ranges between 13 and 36.5 in the channels (Newton & Mudge, 2003) the lagoon does not receive any significant freshwater input and salinity is generally higher than 32 all year round (Coelho *et al.,* 2002).

Owing to its significance as a wetland, conservation area and ornithological importance, the Ria Formosa was designated as a Portuguese Natural Park in 1987 (Coelho *et al.,* 2002). Many of the economically important activities of the surrounding area are directly or indirectly related to the lagoon. The most evident are tourism, abiotic resources exploitation such as salt and sediment extraction and the biotic resource exploitation, including bivalve aquaculture and fisheries (Newton & Mudge, 2005).

The main physical and environmental characteristics of the Ria Formosa have been described elsewhere (Bebianno, 1995; Mudge *et al.,* 1999; Padinha *et al.* 2000; Newton & Mudge, 2003, 2005; Ribeiro *et al.,* 2006; and Aníbal *et al.,* 2007).

3. Methods

The comprehensive procedure has been applied in the Ria Formosa using the data from the BarcaWin2000 online database (http://www.barcaweb.com/). All the data presented in this part are therefore available to the public through this relational database.

3.1. Winter DIN

351 measurements of winter DIN were collected from the relational database BarcaWin 2000. Samples correspond to several sampling campaigns achieved in 22 sampling stations for 9 different years between 1985 and 2001. These sampling stations represent a wide range of sites in the lagoon including those presented in Fig.18.

Ria Formosa lagoon is subject to two seasons, the wet season (from October to March) corresponding to 80% of the total annual precipitation, and the dry season - the rest of the year – (Fig.19; INAG, 2007). According to this, the winter DIN has been calculated for the wet season period.

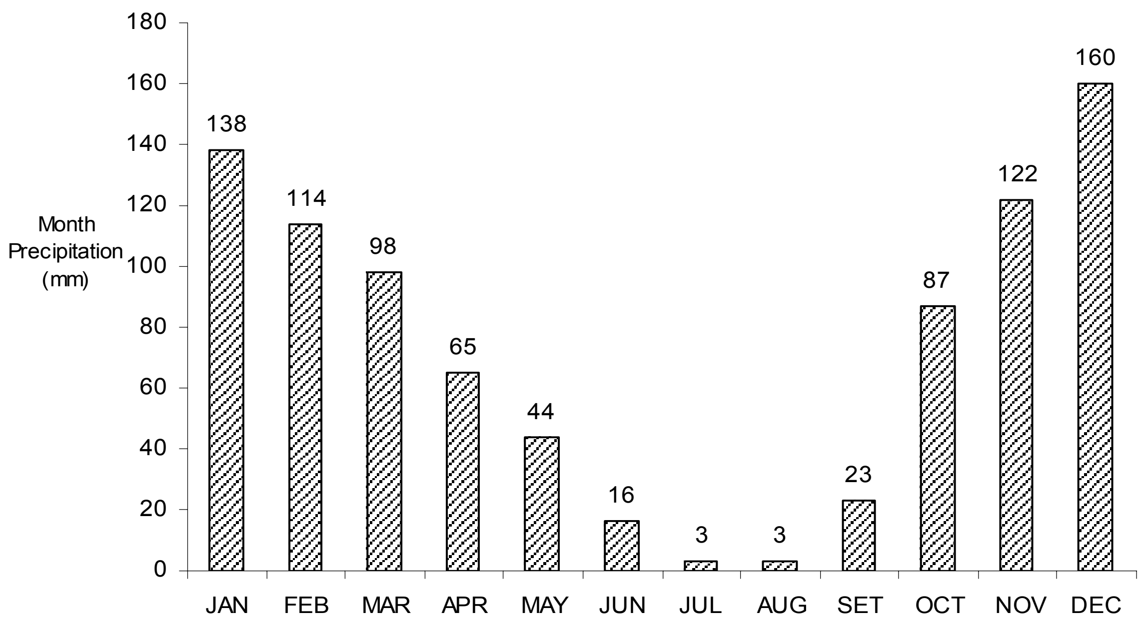

Figure 19: Month average precipitation during the year 2006 in the São Brás De Alportel Meteorogical station (online source. INAG, 2007)

The comprehensive procedure differentiates two winter DIN assessments: one for *"salinity gradient riverine influenced waters"* and one for areas without salinity gradients.

Ria Formosa salinity can vary from 13 to 36.5 (Newton & Mudge, 2003), but generally has a salinity higher than 32 all year round (Coelho *et al.,* 2002). No linear relationship between winter DIN concentration and salinity gradient have been outlined in the Ria Formosa according to the available data (Fig.20). Therefore, according to the procedure, DIN levels are *"simply assessed by calculating mean values for winter period and compared to area specific background concentrations"*.

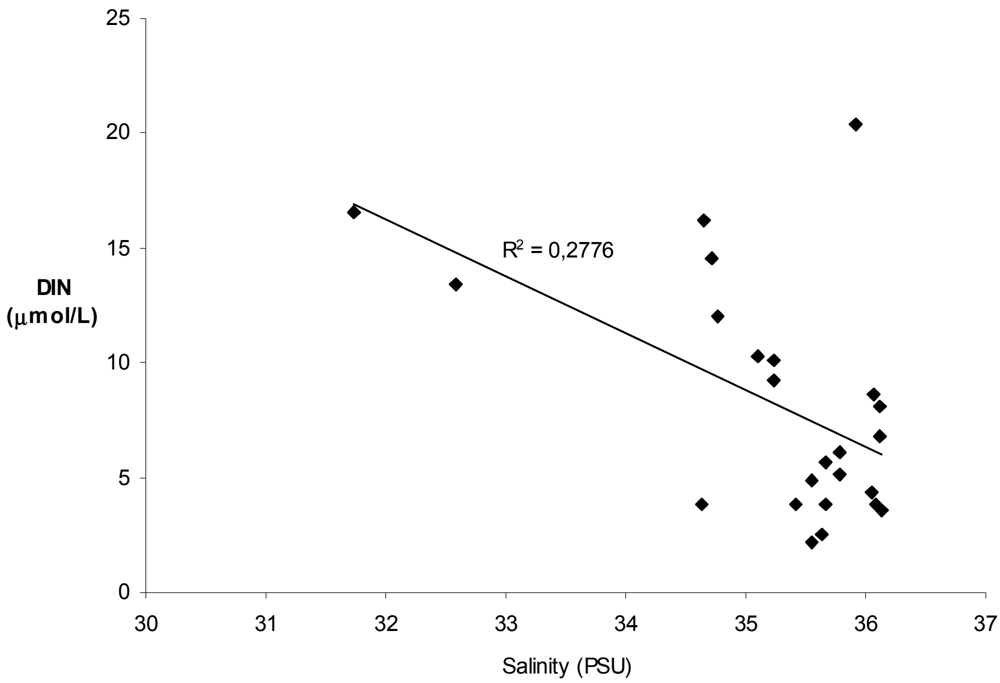

Figure 20: Relationship between salinity and winter nutrient concentrations in Ria Formosa for the year 1998

3.2. Winter N/P, N/Si and P/Si ratios

Winter N/P, N/Si and P/Si ratios have been calculated from the same available data as the winter DIN. This means 351 samples from 22 different stations for 9 years between 1985 and 2001.

3.3. Maximum and mean chlorophyll a concentration

584 estimates of chlorophyll a in the Ria Formosa were collected from the relational database BarcaWin 2000. Growing season occurs all year round in the Ria Formosa. Samples correspond to sampling campaigns realized from 16 stations for 7 different years between 1985 and 2002. From these data, yearly mean and maximum were calculated.

3.4. Oxygen deficiency

A total of 964 measurements for dissolved oxygen were summarized from the relational BarcaWin 2000 database. Samples were collected for 9 different years during the period 1985-2001 from 27 sampling station in the lagoon.

4. Results

4.1. Category I: Degree of nutrient enrichment

Winter DIN

According to the available data, the winter DIN concentrations have been calculated for nine different years in the period 1985-2001. However, the amount and quality of data varies between the different years. 1986 is the year with less data available (7 samples from 2 different sampling stations) whereas 1987 and 1988 are the year with the highest amount of data (96 samples from 16 different sampling stations).

The amount of data available is insufficient for the calculation of average winter DIN for each sampling stations. Therefore, mean winter DIN concentrations for the entire Ria Formosa have been calculated averaging the results from all the stations. The trend of the yearly average winter DIN concentration in the Ria Formosa during the period 1987-2001 is presented in Fig.21.

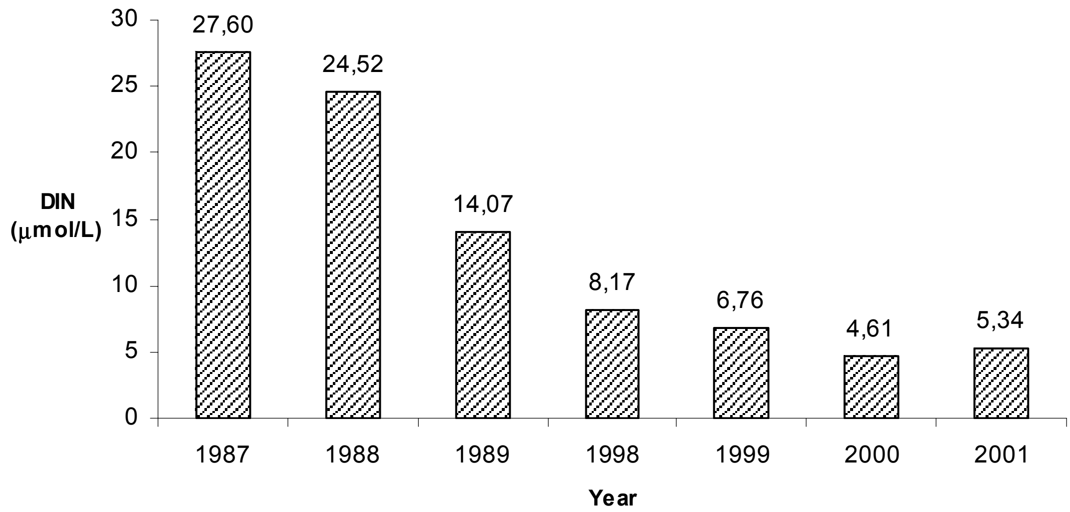

Figure 21: Average yearly winter DIN concentration in the Ria Formosa between 1987 and 2001

The result shows that winter DIN concentration have been decreasing more or less constantly since 1987 to reach 5.34µmol.l^{-1} in 2001 (a reduction of factor greater than 5 compared to 1987 concentration). The low amount of data used to make the calculations for the years 1985-1986 are not very representative of the lagoon as a whole – both in space (2 to 3 stations) and in quantity (7 samples only in 1986). Moreover, the samples have been taken from these station only for these years (1985-1986) making the comparison with the other years not reliable. The other years are therefore more representative of the Ria Formosa with a wider range of sampling station used during the period 1987-2001 (Station 0, 1, 18, 20, 3 and 9 for instance). Considering the sampling station individually during that period, winter DIN concentrations show the same decreasing trend as the general trend presented in Fig.21.

For this study, the background and assessment values from the comprehensive procedure (Annex 2c) can be used. The procedure gives the concentrations of 10 µmol.l^{-1} as background value and 15 µmol.l^{-1} as assessment value for winter DIN concentrations in the Portuguese coast.

Referring to these values, Winter DIN concentrations in the Ria Formosa are below the assessment and background values since 1989 and 1998, respectively.

Classification

According to this, the decreasing winter DIN concentrations trend since 1987 (when the highest value has been measured), and following the comprehensive procedure, winter DIN assessment parameter is scored (-) as:

"neither increased trends nor elevated levels nor shifts nor changes in the respective assessment parameter" (OSPAR, 2005).

Winter DIN:P, DIN:Si and P:Si ratios

DIN:P ratio

The general trend of the DIN:P ratio is similar to the trend of winter DIN concentrations (Fig.22). It reaches two times levels higher than the normal Redfield ratio of 16 in 1987 and 1988. In 1987, the DIN:P ratio had the highest average in the lagoon with a value of 55.28. This value is more than twice higher than the assessment value provided by OSPAR (2005). However, in 2001, this ratio was twice lower than the normal Redfield ratio and three times lower than the assessment level. Individually, the sampling stations covering the period 1987-2001 as described above also shows the same trend as the winter DIN concentration. It can be outlined however that station 18, presented particularly high winter DIN concentrations in the years 1987-88 (up to 128.27 $\mu mol.l^{-1}$ in 1988) and as a result a high DIN:P ratio (up to 148.65 in 1987). This result is not surprising since this station is subject to domestic sewage and riverine inputs from the city of Fuseta and the Ribeira do Tronco River (Newton & Mudge, 2003).

The western and eastern lagoon can be separated for the years 1987-88 and 1998-99. The eastern lagoon (station 9, 18 and 20) in the period 1987-1988 showed winter DIN concentrations much higher than in the western part of the Ria Formosa (stations 0, 1 and 3). But this difference reached "equilibrium" in the period 1998-99 with less difference in winter DIN concentrations between eastern and western lagoon. The analysis of the extreme winter DIN concentrations (Maximum and minimum – Table 1, Appendix D) shows that the lowest values correspond to the outer part or the inlets of the lagoon whereas the maximum concentrations are found in the inner lagoon subject either to freshwater or domestic sewage inputs.

DIN:Si and P:Si ratio

DIN:Si and P:Si ratios have a similar trend (Fig.22). Both show a more irregular trend than DIN:P ratio. Increasing trend from 1985 to 1987 to decrease in 1988 and to increase again until 1999 when it reached the highest value (0.179 for P:Si and 2.6 for DIN:Si). In 1999, the two ratio values were higher than the recommended assessment levels defined by OSPAR (2005) which are 0.125 for P:Si ratio and 2 for DIN:Si ratio (salinity > 34.5). From 1999 to 2001 these ratio decreased to more reasonable levels.

Classification

According to these results and the comprehensive procedure, DIN:P, DIN:Si and P:Si ratio assessment parameters are scored (-) as:

"neither increased trends nor elevated levels nor shifts nor changes in the respective assessment parameter" (OSPAR, 2005).

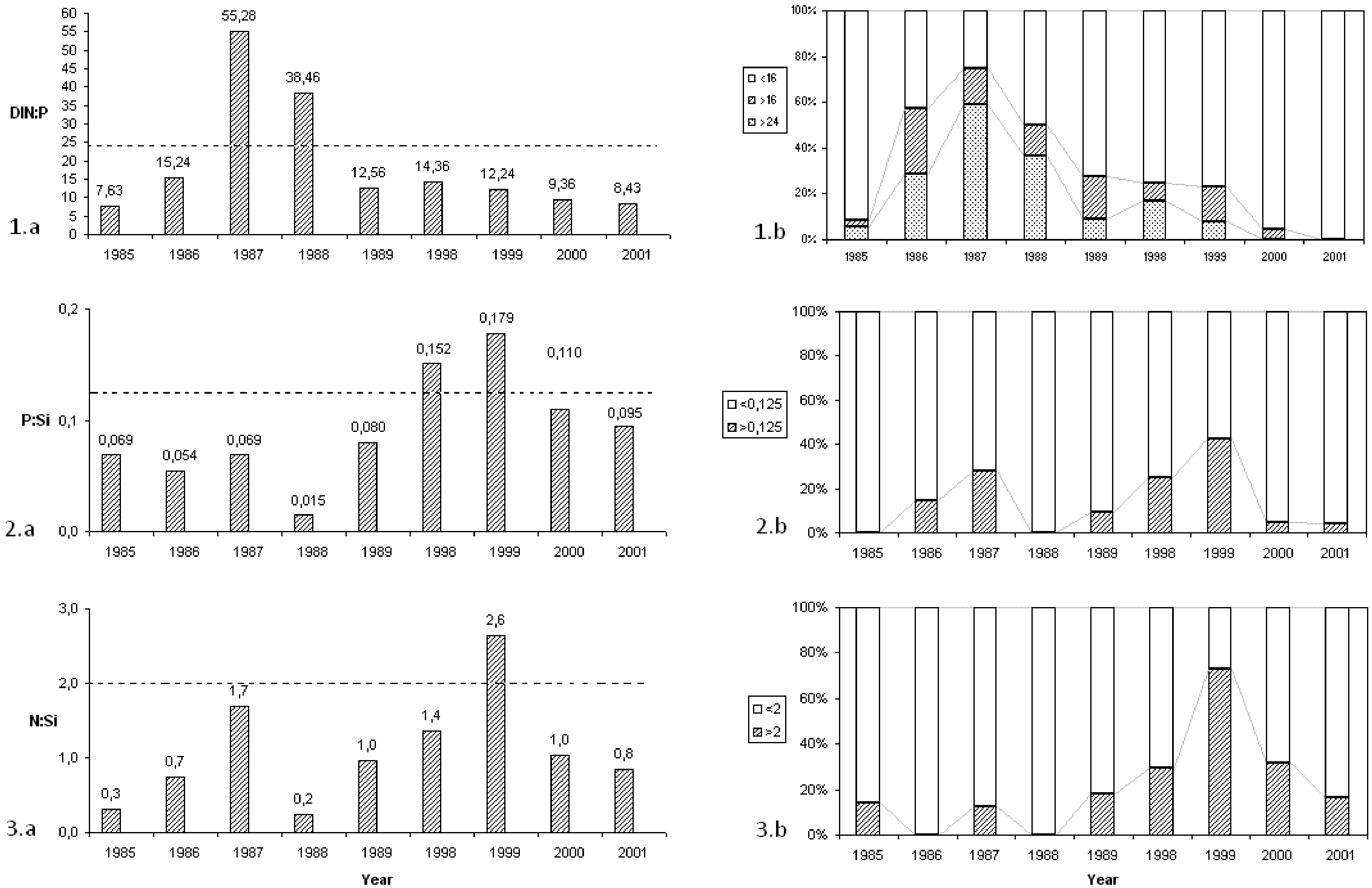

Figure 22: Winter DIN:P, DIN:Si and P:Si Ratio trends between 1985 and 2001 in the Ria Formosa. The dotted lines in figures 1.a, 2.a and 3.a represent the assessment value from OSPAR. Figures 1.b, 2.b and 3.b represent the percentage of samples above and below the assessment values defined by OSPAR comprehensive procedure.

4.2. Category II – Effect of Nutrient enrichment

Maximum and mean chlorophyll a concentrations

From 1985 to 2002, chlorophyll a concentrations show a decreasing trend (Fig.23). Generally, chlorophyll a concentrations are low throughout the period, with at least 90% of the 584 samples with concentration lower than 3.5 $\mu g.l^{-1}$ (90^{th} percentile of all data).

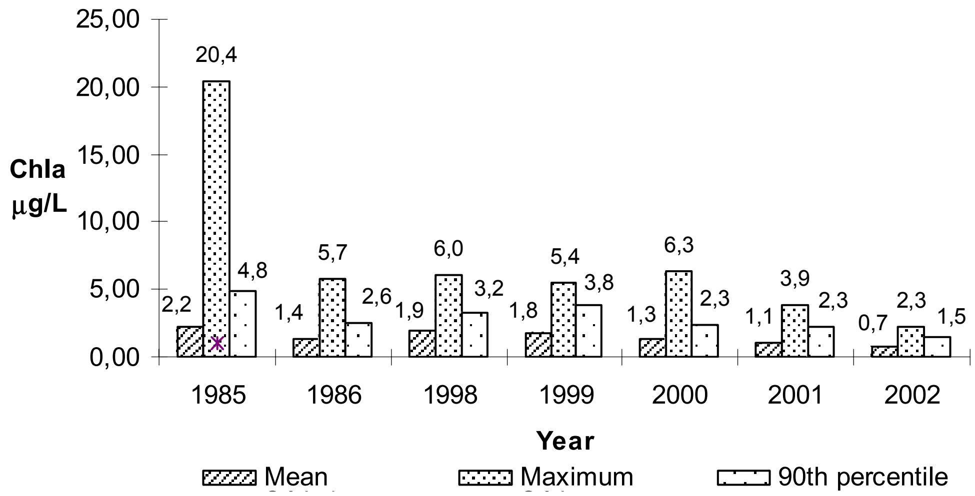

Figure 23: Mean, Maximum and 90^{th} percentile trends in chlorophyll a concentration in the Ria Formosa over the period 1985-2002.

Since no linear correlation have been observed between TN and chlorophyll a concentrations during growing season (Fig.24) it was not possible to determine the assessment levels for chlorophyll a based on natural TN background concentration as suggested by OSPAR (2005). According to the area-specific background concentrations of chlorophyll a during growing season for the Portuguese coast (salinity > 35), the background concentration for the chlorophyll a means is 10 $\mu g.l^{-1}$ and the assessment level is 15 $\mu g.l^{-1}$ OSPAR (2005). From the 584 data, only 3 have levels higher than 15 $\mu g.l^{-1}$ and 7 are higher than 10 $\mu g.l^{-1}$.

The highest chlorophyll a concentrations have been reported in the eastern part of the lagoon over the period 1985-2001 (Tab.2, Appendix D). Moreover, higher mean concentrations are found in the eastern part than the western part of the lagoon in the period 1998-99.

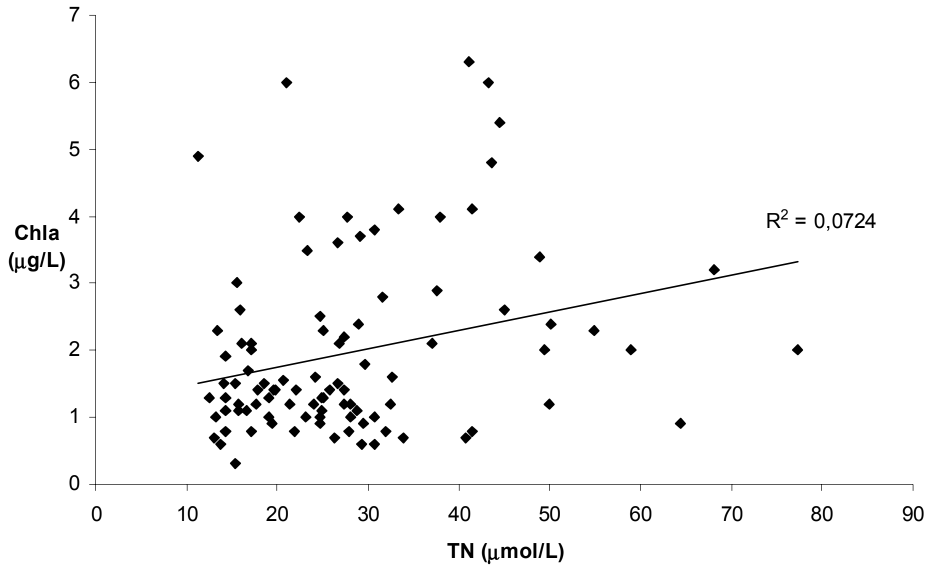

Figure 24: No linear correlation is observed between Chlorophyll a and Total Nitrogen concentration in Ria Formosa coastal lagoon

Classification

According to the decreasing mean and maximum chlorophyll a concentrations trend since 1985, the average low concentrations compared to the assessment levels for the Portuguese coast Chlorophyll a assessment parameter is scored (-) as:

"neither increased trends nor elevated levels nor shifts nor changes in the respective assessment parameter" (OSPAR, 2005).

4.3. Category III – Indirect effect of nutrient enrichment

Oxygen deficiency

The average Dissolved concentration trends have been more or less constant over the period 1985-2001 (Fig.25). The tenth percentile indicated corresponds to the dissolved oxygen concentration above which 90% of the measurements lie. Excepting 1989, at least 90% of the dissolved oxygen concentration measurements lie above the 5 $mg.l^{-1}$ threshold, which indicates biological stress (Ferreira *et al.*, 2002).

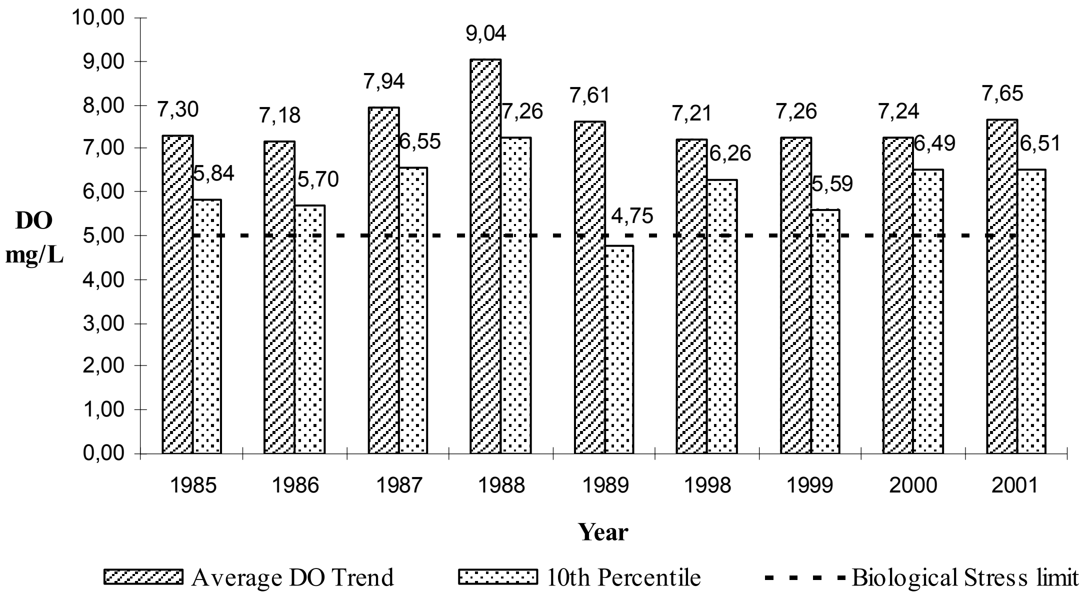

Figure 25: Variation of Dissolved Oxygen in the Ria Formosa over the period 1985-2001

Classification

Given the fact that all the years have a mean dissolved oxygen concentration above the biological stress limit (5 $mg.l^{-1}$) and considering that no increased trend have been registered over the period 1985-2001, the Dissolved Oxygen assessment parameter is scored (-) as:

"neither increased trends nor elevated levels nor shifts nor changes in the respective assessment parameter" (OSPAR, 2005).

4.4. Eutrophication classification of the Ria Formosa – Initial classification

According to the Second step of the comprehensive procedure (initial classification), Ria Formosa coastal lagoon can be classified as a Non-problem area (Table 14).

Table 14: Initial classification of Eutrophication assessment of the Ria Formosa using the OSPAR comprehensive procedure – Calculated according to the Comprehensive procedure guideline (OSPAR Commission, 2005-3)

Category	Assessment Parameter	Description of results	Score (+ - ?)
Degree of Nutrient Enrichment (I)	Riverine input and direct discharge of total N and total P	No data available	?
	Winter DIN and/or DIP concentrations	Decreasing trend – Lower concentration than assessment level	-
	Winter N/P, N/Si and P/Si ratios (Redfield=16)	Decreasing trend – Lower concentration than assessment level	-
Direct effect (II)	Maximum and mean chlorophyll a concentrations	Decreasing trend – Lower concentration than assessment level	-
	Area-specific phytoplankton indicator species	No data available	?
	Macrophytes including macroalgae	No shift in species have been reported (Santos R., personal communication)	-
Indirect effect (III)	Oxygen deficiency	No increase and concentration lower than biological stress level	-
	Change/kills in zoobenthos and fish kills		?
	Organic carbon/organic matter	No data available	?
Other possible effect (IV)	Algal toxins (DSP/PSP mussel infection events)	No Harmful Algal Blooms Have been reported in the literature (Ferreira et al., 2005)	?

The method to integration of the categorized assessment parameters is given in Appendix B.

5. Discussion

5.1. Comparison of the eutrophication assessment of the Ria Formosa using OSPAR comprehensive assessment with results from other methods

The Ria Formosa has been classified as non-problem area using the OSPAR comprehensive procedure. Eutrophication assessment of the Ria Formosa using two other methodologies has been discussed. Indeed, Newton *et al.* (2003) assessed the eutrophication of the Ria Formosa using the EU European Environmental Agency criteria in one hand and the US National Estuarine Eutrophic Assessment (NEEA) in the other hand. The two models produced very different results:

"If the Ria Formosa is assessed on the EEA criteria based on the comparison of nutrient levels in transitional and coastal waters, the situation in the Ria Formosa is ''poor'' to ''bad''. On the other hand, if the Ria Formosa is assessed by the NEEA criteria based on symptoms of eutrophication, such as high Chlorophyll a or low oxygen saturation, the situation in the Ria Formosa is near pristine" (Newton *et al.*, 2003).

Therefore, the results obtained using the OSPAR comprehensive procedure seems to be similar to those obtained using the US assessment.

Even considering the elevated data from the period 1987-88 only as used by Newton *et al.* (2003) to assess eutrophication using EEA methodology, the classification of the Ria Formosa using the comprehensive procedure would stay as "non-problem area".

Similar results with the US NEEA criteria are not surprising since both methodologies are based on a cause/effect relationship of eutrophication process. They actually use parameters to assess primary and secondary symptoms (NEEA) or direct and indirect effects of nutrient enrichment (OSPAR comprehensive procedure). OSPAR and NEEA give more importance on the symptoms from nutrients input than the input itself unlike the EEA method.

5.2. Discussion on the results

A significant amount of data has been measured in the Ria Formosa over the past 20 years (Table 15). However, they are not necessarily representative of a comprehensive system survey (Ferreira *et al.*, 2005; p.34).

Table 15: Available historical datasets for the Ria Formosa coastal lagoon (modified, Ferreira et al., 2005)

Area (km²)	Sampling period	Number of records						
		Stations	Samples	Parameters				Results
				Physico-chemical	*Biological*	*Other*	*Total*	
49	1984-2002	70	97 021	78	74	13	165	139 932

If we consider eutrophication assessment only, few data are available in comparison to the total dataset, with for instance interesting data for the period years 1987, 1988, 1998 and 1998 only. According to Newton & Mudge (2003), 16 sampling stations can be selected to give good spatial coverage, as well as representing the variety of conditions to be experienced within the Ria Formosa. However this study shows that 6 representative sampling stations presented data for a maximum period of 4 years (1987-88 and 1998-99), mainly representing the inner part of the lagoon subject to sewage input. Moreover, it has been observed that sampling stations have been used to measure one parameter for one year but not the others. This lack of continuous monitoring for specific sampling station is therefore a gap that future monitoring should fulfill in order to assure good quality data and trend analysis and complies with the WFD. For instance Newton *et al.* (2003) recommend regular monitoring as time series of 5 years or more for trend analysis and this study shows that none of the parameter analyzed had sufficient and representative data for 5 five years.

Dissolved oxygen concentrations illustrate another gap from the available data. The analysis of the extreme DO concentration over the period 1985-2001 showed that the lowest dissolved concentrations have been found in the inner lagoon and measured in the morning (Table 3, Appendix D). This result can be expected considering that Ria Formosa has a large plant biomass and therefore systems can alternate between supersaturated conditions during daylight hours due to photosynthesis and undersaturated at night due to respiration (Newton and Mudge, 2005).

Therefore, a majority of the dissolved oxygen concentration values available in the TICOR database and the literature might be overestimated due to the time and site where the samples have been collected (de Oliveira, 2005). Sampling dissolved oxygen concentrations early in the morning; de Oliveira shows in his work that for some stations at the inner part of the Ria Formosa lagoon, all DO values are found lower than the biological stress limit (5 $mg.l^{-1}$) reaching hypoxia (< 2 $mg.l^{-1}$) for the lowest values. It means that depending on the location of the sampling station and the sampling time, results in DO may classify some parts of the Ria Formosa as "potential problem area" using the comprehensive procedure.

This study confirm the recommendations from Newton *et al.* (2003) given as responses from the DPSIR framework applied on the eutrophication of the Ria Formosa coastal lagoon (Table 4). It also shows the limits of a tool such as the comprehensive procedure to assess eutrophication. Using the data available nowadays, the Ria Formosa has been assessed as Non-Problem area. However, eutrophication can be observed in some parts of the lagoon.

Chapter 5: Discussion

1. The relation between the comprehensive procedure and European Water Policy

The EU commission developed an important number of directives regarding environmental protection of surface and ground waters, including coastal waters in the last decades, the most recent being the Water Framework Directive (2000/60/EC, WFD). Several directives coexist with the WFD, including: the UWWT Directive (91/271/EEC), Nitrates Directive (91/676/EEC), Bathing Water Directive (2006/7/EC), Habitats Directive (Directives 92/43/EEC) and the Birds Directive (Directive 79/409/EEC). Areas designated under these directives will have the status of Protected Areas under the WFD (Annex IV). Many directives consider eutrophication as a major impact (summarized in Appendix E).

The control of eutrophication is also addressed by a number of international and regional conventions, agreements and policies. These include OSPAR, HELCOM, BARCOM, Black Sea Convention, UNECELRTAP and the Rhine and Danube Conventions. These are summarized in Appendix F (EC eutrophication interim report, 2005).

The eutrophication assessment using the OSPAR comprehensive procedure aims to classify a water body into three categories: Problem, Potential Problem and Non-Problem areas. The comprehensive procedure is therefore related the WFD, the UWWTD and the Nitrate Directive in that sense. The Water Framework Directive actually requires Member States to classify the ecological status of surface water bodies into one of five ecological status classes: high, good, moderate, poor or bad ecological status. The Urban Waste Water Treatment Directive requires Member States to classify the water bodies as Sensitive or Less Sensitive Area and the Nitrate Directive to classify the water bodies as Nitrates Vulnerable Zone (Table 16).

Table 16: Comparison of assessment results under various policies for waters responding to nutrient enrichment (based on the assumption that the WFD classification is the starting point and that the different sources of pollution are relevant) - EC eutrophication interim report (2005)

Assessment of Current Status				
Ecological Status	**WFD normative definition**	**UWWT Directive**	**Nitrates Directive**	**OSPAR**
High	Nearly undisturbed conditions	Non Eutrophic, designation of sensitive area is **not required**	Non Eutrophic, not a Polluted Water, designation of NVZ is **not required**	Non-Problem Area
Good	Slight change in composition, biomass	Non Eutrophic, designation of sensitive area is **not required**	Non Eutrophic, not a Polluted Water, designation of NVZ is **not required**	Non-Problem Area
Moderate	Moderate change in composition, biomass	Eutrophic or may become eutrophic in the near future, designation of sensitive area is **required**	Eutrophic or may become eutrophic in the near future, polluted water, designation of NVZ is **required**	Problem Area
Poor	Major change in Biological communities.	Eutrophic, designation of sensitive area is **required**	Polluted water, designation of NVZ is **required**	Problem Area
Bad	Severe change in biological communities.	Eutrophic, designation of sensitive area is **required**	Polluted water, designation of NVZ is **required**	Problem Area

Figure 26 shows the relationship between the Comprehensive procedure and the Water Framework Directive more in detail.

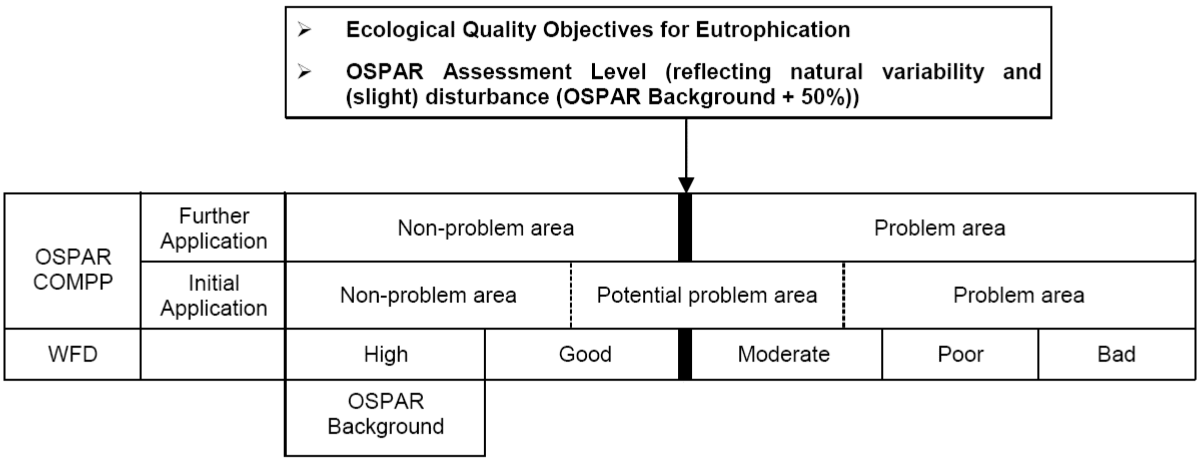

Figure 26: Relationship between the classification under the Comprehensive Procedure, the integrated set of EcoQOs for eutrophication and the Water Framework Directive (OSPAR Commission, 2005-3).

During the eutrophication assessment of the Ria Formosa using the comprehensive procedure, some gaps in the existing data and therefore the monitoring have been observed. Article 8 of the Directive establishes the requirements for the monitoring of surface water status, groundwater status and protected areas; monitoring programs being required to establish a coherent and comprehensive overview of water status within each river basin district (WFD CIS Policy Summary – Monitoring under the Water Framework Directive; available online). In that sense, the comprehensive procedure also relates to the monitoring program of the WFD. By identifying different gaps from the previous water quality monitoring in the Ria Formosa, the comprehensive procedure actually helps in the design of a monitoring program for the determination of ecological status within the WFD.

2. The comprehensive procedure – A tool to inform management

The use of the comprehensive procedure (and other eutrophication assessment such as NEEA) brings together valuable information on the state of eutrophication of the Ria Formosa and is a useful support to the decision making and management of this lagoon (Ferreira *et al.,* 2002). In term of management, the classification contributes to the definition of priorities and strategy: (1) Problem Area means that management measures must be applied; (2) Potential Problem Area means that monitoring and preventive measures must be promoted and (3) Non-Problem Area means that the system has a good trophic status and no particular management response should be done. Moreover, such assessment allows identifying the existing gaps such as monitoring requirements that should be filled in the future for better management response.

The comprehensive procedure has two main strengths. It is based in trend analysis and therefore complies with the statement reported by GESAMP (1996) which says that managers should base their decisions on trends rather than state. The main other strength is that through the analysis of different parameters trend, it transforms rough scientific data with poor meaning for managers into “problem”, “non-problem” or “potential problem” areas more explicit and easily understandable.

Regarding the ICARM, eutrophication assessment using the comprehensive procedure is part of the “Analysis” and the “monitoring” steps of the ICARM planning process detailed in this work (Fig.12). This corresponds to the actual agenda of the WFD, the main legal tool in Europe toward an ICARM (Table 10).

3. Applicability of the OSPAR comprehensive procedure in Brazil

Water quality monitoring in Brazil is conducted through the Environment National Program (PNMA II). A Water Quality Index (IQA) has been developed in order to establish the quality status of surface waters in Brazil. Although this index is the most widely used method to establish surface quality in Brazil, only 11 states are using it for its waters (Diniz, 2006).

In Rio Grande do Sul, water quality monitoring is done by the FEPAM. Four sampling stations monitor water quality in the estuarine area of the Patos Lagoon (GER 64, 65, 66 and 67) twice a year (online source, FEPAM)[1]. The different water quality parameters measured in the Patos L. estuary and for the IQA calculation are summarized in Table 17.

Table 17: Water Quality Parameters monitored in the Patos Lagoon estuary, used for IQA calculation and Water quality classification using the IQA calculation equation (after FEPAM and SEMAD, 2005)

Parameters monitored in the P. Lagoon estuary	Parameters Used For the IQA calculation	Water Quality classification
Chlorine	Dissolved Oxygen (%DO)	Excellent ($90 < IQA \leq 100$)
Conductivity	Faecal Coliforms	
BOD_5	pH	Good ($70 < IQA \leq 90$)
Total Phosphorus	BOD_5	
Mercury	Total Nitrate	Average ($50 < IQA \leq 70$)
Ammoniacal Nitrogen	Total Phosphate	
Total Kjedahl Nitrogen	Turbidity	Bad ($25 < IQA \leq 50$)
Dissolved oxygen	Total Solids	
pH	Temperature Variation	Very Bad ($0 < IQA \leq 25$)
Depth		
Total solids		
Air and water temperatures		
Turbidity		

IQA have been calculated in Rio Grande do Sul State, only in the Guaíba river region and around the city of Porto Alegre (ANA, 2005). Water quality index in the estuarine area of the Patos lagoon does not exist since the monitoring station do not measure all the required parameters for its calculation (Tab.17).

[1] FEPAM. URL: www.fepam.rs.gov.br (accessed on June 13, 2007)

Although the calculation of water quality index using the IQA equation use some parameters which could be used to assess eutrophication, there is no requirement in the Brazilian river basin and coastal management plans to assess eutrophication as required in European Directives. No eutrophication assessment is required in Brazil.

The comprehensive procedure is a tool developed for transitional and coastal waters and therefore this method is limited to assess eutrophication in the Patos lagoon. The comprehensive procedure can be used only in the estuarine part of the Patos lagoon, the inner part being mainly freshwater.

Sources of contamination (Almeida *et al.*, 1993, Abreu *et al.*, 2006, Niencheski & Windom, 1994, Baumgarten *et al.*, 1998) and eutrophication (Persich *et al.*, 1996, Baumgarten *et al.*, 1995, Abreu *et al.*, 2006) have been studied in the estuary of the Patos Lagoon analyzing parameters such as nutrient concentrations, Dissolved oxygen and chlorophyll a concentrations. Therefore the literature point out that the scientific basis exists in the Patos lagoon estuary to achieve an eutrophication assessment using the comprehensive procedure.

One critical parameter toward an integrated eutrophication assessment in the Patos L. nowadays is the monitoring, with lack a of data such as observed in the Ria Formosa. Indeed most of the parameters measured in the estuary and which could be used for the eutrophication assessment have been surveyed for a particular objective (Tagliani & Asmus, 1997) and could be classified as operational and/or investigative monitoring under the WFD, but not as part of a surveillance monitoring program.

However, the development of an integrated monitoring system for the estuarine water quality is planned through the ICZM planning described be Tagliani *et al.* (2003). It might be interesting therefore to include within this monitoring program the parameters needed for the comprehensive procedure to be able to apply it in the future.

4. Applicability of the Water Framework Directive in Brazil

The Brazilian National Plan on Water Resources (PNRH) and the European WFD are both based on the Integrated River Basin Management Principle. Moreover, Brazilian and European governances are comparable to some extent; National and state level for brazil corresponding to the European Commission and the Member States, respectively. Therefore, both management systems are similar so the WFD might be applicable in Brazil in that perspective.

However, the main objective of the water framework directive is to improve/keep the water quality of European water bodies whereas the river basin management in Brazil is mostly focalized on water availability and water use. Water quality is also included but cannot be compared to the extent of the WFD (Tab.18).

Table 18: Main objectives of the Brazilian National Plan on Water Resources and the European Water Framework Directive (MMA, 2006b ; MONAE, 2005)

Brazilian PNRH	European WFD
▪ Improve superficial and ground waters availability in quantity and quality. ▪ Reduce potential and existing conflicts between water users and critical hydrological events. ▪ Perceive water conservation as a relevant socio-environmental value.	▪ Prevent further deterioration of water resources, protecting and enhancing ecosystem status ▪ Promote sustainable water use based on long-term protection of water resources ▪ Enhance protection and improvement of the aquatic environment using specific measures in order to obtain a progressive reduction of discharges, emissions and losses of priority substances, as well as the cessation or phasing out of discharges and emissions of priority hazardous substances ▪ Ensure the progressive reduction and prevent further pollution of groundwater ▪ Contribute to mitigate the effects of floods and droughts

The situation in Brazil regarding water supply partly explain these objectives. More than 10% of the urban population does not have access to water supply in Brazil (Margulis *et al.,* 2002) and water distribution is therefore a priority. Some regions are also affected by drought in the northern part of the country and river basin management is more focalized on the water supply than environmental protection.

Water management in Brazil is based on economic criteria that consider water availability (quantity) the principal decision parameter, the water quality having less priority.

No similar legislation such as the European UWWT and Nitrate directives exist in Brazil and wastewater treatment in Brazil is a big problem to be able to reach objectives such as the set in the WFD. For instance, in the city of Rio Grande located in the estuarine area of the Patos Lagoon 12% of the city area only has a domestic sewage network. According to Almeida *et al.* (1993) 89% of the domestic sewage is released without control on the water surrounding the city and only one out the five existing official sewage treatment plant use a non-advanced secondary treatment (Baumgarten *et al*., 1998). Moreover, state water treatment companies in Brazil historically have been quite independent regarding regulation and they used to set up their own objectives for wastewater collection and treatment (Margulis *et al.,* 2002).

Considering the institutional fragility and the lack of wastewater collection and treatment the implementation of the WFD which such ambitious environmental objectives in a short period of time is not applicable in Brazil nowadays. However, Brazilian and European systems share similarities and the experience of the WFD implementation in Europe could be a good example for Brazil.

Conclusions

During this work, the role of science toward and integrated management of coastal lagoon have been studied through a literature review on the concept of ICARM and the role of science in ICARM but also using study cases from two very distinctive coastal lagoons, the Patos Lagoon in Brazil and the Ria Formosa in Portugal. After the discussion on the role of science in the ICARM process and the two study cases several conclusions can be outlined here:

- Science is the required basis toward a sustainable management of coastal lagoons.
- The study case on the Patos lagoon also pointed out that institutional weaknesses in Brazil make difficult to reach the objectives set up by an ICARM and even with the best science available, sustainable management might be successfully achieved only when science is well integrated to management and policies. The European water framework directive shows the way of integration using science to set up management objectives during the implementation process.
- The study case of the Ria Formosa showed how natural science can inform management to support the implementation of the WFD. Applying the OSPAR comprehensive procedure to determine the eutrophication status of the Ria Formosa, it can be concluded that such method is a good tool to integrate science with management and policies.
- The OSPAR comprehensive procedure is a good tool to inform managers on eutrophication status. However, it relies on good data and this study highlights the need for good quality, spatially and temporally well resolved data.
- The implementation of the WFD would meet nowadays too many challenges, particularly concerning urban waste water treatment and institutional integration to be applicable in Brazil.

- The scientific basis exist in the Patos lagoon estuary to be able to assess eutrophication using the OSPAR comprehensive procedure
- Surveillance monitoring is a key element in natural sciences toward the implementation of an ICARM.

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Appendices

***Appendix A**: Step 1 of the OSPAR comprehensive procedure - Assessment Parameter and Respective Assessment Levels*

Category I Degree of Nutrient Enrichment

1. ***Riverine total N and total P inputs and direct discharges (RID)***
   Elevated inputs and/or increased trends (compared with previous years)
2. ***Winter DIN- and/or DIP concentrations***
   Elevated level(s) (defined as concentration > 50% above 3 salinity related and/or region specific background concentration)
3. ***Increased winter N/P ratio (Redfield N/P = 16)***
   Elevated cf. Redfield (> 25)

Category II Direct Effects of Nutrient Enrichment (during growing season)

1. ***Maximum and mean Chlorophyll a concentration***
   Elevated level (defined as concentration > 50% above 3 spatial (offshore) / historical background concentrations)
2. ***Region/area specific phytoplankton indicator species***
   Elevated levels (and increased duration)
3. ***Macrophytes including macroalgae (region specific)***
   Shift from long-lived to short-lived nuisance species (e.g. *Ulva*)

Category III Indirect Effects of Nutrient Enrichment (during growing season)

1. ***Degree of oxygen deficiency***
   Decreased levels (< 2 mg/l: acute toxicity; 2 - 6 mg/l: deficiency)
2. ***Changes/kills in zoobenthos and fish kills***
   Kills (in relation to oxygen deficiency and/or toxic algae)
   Long term changes in zoobenthos biomass and species composition
3. ***Organic Carbon/Organic Matter***
   Elevated levels (in relation to Category III.1) (relevant in sedimentation areas)

Category IV Other Possible Effects of Nutrient Enrichment (during growing season)

1. ***Algal toxins (DSP/PSP mussel infection events)***
   Incidence (related to Category II.2)

***Appendix B**: Step 2 of the OSPAR comprehensive procedure - Integration of the categorised assessment parameters - Initial Classification*

	Category I Degree of nutrient enrichment Nutrient inputs Winter DIN and DIP Winter N/P ratio	Category II Direct effects Chlorophyll a Phytoplankton Indicator species macrophytes	Categories III and IV Indirect effects/other possible effects Oxygen deficiency Changes/kills zoobenthos, fish kills Organic carbon/matter Algal toxins	Initial Classification
A	+	+	+	Problem area[4]
A	+	+	-	Problem area[4]
A	+	-	+	Problem area[4]
B	-	+	+	Problem area[4 5]
B	-	+	-	Problem area[4 5]
B	-	-	+	Problem area[4 5]
C	+	-	-	Potential Problem area[4]
C	+	?	?	Potential Problem area[4]
C	+	?	-	Potential Problem area[4]
C	+	-	?	Potential Problem area[4]
D	-	-	-	Non Problem area[4]

(+) = Increased trends, elevated levels, shifts or changes in the respective assessment parameter
(-) = Neither increased trends nor elevated levels nor shifts nor changes in the respective assessment parameter
? = Not enough data to perform an assessment or the data available is not fit for the purpose
Note: Categories I, II and/or III/IV are scored '+' in cases where one or more of its respective assessment parameters is showing an increased trend, elevated level, shift or change.

A. Areas showing an increased degree of nutrient enrichment accompanied by direct and/or indirect/other possible effects are regarded as '**problem areas**'[4];
B. Areas may show direct effects and/or indirect or other possible effects when there is no evident increased nutrient enrichment, e.g. as a result of transboundary transport of (toxic) algae and/or organic matter arising from adjacent/remote areas. These areas could be classified as '**problem areas**'[4 5];
C. Areas with an increased degree of nutrient enrichment, but without showing direct, indirect/other possible effects, are classified initially as '**potential problem areas**'[4];
D. Areas without nutrient enrichment and related (in)direct/other possible effects are considered to be '**non-problem areas**'[4].

[4] ***"problem areas with regard to eutrophication"*** are those areas for which there is evidence of an undesirable disturbance to the marine ecosystem due to anthropogenic enrichment by nutrients;
"potential problem areas with regard to eutrophication" are those areas for which there are reasonable grounds for concern that the anthropogenic contribution of nutrients may be causing or may lead in time to an undesirable disturbance to the marine ecosystem due to elevated levels, trends and/or fluxes in such nutrients;
"Non-problem areas with regard to eutrophication" are those areas for which there are no grounds for concern that anthropogenic enrichment by nutrients has disturbed or may in the future disturb the marine ecosystem.
[5] caused by transport from other parts of the maritime area.

Appendix C*: Step 3 of the OSPAR comprehensive procedure - Appraisal of all relevant information - Final Classification*

Supporting environmental factors and region specific characteristics should be taken into account, such as physical and hydrodynamical aspects, and weather/climate conditions (see Figure 1). These region specific characteristics play a role in explaining the results of the classification. The following types of areas can be distinguished (OSPAR Commission, 2003):

- Coastal/salinity gradient (riverine influenced) waters (salinity ≤34,5) *vs.* offshore waters (salinity> 34,5);
- Stratified waters (may be both coastal and offshore, e.g. Oyster Grounds) *vs*. mixed waters;
- Sedimentation areas (may both be coastal, e.g. Wadden Sea, and offshore, e.g. Oyster Grounds, ancient Elbe river valley (short-term sedimentation), Skagerrak (long-term sedimentation) *vs*. 'high energy' areas (e.g. offshore part of Southern North Sea);
- Areas with extended residence time of water masses which may enhance algal bloom formation and/or accumulation of organic material;
- Areas affected or likely to be affected by transboundary transport of nutrients and organic matter (e.g. German Bight and Skagerrak influenced by Southern North Sea waters; Oyster Grounds and Frisian Front may be affected by UK coastal erosive areas);
- Areas susceptible to the intermittent transport of nutrient rich oceanic water to the euphotic zone (episodic upwelling, mixing, currents) which may enhance eutrophication effects.

Appendix D - Result of the extreme DIN, Chlorophyll a and Dissolved oxygen concentrations and the corresponding physico-chemical parameters

Table 1: Winter DIN extreme concentrations in the Ria Formosa

Year	Parameter	Lowest DIN	Highest DIN
1985 35 samples (Tavira inlet, Tavira channel, station A3) No Salinity data (only 1)	Station name	Tavira Channel	Tavira Channel
	Month	October	February
	Salinity	???	???
	Phosphate ($\mu mol.l^{-1}$)	0.84 *(0.05-0.33-0.84)*	0.16
	Silicates ($\mu mol.l^{-1}$)	6.25 *(0.82-9.31-38.63)*	25.59
	DIN ($\mu mol.l^{-1}$)	0.4 *(1.7)*	4.6
1986 7 samples (Tavira inlet & Tavira channel) No salinity data	Station name	Tavira Channel	Tavira inlet
	Month	January	February
	Salinity	???	???
	Phosphate ($\mu mol.l^{-1}$)	0.99 *(0.08-0.49-1.62)*	0.09
	Silicates ($\mu mol.l^{-1}$)	23.73 *(1.46-8.40-23.73)*	1.46
	DIN ($\mu mol.l^{-1}$)	0.48 *(1.90)*	3.23
1987 96 Samples (0, 1, 10, 12, 14, 16, 18, 2, 20, 22, 3, 4, 5, 6, 7, 9)	Station name	5	18
	Month	November	December
	Salinity	35.1 *(26.80-34.57-36.00)*	32
	Phosphate ($\mu mol.l^{-1}$)	0.76 *(0-0.73-4.02)*	0.51
	Silicates ($\mu mol.l^{-1}$)	10.58 *(1.86-28.29-323.3)*	265.05
	DIN ($\mu mol.l^{-1}$)	4.36 *(27.60)*	191.43
1988 96 Samples (0, 1, 10, 12, 14, 16, 18, 2, 20, 22, 3, 4, 5, 6, 7, 9)	Station name	7	18
	Month	March	January
	Salinity	35.2 *(15-33.57-36.4)*	15
	Phosphate ($\mu mol.l^{-1}$)	1.11 *(0.1-0.8-3.01)*	1.47
	Silicates ($\mu mol.l^{-1}$)	29.25 *(23.45-107.17-1200.84)*	790.73
	DIN ($\mu mol.l^{-1}$)	1.97 *(24.52)*	354.93
1989 22 Samples (0)	Station name	0	0
	Month	February	October
	Salinity	30 *(28.32-32.66-37.15)*	34.5
	Phosphate ($\mu mol.l^{-1}$)	0.8 *(0.5-1.11-2)*	2
	Silicates ($\mu mol.l^{-1}$)	11.7 *(10-15.2-26.5)*	11.5
	DIN ($\mu mol.l^{-1}$)	3.6 *(14.7)*	43.5
1998 24 Samples (IH, 0, 1, 18, 20, 3, 9)	Station name	3	9
	Month	January	November
	Salinity	35.55 *(31.74-35.26-36.14)*	35.92
	Phosphate ($\mu mol.l^{-1}$)	0.24 *(0.16-0.84-6.13)*	6.13
	Silicates ($\mu mol.l^{-1}$)	3.35 *(3.31-6.10-16.38)*	6.98
	DIN ($\mu mol.l^{-1}$)	2.21 *(8.17)*	20.4
1999 26 Samples (IH, 0, 1, 18, 20, 3, 9)	Station name	IH	9
	Month	March	March
	Salinity	36.17 *(35.23-36.05-36.57)*	36.39
	Phosphate ($\mu mol.l^{-1}$)	0.04 *(0.04-0.51-0.88)*	0.65
	Silicates ($\mu mol.l^{-1}$)	1.85 *(1.14-3.25-7.26)*	1.39
	DIN ($\mu mol.l^{-1}$)	0 *(6.76)*	19.54
2000 22 Samples (Formed inlet, IH, Ramalhete, 0, 20, 3, 9) 10 with salinity	Station name	0	20
	Month	October	January
	Salinity	36.3 *(32.28-36-36.68)*	32.28
	Phosphate ($\mu mol.l^{-1}$)	0.12 *(0.12-0.47-1)*	1
	Silicates ($\mu mol.l^{-1}$)	1.78 *(1.78-4.64-13.17)*	13.17
	DIN ($\mu mol.l^{-1}$)	0.11 *(4.61)*	15.96
2001 23 Samples (Formed inlet, Ramalhete, 0)	Station name	Formed inlet	Ramalhete
	Month	December	March
	Salinity	36 *(31.80-35.56-36.1)*	35.2
	Phosphate ($\mu mol.l^{-1}$)	0.14 *(0.14-0.54-1.12)*	0.91
	Silicates ($\mu mol.l^{-1}$)	1.79 *(1.66-6.41-23.95)*	9.46
	DIN ($\mu mol.l^{-1}$)	0.49 *(5.29)*	13.59

The values in the parenthesis represent the *(mean)* for DIN and the *(minimum-mean-maximum)* for Salinity, Phosphates and Silicates.

Table 2: Chlorophyll a extreme concentrations in the Ria Formosa

Year	Parameters	Lowest Chla	Highest Chla
1985 173 samples (Tavira inlet & channel, A3, B3, C3, D3, E3)	Station name	C3/D3	Tavira Inlet
	Month	September	June
	Temperature (°C)	23 *(14-19.22-25)*	???
	Salinity (PSU)	36.18 *(34.49-36.31-36.93)*	???
	Nitrate(μmol.l^{-1})	0.30 *(0.01-0.75-9.90)*	0.28
	Phosphate (μmol.l^{-1})	0.71 *(0.05-0.51-2.15)*	0.42
	Silicates (μmol.l^{-1})	2.60 *(0.13-5.75-38.63)*	14.15
	Chla (μg.l^{-1})	0.23 *(2.24)*	20.35
1986 156 samples (Tavira inlet & channel, A3, B3, C3, D3, E3)	Station name	C3	D3
	Month	June	July
	Temperature (°C)	21.50 *(11.80-18.46-26.30)*	25.30
	Salinity (PSU)	36.01 *(25.22-35.77-36.88)*	36.47
	Nitrate(μmol.l^{-1})	0.20 *(0.10-1.57-21.60)*	0.20
	Phosphate (μmol.l^{-1})	0.05 *(0.05-0.99-5.60)*	0.05
	Silicates (μmol.l^{-1})	1.00 *(0.30-5.03-23.73)*	0.60
	Chla (μg.l^{-1})	0.20 *(1.36)*	5.70
1998 37 samples (IH, 0, 1, 18, 20, 3, 9)	Station name	Station 1	Station 20
	Month	April (afternoon)	April (morning)
	Temperature (°C)	17 *(12-17.62-25)*	16
	Salinity (PSU)	36.02 *(31.74-35.47-36.54)*	33.98
	Nitrate(μmol.l^{-1})	4.71 *(0-3.87-31.41)*	6.21
	Phosphate (μmol.l^{-1})	1.19 *(0.07-0.47-1.26)*	0.30
	Silicates (μmol.l^{-1})	8.69 *(2.53-7.22-25.28)*	10.43
	Chla (μg.l^{-1})	0.70 *(1.94)*	6.00
1999 39 samples (IH, 0, 1, 18, 20, 3, 9)	Station name	Station IH	Station IH
	Month	May (morning)	July (afternoon)
	Temperature (°C)	15 *(14-18.10-26)*	26
	Salinity (PSU)	35.89 *(30.46-35.91-37.27)*	37.27
	Nitrate(μmol.l^{-1})	0 *(0-2.50-14.28)*	1.50
	Phosphate (μmol.l^{-1})	0.05 *(0.04-0.47-0.88)*	0.41
	Silicates (μmol.l^{-1})	0 *(0-4.14-18.87)*	4.63
	Chla (μg.l^{-1})	0.30 *(1.85)*	5.40
2000 62 samples (Formed inlet, IH, Ramalhete, 0, 20, 3, 9)	Station name	Ramalhete	Station 20
	Month	December	April (morning)
	Temperature (°C)	??? *(13-19.22-24.70)*	15.50
	Salinity (PSU)	??? *(28.99-36.09-37.02)*	28.99
	Nitrate(μmol.l^{-1})	??? *(0-1.63-4.47)*	4.14
	Phosphate (μmol.l^{-1})	??? *(0.10-0.45-1)*	0.73
	Silicates (μmol.l^{-1})	??? *(1.42-5.28-25.28)*	25.28
	Chla (μg.l^{-1})	0.22 *(1.31)*	6.30
2001 92 samples (Formed inlet, Ramalhete, 0)	Station name	Ramalhete	Station 0
	Month	December	June (afternoon)
	Temperature (°C)	??? *(14.50-19.38-24.70)*	24.10
	Salinity (PSU)	??? *(31.80-36-37)*	36.60
	Nitrate(μmol.l^{-1})	??? *(0.02-1.94-9.98)*	???
	Phosphate (μmol.l^{-1})	??? *(0.14-0.54-1.12)*	???
	Silicates (μmol.l^{-1})	??? *(1.66-6.16-23.95)*	???
	Chla (μg.l^{-1})	0.15 *(1.11)*	3.90
2002 25 samples (Formed inlet, Ramalhete, 0)	Station name	Formed inlet	Station 0
	Month	April (morning)	July (evening)
	Temperature (°C)	20.20 *(15.60-20.61-24.30)*	22.90
	Salinity (PSU)	35.90 *(35.40-35.84-36.40)*	36
	Nitrate(μmol.l^{-1})	0.17 *(0.01-0.27-0.95)*	0.04
	Phosphate (μmol.l^{-1})	0.31 *(0.15-0.39-0.85)*	0.34
	Silicates (μmol.l^{-1})	3.77 *(1.65-4.57-10.50)*	5.02
	Chla (μg.l^{-1})	0.16 *(0.69)*	2.25

The values in the parenthesis represent the *(mean)* for Chla and the *(minimum-mean-maximum)* for Temperature, Salinity, Nitrate, Phosphates and Silicates.

Table 3: Dissolved oxygen extreme concentrations in the Ria Formosa

Year	Parameters	Lowest DO	Highest DO
1985 80 samples (Stations A3, B3, C3, D3, E3)	Station name Month Salinity (PSU) Temperature (°C) DO (mg.l^{-1})	Station E3 September 35.72 *(34.49-36.31-36.93)* 23.8 *(14-19.22-25)* 4.80 *(7.30)*	Station C3 October 36.34 20 9.12
1986 252 samples (Tavira inlet, Tavira channel, A3, B3, C3, D3, E3)	Station name Month Salinity (PSU) Temperature (°C) DO (mg.l^{-1})	Tavira Channel July (morning) 37.1 *(25.22-36.06-37.90)* 25.2 *(11.80-18.56-27.60)* 3.40 *(7.18)*	Station C3 March 34.26 17 10.70
1987 210 Samples (0, 1, 10, 12, 14, 16, 18, 20, 22, 3, 4, 5, 6, 7, 9)	Station name Month Salinity (PSU) Temperature (°C) DO (mg.l^{-1})	Station 10 November 34.6 (*26.80-35.16-38)* 18.2 *(13-20.45-28.40)* 3.18 *(7.94)*	Station 5 November 35.55 18.6 13.31
1988 210 Samples (0, 1, 10, 12, 14, 16, 18, 20, 22, 3, 4, 5, 6, 7, 9, E3)	Station name Month Salinity (PSU) Temperature (°C) DO (mg.l^{-1})	Station F3 March ??? *(15-34.04-36.4)* 16.3 *(10-16.98-23.5)* 2.40 *(9.04)*	Station F3 March ??? 21.5 18.10
1989 201 Samples (Station 0)	Station name Month Salinity (PSU) Temperature (°C) DO (mg.l^{-1})	Station 0 September (afternoon) 38.25 *(28.32-37.05-39.05)* 24.5 *(12-21.8-30)* 0 *(7.65)*	Station 0 March (afternoon) 28.32 15.5 12.04
1998 52 Samples (IH, 0, 1, 18, 20, 3, 9)	Station name Month Salinity (PSU) Temperature (°C) DO (mg.l^{-1})	Station 18 November (morning) 35.78 *(31.74-35.60-36.54)* 18 *(12-17.6-25)* 5.24 *(7.21)*	Station IH April (morning) 35.98 15 8.97
1999 54 Samples (IH, 0, 1, 18, 20, 3, 9)	Station name Month Salinity (PSU) Temperature (°C) DO (mg.l^{-1})	Station 18 July (morning) 37.12 *(30.46-35.95-37.27)* 22 *(14-18.1-26)* 4.41 *(7.26)*	Station 18 May (midday) 35.49 19 11.27
2000 19 Samples (IH, 0, 20, 3, 9)	Station name Month Salinity (PSU) Temperature (°C) DO (mg.l^{-1})	Station 9 July (morning) 36.67 *(28.99-35.76-37.02)* 22.5 *(13-17.68-24.5)* 5.57 *(7.24)*	Station 3 October (morning) 36.33 18 8.03
2001 96 Samples (Anção Basin, Barra, Formed inlet, Ramalhete, IH, 0, 14) No salinity/Temperature	Station name Month Salinity (PSU) Temperature (°C) DO (mg.l^{-1})	Anção Basin July (morning) ??? *(???-???-???)* ??? *(???-???-???)* 6.07 *(7.65)*	Anção Basin July (afternoon) ??? ??? 9.59

The values in the parenthesis represent the *(mean)* for Dissolved Oxygen and the *(minimum-mean-maximum)* for Temperature and Salinity.

Appendix E - Summary of the EU Directives addressing EU water policy

Directive	Relevant Section
Water Framework Directive (WFD) (2000/60/EC)	Article 1.a (purpose); Article 4.1.a.i and ii (Environmental objectives and programs of measures for surface waters); Article 5 (Characterization); Article 6 (Register of Protected areas); Article 7.3 (Drinking Water); Article 8 (Monitoring); Article 10 (The combined approach for point and diffuse sources); Article 11 (Program of measures); Annex II (Characterization), Annex IV.1.iv, (Protected Areas, nutrient-sensitive areas); Annex V (1) (Assessment of Surface Water Status) and Annex VIII (indicative list of main pollutants).
Urban Waste Water Directive (UWWD) (91/271/EEC)	The Directive aims to protect the environment from adverse effects of urban waste water discharges and direct discharges from certain (food processing) industries. It sets treatment levels on the basis of the agglomeration size and the sensitivity of waters receiving the discharges. Surface waters must be designated as Sensitive Areas (SA) if, inter alia, they are eutrophic or if they may become eutrophic in the near future if protective action is not taken (Annex II A(a)).
The Nitrates Directive (91/676/EC)	The Directive aims to reduce water pollution by nitrate from agricultural sources and to prevent such pollution occurring in the future. The Directive requires Member States to identify polluted waters and apply Action Program measures (Annex III of the directive) within designated Nitrate Vulnerable Zones (NVZs) or throughout their whole territory. The measures of the Code of Good Agricultural Practice (in Annex II), which are not included in the action program, must also be implemented in NVZs, or across the whole territory if the Member State choose the whole territory approach according to article 3 (5) of the Directive and, therefore, did not designate specific NVZs.
The Shellfish Waters Directive (79/923/EEC)	The Directive seeks to protect and improve shellfish waters in order to support shellfish life and growth and thus to improve the high quality of shellfish products for consumption. The Directive sets physical, chemical and microbiological water quality requirements that designated shellfish waters must either comply with or endeavor to meet. The Shellfish Water Directive does not require an assessment of eutrophication per se; however Article 6 does require a number of parameters to be monitored to check the quality required for shellfish waters. Some of these parameters are relevant to assessments of eutrophication – in particular dissolved oxygen and saxitoxins (produced by dinoflagellates). The Shellfish Water Directive will be repealed by the WFD by 2013.
Freshwater Fish Directive (78/659/EEC)	The Directive is to protect or improve the quality of running or standing freshwaters capable of sustaining fish populations. It sets physical and chemical water quality objectives for salmonid waters and cyprinid waters. Member States must designate salmonid waters and cyprinid waters and ensure they meet the quality objectives. There is no direct requirement for an assessment of eutrophication in the Directive. However, standards are set to safeguard fish populations from the harmful resulting from the discharge of pollutant substances into waters (including the reduction of the number of fish belonging to a certain species). The Freshwater Fish Directive will be repealed by the WFD by 2013.
Bathing Waters Directive (76/160/EEC)	The Directive seeks to protect the environment and public health, by reducing the pollution of bathing waters and protecting such waters from further deterioration. Bathing waters are classified as all surface freshwater and seawater, where bathing is authorized by competent authorities of Member Sates and is not prohibited. The Directive does not require a direct assessment of eutrophication. However, there is a requirement to monitor several parameters relevant to the assessment of eutrophication, i.e. transparency (fortnightly), dissolved oxygen, nitrates and phosphate when the quality of the water has deteriorated. Furthermore samples must be collected for ammonia and nitrogen (Kjeldahl) when there is a tendency towards eutrophication of the water.
Abstraction of Drinking Water Directive (75/440/EEC)	The Directive sets water quality requirements, which must be met for surface freshwater which is used, or intended for use, in the abstraction of drinking water. The Directive does not cover groundwater, brackish water or water intended to replenish water-bearing beds. The Directive distinguishes three different categories of surface waters (A1, A2 and A3) requiring three different level of treatment to transform them into drinking water. The Abstraction of Drinking Water Directive does not refer directly to any methods for assessing eutrophication. However, there is a requirement to monitor many parameters relevant to eutrophication (i.e. conductivity, nitrates, phosphates, and dissolved oxygen). This Directive will be repealed by the WFD in 2007.

Emission Ceilings Directive (2001/81/EC)	The Directive aims to limit atmospheric emissions of acidifying and eutrophying pollutants and ozone precursors in order to improve the protection of the environment and human health. The protection will be against the adverse effects of acidification, eutrophication and ground level ozone. The long-term objectives of the Directive are to establish national emission ceilings aiming at avoiding exceedances of critical loads and levels50 and to protect all people against recognized health risks from air emissions. The Directive covers atmospheric emissions from Member States which arise as a result of human activity. It is expected that Member States will lower their annual national emissions of acidifying and eutrophying substances (i.e. sulphur dioxide, nitrogen oxides and ammonia) to levels not greater than those laid down in Annex I by 2010 (Article 4 and 5). Meeting these objectives is expected to result in a reduction of water and soil eutrophication by deposition of nitrogen. There is no direct requirement for an assessment of eutrophication in the Directive. However, the Directive does refer to the quantitative relationship between the emission levels of pollutants and levels of eutrophication. This is based on the exceedance of critical loads at which level the pollutants have a significant adverse effect on the environment. In this instance causing eutrophication, acidification and the formation of ground level ozone. Following the adoption of the Thematic Strategy on air pollution in September 2005, new objectives for eutrophication, acidification, ozone and health have been defined to be met in 2020. The NEC Directive will be reviewed accordingly in 2006. The objective for what concerns eutrophication is a reduction of 43% of the ecosystems in which the critical loads are exceeded as to compare to 2000 situation.
The European Marine Strategy	The Strategy is being developed under the 6th Environment Action Program (6th EAP) with the overall aim to 'promote sustainable use of the seas and conserve marine ecosystems' (European Commission 2002a). The strategy will be very broad and should provide a framework to embrace a wide range of issues. In some aspects it will be analogous to the WFD in a way that it will be based on an ecosystem approach that will support a regional approach considering that problems are different in different seas or parts thereof. Although many of them originated activities on land, it only deals with issues pertinent to the marine environment. Eutrophication will be addressed within the strategy as one of several priority issues. A common approach toward marine monitoring and assessment will be developed under the Strategy.

Appendix F - Overview of Eutrophication in other international policies than the EU policy (EC eutrophication interim report, 2005)

Name	General objective	Waters covered	Website
OSPAR Convention	To take steps to prevent and eliminate pollution and the necessary measures to protect the maritime area against the adverse effects of human activities so as to safeguard human health and to conserve the marine ecosystem and, when practicable, restore marine area which have been adversely affected.	North East Atlantic Sea	www.OSPAR.org
Helsinki Convention (HELCOM)	To take measures to prevent and eliminate pollution in order to promote the ecological restoration of the Baltic Sea Area and the preservation of its ecological balance.	Baltic Sea	www.HELCOM.fi
Barcelona Convention (UNEP/MAP)	To take concerted actions to prevent and eliminate marine pollution and sustainable management of the Mediterranean.	Mediterranean Sea	www.unepmap.org
Bucharest Convention	To take all necessary measures… to prevent, reduce and control pollution in order to protect and preserve the marine environment of the Black Sea.	Black Sea	www.blackseaenvironment.org
UNECE Convention on Long-range Transboundary Air Pollution (LRTAP)	An international legally binding instrument to deal with problems of air pollution on a broad regional basis. Signed by 34 governments and the EC. Includes a protocol to abate acidification and eutrophication. The Working Group on Effects under the Convention is in charge of monitoring the impact of air pollution on health and environment (notably eutrophication and acidification).	Air Pollution (Europe)	www.unece.org/env/lrtap/welcome.html http://www.unece.org/env/wge/welcome.html
Convention for the protection of the Rhine	Aims to strengthen cooperation between the Community and the Rhine riparian States in order to preserve and improve the ecosystem of the river. Council Decision 2000/706/EC	Rhine River Basin	http://europa.eu.int/scadplus/leg/en/lvb/l28115.htm
Danube River Protection Convention	Aims to achieve sustainable and equitable water management in the Danube Basin. Agreement to reduce pollution loads to the Black Sea. International Commission for the Protection of the Danube River (ICPDR) acts as the permanent secretariat. Supported by a communication from Commission -COM (2001) 615 – on Environmental Co-operation in the Danube.	Danube River Basin	http://www.icpdr.org/pls/danubis/danubis_db.dyn_navigator.show http://europa.eu.int/scadplus/leg/en/lvb/l28016.htm