

Tools for seagrass conservation and management in Portugal

Alexandra Henriques Cunha and Ester Álvares Serrão

acunha@ualg.pt; eserrao@ualg.pt

CCMAR - Centro de Ciências do Mar e CIMAR, Edifício 7, Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal. Tel and fax + 351 289 800 051

Resumo

Recentemente têm surgido a nível mundial inúmeras referências ao decréscimo de área de pradarias marinhas, o que reflete a importância marginal destes habitats nos programas de conservação nacionais e internacionais. As populações de pradarias marinhas da costa Portuguesa também têm vindo a mostrar sinais de forte declínio nos últimos 20 anos, seguindo a tendência encontrada a nível mundial.

Portugal, localizado numa zona de transição entre o Atlântico Norte e o Mar Mediterrâneo, possui um conjunto de espécies com uma especificidade genética única no panorama Europeu. É o único ponto da costa Atlântica onde *Cymodocea nodosa*, *Zostera marina*, e *Zostera noltii* ocorrem em simultâneo; sendo o limite norte e oeste de distribuição de *C. nodosa*, o limite sul de *Z. marina* e zona de transição para *Z. noltii*.

Neste artigo são apresentados um resumo sobre a evolução da investigação em pradarias marinhas da costa Portuguesa, os esforços de conservação e recuperação de pradarias realizados no nosso país e os aspectos mais relevantes da legislação que enquadra a proteção deste habitat. São apresentadas as principais ameaças à sua preservação bem como sugeridas várias medidas de gestão e proteção deste habitat.

Abstract

Numerous recent references about decreasing trends in seagrass cover worldwide are leading to concerns about the adequacy of tools for conservation management of this habitat. Seagrass populations of the Portuguese coast have been facing unprecedented declines in distribution over the last 20 years, matching the general trends described for most world seagrasses. Portugal, located in the transition zone between the Atlantic Ocean and the Mediterranean Sea, has genetically unique European seagrass meadows. It is the only location in Atlantic Europe where the seagrass species *Cymodocea nodosa*, *Zostera marina*, and *Zostera noltii* occur together, and represents the northern and western distributional limits for *C. nodosa*, the southern limit for *Z. marina* and a climatic transitional zone for *Z. noltii*.

Here, we discuss recent trends in seagrass research in Portugal, main threats and solutions, restoration efforts, environmental policies implementation, monitoring and awareness programs that are now starting to be put together in an effort to stop and invert the observed decreasing trend.

Status of the seagrass habitat in Portugal

A recent survey of the past and present distribution of seagrass meadows in Portugal (Cunha *et al.* 2011) showed that the most widely distributed seagrass on the Portuguese coast is *Zostera noltii* (15.74 km²). It occurs in 11 of the 18 sites (Fig.1) with seagrasses, namely in the estuaries of Mondego, Tagus, Sado, Mira, Arade and Guadiana rivers, and in Ria de

Aveiro, Ria de Alvor and Ria Formosa coastal lagoons. It also occurs in two open coast locations, Galé and Ponta do Adoche, both in the Tróia Peninsula. In some locations such as Ria de Aveiro (Canal de Ovar), Sado Estuary, Mira Estuary and Ria Formosa, it is still possible to observe extensive meadows. *Zostera marina* appears to be the most endangered seagrass species on the Portuguese coast, taking into account its historical patterns (Cunha *et al.*, 2011). From the eight sites

where this plant was once abundant, only two had *Z. marina* populations in 2010, with a total coverage of 0.075 km². The populations at these two sites (Lagoa de Óbidos and Ria Formosa) are subject to continued use of bivalve hand trawling (Fig. 2) and intense boat mooring, in addition to recent channel dredging and the opening of inlets (in Ria Formosa). The future of this species in Portugal is therefore, at the moment, uncertain. As for *C. nodosa* (Fig. 3), there are 3 main

populations identified, with a total acreage of approximately 1.09 km². Nevertheless, it is hard to be fully acquainted with the cover distribution trends as this species was often confused with *Z. marina*, and was never referred to in documents prior to 1992. Still, due to its limited distribution and low clonal diversity with a unique genetic background, it is a species of special concern and action should be taken to avoid its local disappearance.

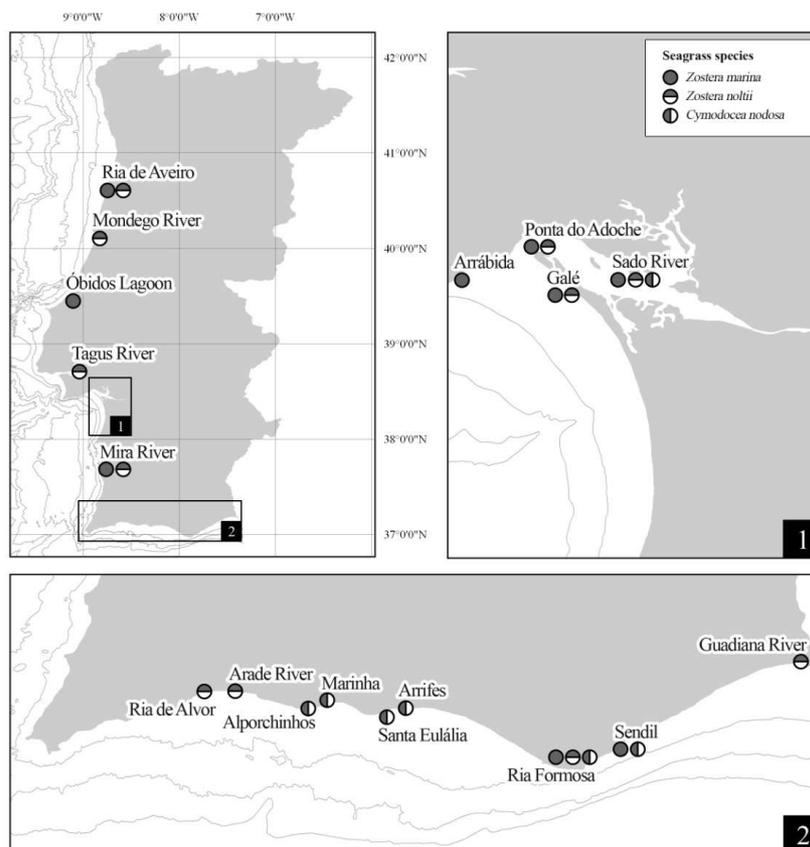


Figure 1. Seagrass distribution in the Portuguese coast (adapted from Cunha *et al.* 2011)



Figure 2. *Cymodocea nodosa* meadows growing on rocky pools in Santa Eulália Beach in southern Portugal.



Figure 3. Hand rack for clam collection in Tagus River Estuary.

Another group of seagrasses present in Portugal is widgeon grass (*Ruppia maritima* and *Ruppia cirrhosa*), which occur widely in many coastal lagoons and saltmarshes. It occurs in Lagoa de Albufeira, (covered 0.425 km² a few decades ago, Salgado and Santos 1985, recently much reduced, Cunha *et al.*, 2011) and in the Óbidos Lagoon (patches covered 0.083 km² in 2008, Cunha *et al.*, 2011). There are reports of *R. maritima* in the Arade River (Santos *et al.*, 2004), which have completely disappeared in 2009 (Cunha *et al.* 2011), in Ludo-Ria Formosa (JM Silva, J Gonçalves pers. obs., 2010), and *Ruppia cirrhosa* at Ria de Aveiro (Silva *et al.*, 2004). Many other locations, namely coastal lagoons such as Santo André Lagoon (Calado and Duarte, 2000) and others on the west coast as well as the Castro Marim saltmarshes in the Guadiana

Estuary, might have populations but are not referenced to date.

Seagrass research in Portugal

Scientific information on seagrass distribution, ecology and biology is recent, and historical information is mostly available in grey literature (Fig. 4a). Scientific production only started to increase in the nineties, now reaching more than 100 articles (Fig. 4b). Among the three species that exist on the Portuguese coast, *Z. noltii* is the most studied, probably because it is the most abundant and occurs mostly on the intertidal zone, which facilitates sampling and experimental research (Fig.4c). The seagrass sites most intensively studied are Ria Formosa followed by the Mondego and Mira rivers (Fig.4d).

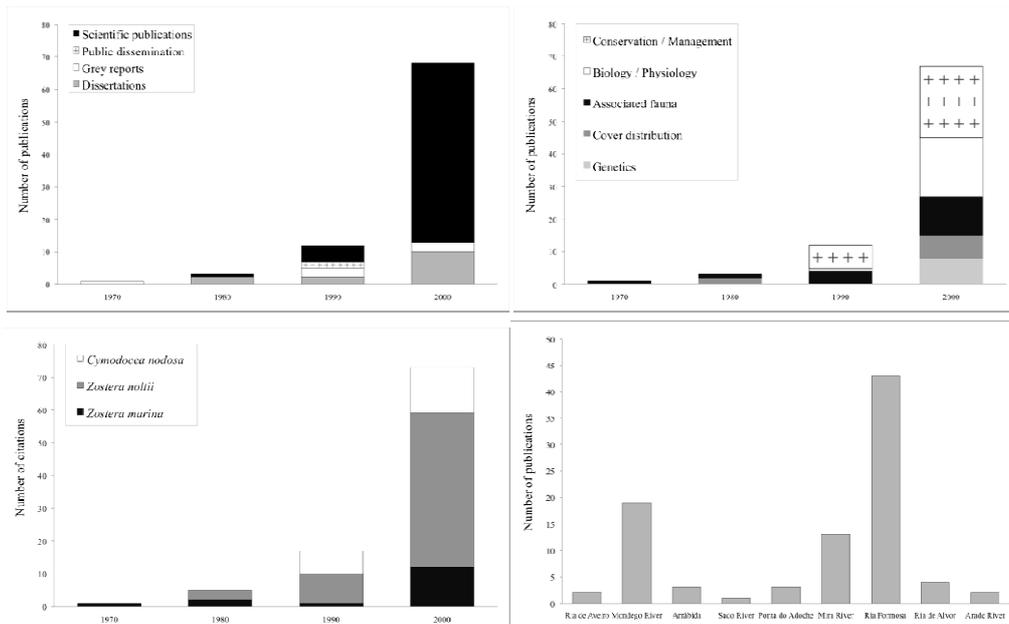


Figure 4. Number of publications on Portuguese seagrasses since the 1970s, a), by study theme, b); by seagrasses species, c); by study site, d).

Historical distribution records were retrieved from scientific seagrass literature when existent, but mostly from "grey" literature. "Grey" literature used in this study comprised documents about seagrasses for the general public, field campaign reports from students or governmental institutes, and master's and doctoral theses that were never published in peer reviewed journals, but that could be obtained directly from the authors or from institutions' libraries. Most scientific references were identified via searches of electronic library databases (Aquatic Sciences and Web of Science), and personal communications with national and international seagrass researchers were obtained directly by asking/emailing fellow researchers from the research centres in Portugal and Spain.

Restoration efforts

Only two restoration efforts have been implemented in Portugal to the moment. The first was in the Mondego Estuary, where the *Z. noltii* meadow decreased from approximately 150.000 m² in 1986 to 200 m² in 1997 (Martins *et al.*, 2005). In the early 1990s, the communication between the two arms of the estuary became totally interrupted in the upstream area. The combined effect of an increased water residence time and of nutrient concentrations became major driving forces behind the occurrence of seasonal *Ulva* spp. blooms and a concomitant severe reduction of the area occupied by *Z. noltii* beds was observed. Today the meadow recovered up to 4.423 m² (Cunha *et al.* 2011) after a recovery plan implemented by the Water Management Authority which included the physical protection of the remaining few shoots and rhizomes, the management of the freshwater inputs to the system and the implementation of seagrass transplantation (Martins *et al.*, 2005).

In 2007 the LIFE Biomares project (LIFE 06 NAT/ P/192), started a restoration program at Professor Luiz Saldanha Marine Park, part of the Arrábida Natural Park. Once covered by luxuriant *Z. marina* meadows, this coast suffered a sharp seagrass loss at an alarming rate since 1983, as documented in the MSc thesis of Morais da Silva (Silva, 2004). By 2001 only a 50 m² patch could be seen on the aerial photos, and monitoring by the team of E. Gonçalves (ISPA) quantified an increase in this patch by only 0.001 ha (10 m²) between 2002 and 2004, and almost no natural recruitment for a decade showing

that natural recovery of the pre-existing meadow was not to be expected over the next several decades. In 2006, a consortium of institutions: the Centre of Marine Sciences of the University Algarve (CCMAR), the Institute for Nature Conservation (ICN), the Applied Psychology Institute (ISPA), the National Fisheries Institute (IPIMAR), the Spanish CSIC, and the National Oceanic and Atmospheric Administration (NOAA), achieved funding from the EU LIFE program and the private cement company SECIL to implement a marine conservation project (project BIOMARES) in the Park that included a task for restoration of the seagrass meadow of Portinho da Arrábida.

The LIFE Biomares project undertook a large-scale seagrass restoration operation in an open ocean setting. The three seagrass species that occur in the nearby Sado estuary, *Z. marina*, *Z. noltii* and *C. nodosa*, were transplanted between 2007 and 2011, creating 65 restoration plots, along a 4 km distance. During the first year, transplants came from a salvage area in the Culatra Island (Ria Formosa) where a fisheries port was being constructed over a *C. nodosa* patch. Transplants were collected with the help of a water pump that released the sediment and allowed for the transportation of large amounts of plants carried in 80 liters coolers to the Portinho da Arrábida. Plants were then attached to iron frames with raffia. During the following years this method was discontinued because the location had stronger than expected currents and the iron frames hurt the rhizomes, decreasing survivorship. Furthermore, the method was very time consuming. This was followed by seagrass transplants using sods (Fonseca *et al.*, 1998), that proved to be very effective for the establishment of the plants. Seed-releasing sacs attached to buoys set in the restoration site (Pickerell *et al.*, 2005) as well as several attempts on growing plants from seeds in laboratory and open-culturing systems (Cabaço *et al.*, 2010) proved to be ineffective to achieve seagrass cover, but are still considered useful methods for the aim of increasing the genotypic diversity of the meadow, to avoid a highly clonal setting that may be less capable of adapting to future environmental threats.

Among the three species, *C. nodosa* and *Z. marina* had better survivorship than *Z. noltii*. Transplants resulted in good adjustment (rooting and growth) of the plants to the restoration sites, and a highly successful establishment of new patches,

as 80% of all plots planted had successfully established plants by the end of the summer of 2009. However, after the very catastrophic winter of 2009/2010, by March 2010 very few seagrass shoots had survived. The winter, with several unusually strong southern storms covered the restoration sites with sand and coastal debris, blasting over the transplants. Furthermore, the water was thick brown with heavy sediment load in suspension during four months because of intensive rain and sediment run-off, possibly both from the river and also washed down the Arrábida mountain, which would have left the plants with insufficient photosynthetic irradiance for months. Furthermore, intense seagrass grazing by the fish species *Sarpa salpa* is common in this site, but this effect on the few plants that remained, probably acted against their recovery capacity, magnifying the effects of the worst winter storms in over 50 years, leaving only 5 plots after the first 3 years of restoration. The high levels of herbivory that can be caused by *Sarpa salpa* have been reported elsewhere (Cebrián and Duarte, 1998; Heck *et al.*, 2006) and are very important for further investigation as they might be contributing to the disappearance of large algal communities (e.g., kelp) from the Portuguese coast as well. The nearby natural open coast *Z. marina* populations (Ponta do Adoche and Galé coast) were also completely destroyed by the same winter storms in 2009/2010, and also suffered from intensive herbivory pressure afterwards (pers.obs.).

In September 2010, the 1st European Seagrass Restoration Workshop was held in Portinho da Arrábida, and many researchers shared common problems. Among the 10 restoration projects developed in European waters and presented in that meeting, none met expectations successfully, leading the restoration researchers to write a document with recommendations for scientists, managements and practitioners (Cunha *et al.* 2012b). The main recommendation was that, although possible to restore seagrass meadows as seen in several restoration efforts around the world, restoration efforts should always be the last resource in seagrass conservation.

In Portugal, restoration of *Z. marina* meadows will always be hard because of the shortage of donor populations. Nevertheless, the rapid growth from

massive seed recruitment of the natural meadows of *Z. marina* in the Tróia peninsula, between 2007 and 2009 (recorded during the Biomares project) is encouraging, suggesting that banks of seeds may provide a means of long-term persistence mode for this species on some sites of the Portuguese coast. The larger areas available in Portugal with the seagrasses *C. nodosa* (in Ria Formosa) but especially for *Z. noltii*, should facilitate restoration efforts involving these two species. Nevertheless, since *C. nodosa* populations have very low clonal diversity and most of the plants available in Portugal are male, restoration efforts will always be very dependent on adult plants with very limited genetic diversity; the only seed-rich, genetically diverse and similar appropriate donor site would be the Cadiz bay population in Spain (Alberto *et al.*, 2008).

Seagrass monitoring and awareness programs

As early as 2004, an European Union project, "European seagrasses: an introduction to monitoring and management" (Borum *et al.*, 2004) involved the ICN (Institute for Nature Conservation) and the University of Algarve, in the first attempts to incorporate managing and monitoring actions in Portugal, although there was no follow up. In Portugal, the first attempts for long-term monitoring of seagrasses were done in the Mondego Estuary (Baeta *et al.*, 2009) and in Tróia by Andrade (2006; 2007; 2011). Before that, information on the status and ecology of seagrasses were retained in the projects of the scientific community. The few attempts from scientists to reach coastal authorities managers have been poorly effective. Recently many seagrass monitoring programs were launched. The Center for Marine Sciences (CCMAR) at the Algarve University is leading the SeagrassNet (<http://www.seagrassnet.org>) site in Ria Formosa launched in 2009, and a COST Action (COST Action ES0906) started in 2010, named "Seagrass productivity: from genes to ecosystem management" (<http://www.seagrassproductivity.com>) that aims to develop monitoring tools and fill in gaps on the development of comprehensive best practices for integrated seagrass habitat management.

The current distributional patterns of seagrasses in Portugal were assessed from 2007 to 2010 during the LIFE Biomares

project (LIFE 06 NAT/P/192) that aimed at restoration of a seagrass meadow in the Marine Park Luiz Saldanha, on the Arrábida coast (Cunha *et al.*, 2009; Cunha *et al.*, 2012a). The discovery of recent decreasing seagrass cover or even total disappearance along the Portuguese coast highlighted the urgent need to evaluate their past versus current distribution and to evaluate more deeply the conservation status of seagrasses on the Portuguese coast.

Rooted in the LIFE Biomares project, an awareness and monitoring project was launched in 2010, Adopt-A-Seagrass-Meadow, to create a network of volunteers that will monitor and keep surveillance of seagrass sites on all Portuguese coast (www.pradariasmarinhas.com), including also many dissemination initiatives for the general public. This website holds a "library" with published and grey literature on Portuguese seagrasses (grey reports, thesis and scientific papers). The partners (already 20) commit to, twice a year, monitor their adopted meadow, to conduct awareness activities to the general public, and to promote meetings with managers and coastal authorities.

Another important monitoring program that it was expected be launched in 2011, is LTER (Long Term Ecological Research), funded by FCT (the Portuguese Foundation for Science and Technology) that awarded the University of Aveiro and the University of Coimbra a grant to set up LTER in the Aveiro lagoon, the Mondego and Mira Rivers respectively. Although these programs are not specifically aimed for seagrass monitoring, the tasks entails several monitoring actions that will promote seagrass surveillance on the sites.

Legislation for seagrass protection

The first regulation in Portugal that protected seagrasses from being destroyed was implemented in 1914, to regulate the collection of seagrasses for fertilizer (the "moliço") in Ria de Aveiro during the fish breeding period (Nobre *et al.*, 1915). This regulation was created after fishermen complained to the local government authorities that fish breeding and fisheries stocks were very affected by seagrass collection for fertilizer. Since the XIX century (Sousa, 1936) large tons of moliço used to be collected (e.g., 505.500 tons/year of "moliço" in 1889) and remarkably it was the fishermen that complained about this intensive "moliço" collection destroying fisheries and asked for the ban. They were not able to get the

ban through until 1914, because agriculture at the time was a more important economic activity than fisheries. It is interesting to read in a old magazine from 1915 (Nobre *et al.*, 1915) that "the collection of seagrasses during the fish breeding period contributes to the destruction of the shelter provided by the plants,...sea bass the most voracious fish, completely devastates fingerlings of all species that do not have a place to hide,...seagrasses are also very important for other small animals that are fish feed". Even with the ban, collection of "moliço" during this period (1920 to 1931) was estimated to be 400.000 tons per year. Seagrasses were collected for fertilizer in other regions of Portugal such as the Óbidos Lagoon and Ria Formosa (Peixoto, 1903).

Although the understanding about the seagrass importance as marine habitat was at least as old as these references above, seagrass habitat received little attention from the public and coastal manager authorities in Portugal. Several international and national regulations that aim at marine and coastal habitat protection have been signed by the Portuguese Government, but despite the good intentions, little has been done to protect seagrass habitat. Recently (2007), a small fishing harbor was built in Ria Formosa over a *C. nodosa* meadow (that was used as salvage area for the Biomares restoration project), and in 2010, despite several warnings by researchers, the only *Z. marina* meadows existent in the west area of Ria Formosa (Fuseta channel) were destroyed by the channel dredging and the opening of an inlet in the barrier islands. Sailing boats still anchor freely over *Z. marina* and *C. nodosa* meadows at Ria Formosa, and in this Natural Park the only human usage authorized in the "Total Protection Reserve Zoning", is clam digging, which impact *Z. noltii* meadows existing in the area. In 2009 a ferry boat pier was constructed over a *Z. marina* meadow in the Sado Estuary and, fishing vessels using highly impacting fishing gear ("ganchorra") are still operating in areas with very important *Z. marina* populations, such as the Galé coast.

Nevertheless, the three species of seagrasses present in Portugal are listed as vulnerable and in critical conditions in the OSPAR Convention (EUNIS Code: A2.611, A5.533, A5.531, A5.5312, A5.53131 for *Z. marina* e *Z. noltii*, and A5.53132 for *C. nodosa*). The OSPAR Convention is the current legal instrument

guiding international cooperation on the protection of the marine environment of the North-East Atlantic. Furthermore, *Z. marina* and *C. nodosa* are in the list of strictly protected flora species of the Bern Convention (Appendix I) in force since March 2002 (Portugal ratified the Bern Convention in 1989, Decreto-Lei n°316/89), as well as on the vulnerable flora species list of UNEP-WCMC.

One of the most important regulations of the European Union, the Habitats Directive (Directive 92/43/CEE) ratified by Portugal in 1999, despite not protecting the species itself (only *Posidonia oceanica* is on the species list as priority species) provides a list of European habitats that are of European interest to protect. Several habitats are coincident with seagrass habitat. These are Habitat 1110 Sandbanks which are slightly covered by sea water all the time; Habitat 1130 Estuaries; Habitat 1150 Coastal lagoons; Habitat 1170 Reefs, Habitat 1160 Large shallow inlets and bays, and all of them include several references to the presence of European seagrasses. Furthermore, the Natura Network Sectorial Plan (RCM n°115 – A/2008; D.R. n°139, Série I, 21 July) states specifically that *C. nodosa* banks (1110pt2), *Z. marina* (1110pt3), *Z. noltii* (1110pt4), are subtypes with high sensitivity with small distributional areas subject to relevant threats and in need for conservation actions. All these habitats are subject to environmental impact assessment and need permits from the National Nature Conservation Institute for any activity that could impact the habitat.

Portugal designated as Ramsar sites the Sado Estuary, the Ria de Alvor and Castro Marim (Guadiana Estuary saltmarshes), thereby implying that these wetland habitats are protected and the state commits to develop actions to protect them.

The most powerful regulation that should afford protection to European seagrasses is the Water Framework Directive (WFD; 2000/60/EC). The European Water Framework Directive (WFD) establishes a framework for the protection of groundwater, inland surface waters, estuarine waters, and coastal waters (Borga, 2005). The WFD constitutes a new view of the water resources management in Europe because, for the first time, water management is based mainly upon biological and ecological elements, with ecosystems being at the centre of management decisions to prevent further

degradation and to improve the ecosystem status by 2015. The biological elements to be considered are phytoplankton, macroalgae, benthos and fishes (the latter only in transitional waters). For angiosperms, the most important parameter is distribution extension and variation in time and space (WFD Guidance Document).

Other marine conservation initiatives that should afford protection to marine habitats are the Marine Strategy Directive (EU 2008) and the Biological Diversity Convention (CDB/ UNEP/CBD/494/2) that urged for a Global Biodiversity Monitoring, which were also signed by the Portuguese government. Although under the CBD no specific monitoring is required, the state of the marine environment will be evaluated through a global assessment, based on regional assessments. Many European legislation actions advise on monitoring plans that include seagrasses. The European Environment Agency (EEA) works at the moment with two types of actions: *Increasing efficiency of monitoring* by simplifying, streamlining and making comparable existing marine monitoring data and *Convergence of assessments* by leading work towards the development of a common set of pan-European marine indicators to be complemented regionally, in order to support the implementation of the European Marine Strategy (EMS) and proposed Marine Strategy Directive's (MSD) as well to further develop its own pan-European marine assessments. Other national legislation (e.g. Regulation for nitrate release to the environment; Regulation for sand extraction operation, the Watershed National Plan) are in place, and if enforced could strongly contribute to the protection of seagrass habitat.

Conservation challenges

The Portuguese coast is the northern and western limit for *C. nodosa*, and the current known southern distributional limit for *Z. marina*. Because of this these populations are especially vulnerable to global climate change (Short and Neckles, 1999). It is also the middle of the distributional range for *Z. noltii*, a mostly intertidal species ranging from Mauritania (Cunha and Araújo, 2009), to the southern fjords of Norway (den Hartog, 1970). Among all four native seagrass species of Europe, only the Mediterranean endemic *Posidonia oceanica* is not present in Portugal, making this coastline particularly unique in terms of European seagrass biodiversity. The Portuguese meadows are

highly unique, genetically differentiated from all other worldwide populations surveyed in Europe and throughout the rest of the world. Signatures of past climatic events, possibly interacting with local adaptation traits for these seagrass species with contrasting environmental affinities, have resulted in a unique population genetic constellation of the seagrasses along the Portuguese coast (Olsen *et al.*, 2004; Coyer *et al.*, 2004; Diekmann *et al.*, 2005; Alberto *et al.*, 2008). This situation confers the Portuguese seagrass population a higher level of susceptibility, and enforces the need for implementing conservation efforts.

Seagrass meadows are declining around the world at an unprecedented rate, suggesting a global crisis, yet most decline references are from the most developed countries (Orth *et al.*, 2006; Duarte *et al.*, 2008; Hughes *et al.*, 2009). Reported losses (29% of the maximum area measured; Waycott *et al.*, 2009), probably represent a underestimated fraction of those that have occurred, many losses remain unreported, and actual losses may never be known because most will disappear without ever having been reported to have occurred (Duarte, 2002). Furthermore, it appears that, the rate of loss is accelerating, from 4.3% between 1970 and 1980 to 8.4% in the period from 1990 to the 2000s (Waycott *et al.*, 2009). Striking seagrass losses have been documented in North America, Europe and Australia (Orth *et al.*, 2006; Waycott *et al.*, 2009). Major gaps in knowledge of seagrass cover and distribution exist for West Africa (Duarte *et al.*, 2008; Cunha and Araújo, 2009) northeast South America, the northwest Pacific and the tropical Indo-Pacific (from East Africa to Hawaii) where seagrasses are widespread and abundant (Waycott *et al.*, 2009). In southern Europe and the Mediterranean, information on seagrass distribution and abundance trends are scarce (Cunha *et al.*, 2011). Most threats leading to the decreasing patterns observed worldwide (Orth *et al.*, 2006; Duarte *et al.*, 2008; Waycott *et al.*, 2009) are the same existing on the Portuguese coast (Table 1) and have very diverse origins, with solutions that are common across a worldwide scale yet requiring local scale actions (Table 2).

The previous chapter shows that there is enough legislation and a comprehensive body of plans and strategies that, if implemented, should afford the necessary protection levels needed for these coastal

habitats to be preserved. Nevertheless, besides the lack of information and awareness, one of the biggest challenges for seagrass conservation in Portugal is the harmonization and collaboration between the several entities that manage the coast. Estuaries, one of the most ecological sensitive areas of the coast, and main habitat for seagrasses, were managed by IPTM (Ports and Maritime Transportation Institute). The mission of this institute is to build ports, harbors, marinas, dredging of navigation channels, and all their activities impact on seagrass habitat. Only very recently is the institute becoming slightly sensitive to ecological issues, due to international legislation pressures, but has little tradition in incorporating habitat protection issues into their policies and actions. Another institute that managed the coastal areas is INAG (National Institute for the Water) that oversees coastal water quality including beaches, regulates the constructions outside the jurisdiction of IPTM, and the building of river dams. INAG recently launched several plans that aim (among other) to confer protection to coastal habitats and contribute to the sustainable use of the coastal resources, (i) the POC (Coastal Zones Management Plan); (ii) the POEM (National Maritime Spatial Planning) (iii) the ICZM (National Strategy for Integrated Coastal Zone Management), (iv) the National Strategy for the Seas (RCM163/2006).

In 2009 a new coastal management authority was created the ARH (Hidrological Regional Administration), but besides being responsible for giving permits to coastal construction, it is not very clear yet what exactly the role of this entity is. The Institute of Nature Conservation and Biodiversity managed the areas that are classified as Parks and Reserves and the Natura 2000 network, which includes at least 8 sites with seagrasses. The Defense Ministry through the "Capitanias do Porto" is the entity responsible for law enforcement in coastal areas, which collaborates with SEPNA (GNR), a police body that complements these actions on their environmental concerns, although they are not very effective on coastal areas as they do not yet take action in the sea.

Table 1. Threats to seagrass habitats by location

Location	Threats
Ria de Aveiro	Coastal construction and dredging operations (Silva <i>et al.</i> , 2004)
Mondego River	Low water quality (Cardoso <i>et al.</i> , 2004a,b)
Óbidos Lagoon	Dredging operations (Carvalho <i>et al.</i> , 2005); Low water quality from urban sewage and agriculture and industry runoff (Carvalho <i>et al.</i> , 2006)
Tagus River	Clam digging (Cunha <i>et al.</i> , 2011a)
Arrábida *	Boat anchoring; clam trawling; collection of clams with scuba gear (Silva, 2004)
Sado River	Coastal construction; industrial pollution, fishing with nets (Cunha <i>et al.</i> , 2009; Cunha <i>et al.</i> , 2011a)
Ponta do Adoche	Coastal construction (Andrade 2006, 2007, 2011); herbivory (Cunha <i>et al.</i> , 2011b)
Galé	Clam trawling (Cunha <i>et al.</i> , 2011a)
Mira River	Watershed malpractices (sedimentation); clam and bait digging; fish herbivory (Cunha <i>et al.</i> , 2011a)
Ria de Alvor	Coastal construction; bivalve aquaculture establishments; poor water quality; clam collection (Cunha <i>et al.</i> , 2011a)
Arade River	Coastal construction; channel dredging (Cunha <i>et al.</i> , 2011a)
Alporchinhos Beach	Beach filling (Cunha <i>et al.</i> , 2011a)
Marinha Beach	Beach filling (Cunha <i>et al.</i> , 2011a)
Santa Eulália Beach	Beach filling; trampling (Cunha <i>et al.</i> , 2011a)
Arrifes Beach	Beach filling (Cunha <i>et al.</i> , 2011a)
Ria Formosa	Coastal construction; channel dredging and inlet opening (Cunha <i>et al.</i> , 2011a); natural sand bar movements (Cunha <i>et al.</i> , 2005; Vila - Concejo <i>et al.</i> , 2002); clam farming (Guimarães <i>et al.</i> , 2011); clam and bait collection (Alexandre <i>et al.</i> , 2005); (urban sewage and agriculture runoff Cabaço <i>et al.</i> , 2007; 2008; Newton <i>et al.</i> , 2003; 2005); free boat anchoring (Cunha <i>et al.</i> , 2011a)
Guadiana River	Coastal construction; channel dredging; clam and bait collection; channel erosion by boating; and sediment suspension (Cunha <i>et al.</i> , 2011a)

* threats discontinued after the marine park implementation

Table 2. Threats to seagrass habitats and management needs

Factors	Threats	Management needs
Habitat destruction	Construction of marinas, ports, other coastal construction; channel dredging; beach filling	Law enforcement (national and international) Public and coastal management institutions awareness
Fragmentation	Anchoring and boat propeller scars; boat propellers; clam and bait collection	Permanent buoys; better channel signalization; public information with boat license; policy law enforcement
Sedimentation	Dredging operations Bad watershed soil practices Winter storms	Improvement o water drainage practices (agriculture and natural barriers) Better practices in dredging activities – observer on board Implementation of Water Framework Directive
Eutrophication	Urban and industrial sewage Bad watershed soil practices	Implementation of Water Framework Directive Public and coastal management institutions awareness
Habitat destruction by fishing and clam collection	Clam trawling; clam and bait collection; beach seining;	Clam trawling banning from seagrass habitats; create management plan for clam/bait collection areas, public awareness programs; implementation of clam hatcheries and bait farms with progressive abandonment of collection of this species from the wild Law enforcement
Algae blooms	<i>Ulva</i> spp. and other fast growing algae Exotic species	Improvement of water drainage practices (agriculture and natural barriers) Implementation of Water Framework Directive Implementation of management plans for exotic species Public awareness programs

Needless to say that there is little interaction between all these institutions in what concerns seagrass habitat protection. The universities and research centers have most information on seagrass ecology and coastal impacts, but only recently is a more interactive integration developing among such institutions and universities. This was the main task of the Marbis Project (Marine Biodiversity Information System) coordinated by the Task-group for Maritime Affairs - Portugal (ENAM - Defense Ministry). Coastal managers and politicians seldom read scientific papers and researchers should, therefore, make an effort to publish layman reports more often and disseminate information produced in a more effective way. In fact, the worse threat for seagrass conservation might be the lack of information that all the institutions above have about the existence of seagrass habitat, its importance for coastal ecosystem health, its distribution and poor conservation status. Furthermore, there is little awareness of the levels of protection, if any, afforded by international and national laws and regulations in reality. Government institutions in Portugal are undergoing major changes, which entail the disappearance and fusion of many of the previous institutions that have jurisdiction over the seas and coast. While the goal behind these changes is mainly economical, this could be a chance to develop a more integrated view of seas affairs. Nevertheless, a lengthy period of re-organization and a fresh start of the new institutions could bring a more stressful time for marine conservation in general and seagrass habitat in particular.

Acknowledgments

This research was funded by the European commission through the LIFE Biomares project (LIFE 06 NAT/P/192).

References

- Alberto FS., Massa P, Manent E, Diaz-Almela S, Arnaud-Haond CM, Duarte Serrão EA, 2008. Genetic differentiation and secondary contact zone in the seagrass *Cymodocea nodosa* across the Mediterranean - Atlantic transition region. *J Biogeogr* 35: 1270 - 1294.
- Alexandre A, Santos R, Serrão EA, 2005. Effects of clam harvesting on sexual reproduction of the seagrass *Zostera noltii*. *Mar. Ecol. Prog. Ser.* 298: 115-122.
- Andrade F, 2006. Relatório do Programa de Monitorização Ambiental do projecto da Marina e novo Cais dos "ferries" do Troiaresort. Instituto do Mar, Lisboa, Portugal.
- Andrade F, 2007. Relatório do Programa de Monitorização Ambiental do projecto da Marina e novo Cais dos "ferries" do Troiaresort. Instituto do Mar, Lisboa, Portugal.
- Andrade F, Ferreira A, 2011. A method for monitoring shallow seagrass meadows (*Zostera* spp.) using terrestrial oblique large-scale photography. *Aquat. Bot.* 95: 103 - 109.
- Baeta A, Valiela I, Rossi F, Pinto R, Richard P, Niquil N, Marques JC, 2009. Eutrophication and trophic structure in response to the presence of the eelgrass *Zostera noltii*. *Mar. Biol.* 156: 2107 - 2120.
- Borja A, 2005. The European water framework directive: a challenge for nearshore, coastal and continental shelf research, *Cont Shelf Res* 25: 1768 - 1783.
- Borum J, Duarte CM, Krause-Jensen D, Greve TM, 2004. European seagrasses: an introduction to monitoring and management. M&Ms, EVK3-CT-2000-00044. <http://www.seagrasses.org>. Acesso: 4 Novembro 2011.
- Cabaço C, Machás R, Santos R, 2007. Biomass-density relationships of the seagrass *Zostera noltii*: a tool for monitoring anthropogenic nutrient disturbance. *Estuar Coast Shelf Sci* 74: 557 - 564.
- Cabaço S, Machas R, Vieira V, Santos R, 2008. Impacts of urban wastewater discharge on seagrass meadows (*Zostera noltii*). *Estuar Coast Shelf Sci* 78: 1 -13.
- Cabaço S, Santos R, 2010. Reproduction of *Zostera marina* at the species southern distributional limit in the eastern Atlantic. *Mar Ecol* 31: 300 - 308.
- Calado G, and Duarte P, 2000. Modelling growth of *R.cirrhusa*. *Aquat Bot* 68:29 - 44.
- Cardoso PG, Pardal MA, Lillebø AI, Ferreira SM, Raffaelli D, Marques JC, 2004a. Dynamic changes in seagrass assemblages under eutrophication and implications for recovery. *J Exp Mar Biol Ecol* 302:233 - 248.

- Cardoso PG, Pardal MA, Raffaelli D, Baeta A, Marques JC, 2004b. Macroinvertebrate response to different species of macroalgal mats and the role of disturbance history. *J Exp Mar Biol Ecol* 308: 207 - 220.
- Carvalho S, Gaspar MB, Moura A, Vale C, Antunes P, Gil O, Fonseca LC, Falcão M, 2006. The use of marine biotic index AMBI in the assessment of the ecological status of the Óbidos lagoon (Portugal). *Mar Pollut Bull*, 52: 1414 - 1424.
- Carvalho S, Moura A, Gaspar MB, Pereira P, Cancela da Fonseca L, Falcão M, Drago T, Leitão F, Regala J, 2005. Spatial and inter-annual variability of the macrobenthic communities within a coastal lagoon (Óbidos lagoon) and its relationship with environmental parameters. *Acta Oecologica* 27: 143 - 159.
- Cebrián J, Duarte CM, 1998. Patterns in leaf herbivory on seagrasses. *Aquat Bot* 60: 67 - 82.
- COST Action 2010. Action ES0906: Seagrass productivity: from genes to ecosystem management. <http://www.seagrassproductivity.com/pm.cgi?action=show&temp=homepage> Acesso: 4 Nov 2011.
- Coyer JA, Diekmann OE, Serrão EA, Procaccini G, Milchakova NGA, Pearson S WT, Olsen JL, 2004. Population genetics of dwarf eelgrass *Zostera noltii* throughout its biogeographic range. *Mar Ecol Prog Ser* 281: 51 - 62.
- Cunha AH, Assis J, Serrão E, 2011. Seagrasses in Portugal: a most endangered marine habitat. *Aquatic Botany* (online 10.1016/j.aquabot.2011.08.00)
- Cunha AH, Erzini K, Serrão E, Gonçalves E, Gonçalves V, Henriques M, Guerra M, Duarte CM, Marba N, 2012a. Biomares a Life project to restore and manage the biodiversity of the marine park site Arrábida-Espichel (PTCON0010) LIFE06 NAT/P/000192. *J of Coast Conserv* (accepted).
- Cunha AH, Marbá N, van Katwijk M, Pickerell C, Henriques M, Bernard G, Ferreira A, Garcia S, Garmendia JM, Manent P, 2012b. Changing paradigms in seagrass restoration: conclusions and recommendations from the European Seagrass Restoration Workshop, *Rest Ecol* (accepted).
- Cunha AH, Assis J, Serrão E, 2009. Estimation of available seagrass meadow area in Portugal for transplanting purposes. *J Coast Res* 56: 1100 - 1104.
- Cunha AH, Santos R, Gaspar AP, Bairros M, 2005. Seagrass landscape-scale changes in response to disturbance by barrier - islands dynamics: a case study from Ria Formosa (South of Portugal). *Estuar Coast Shelf Sci* 64: 636 - 644.
- Den Hartog C, 1970. The seagrasses of the world. *Verh. Kon. Ned. Akad. Wet. Afd. Natuurkd.* 59: 1 - 275.
- Diekman OE, Coyer JA, Ferreira J, Olsen JL, Stam WT, Pearson GA, Serrão, EA, 2005. Population genetics of *Zostera noltii* along the west Iberian coast: consequences of small population size, habitat discontinuity and nearshore currents. *Mar Ecol Prog Ser* 290: 89 - 96.
- Duarte CM, 2002. The future of seagrass meadows. *Environ Conserv* 29: 192 - 206.
- Duarte CM, Borum J, Short F, Walker D, 2008. Seagrass ecosystems: their global status and prospects. Chapter 18: In *Aquatic Ecosystems*: ed. N. Polunin. Published by Cambridge University Press. Foundation for Environmental Conservation 281 - 294.
- Fonseca, M.S., Kenworthy, W.J., Thayer, G.W., 1998. Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters. National Marine Fisheries Service, NOAA Coastal Ocean Program, Decision Analysis Series.
- Heck Jr KL, Valentine JF, 2006. Plant-herbivore interactions in seagrass meadows. *J Exp Mar Biol Ecol* 330: 420 - 436.
- Hughes AR, Williams SL, Duarte CM, Heck k LJr, Waycott M. 2009. Associations of concern: declining seagrass and threatened dependent species, *Front Ecol Environ* 7: 241 - 246.
- Guimarães H, Cunha AH, Nzinga R, Marques J, 2011. The distribution of seagrass (*Zostera noltii*) in the Ria Formosa lagoon system and the implications of clam farming on its conservation. *J Nat Conserv* (published online <http://dx.doi.org/10.1016/j.jnc.2011.07.005>).

- Martins I, Neto JM, Fontes MG, Marques JC, Pardal MA, 2005. Seasonal variation in short-term survival of *Zostera noltii* transplants in a declining meadow in Portugal. *Aquat Bot* 82: 132 - 142.
- Newton A, Icely JD, Falcão M, Nobre A, Nunes JP, Ferreira JG, Vale C, 2003. Evaluation of eutrophication in the Ria Formosa coastal lagoon, Portugal, *Cont Shelf Res* 23: 1945 - 1961.
- Newton A, Mudge SM, 2005. Lagoon-sea exchanges, nutrient dynamics and water quality management of the Ria Formosa (Portugal). *Estuar. Coast Shelf Sci* 62: 405 - 414.
- Nobre A, Afreixo, J, and Macedo J, 1915. *A Ria de Aveiro*, Relatório oficial do regulamento da Ria de 28 de Dezembro de 1912. Imprensa Nacional, Lisboa. 197 p.
- Olsen JL, Stam WT, Coyer JA, Reusch TBH, Billingham M, Bostrom C, Calvert E, Christie H, Granger S, La Lumiere R, Milchakova N, Oudot-Le Secq MP, Procaccini G, Sanjabi B, Serrão E, Veldsink J, Widdecombe S, Wyllie-Echeverria S, 2004. North Atlantic phylogeography and large-scale populations differentiation of the seagrass *Zostera marina* L. *Mol Ecol* 13: 1923 - 1941.
- Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck KL, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Waycott M, Williams SL, 2006. A global crisis for seagrass ecosystems. *Bioscience* 56: 987 -996.
- OSPAR Commission, 2008, OSPAR List of Threatened and/or declining Species and Habitats (Reference Number: 2008 - 6.) <http://www.ospar.org/eng/html/welcome.html>. Acesso 3 Novembro 2011.
- Peixoto R, 1903. Os palheiros do litoral, Portugália I. Porto. Portugal. 79 - 96.
- Pickerell CH, Schott S, Wyllie-Echeverria S, 2005. Buoy deployed seeding: demonstration of a new eelgrass (*Zostera marina* L.) planting method. *Ecol Eng* 25: 127 - 136.
- Salgado P, Santos R, 1985. Estudo da distribuição da componente macrofitobentónica da Lagoa de Albufeira (Relatório de Síntese). Laboratório Nacional de Engenharia e Tecnologia Industrial, Ministério da Indústria e Tecnologia Industrial, Sacavém, 131 - 149.
- Santos R, Silva J, Cunha A, 2004. Relatório final do estudo de caracterização dos bancos de fanerogâmicas e macroalgas no estuário do Rio Arade. Centre of Marine Sciences, University of Algarve, Faro, Portugal.
- Short FT, Neckles HA, 1999. The effects of global climate change on seagrasses. *Aquat Bot* 63: 169 - 196.
- Silva JF, Duck RW, Catarino JB, 2004. Seagrass and sediment response to changing physical forcing in a coastal lagoon. *Hidrol an Heath Syst Sci* 8: 15 - 159.
- Silva JAM, 2004. Estudos iniciais para a recuperação da população de fanerogâmicas marinhas do Parque Marinho da Arrábida, Setúbal, Portugal. Master thesis, University of the Algarve, Portugal.
- Sousa TT, 1936. Os moliços: Flora dos moliços; localização de produção das várias espécies. Arquivo do distrito de Aveiro, II, 177 - 190.
- Vila - Concejo A, Matias A, Ferreira A, Ferreira Ó, Duarte C, Dias JMA, 2002. Recent evolution of the natural inlets of a barrier island system in Southern Portugal. *J of Coast Res* 36: 741 - 752.
- Waycott M, Duarte CM, Carruthers TJB, Orth RJ, Dennison, WC, Olyarnik S, Calladine A, Fourqurean JW, Heck KL, Hughes AR, Kendrick GGA, Kenworthy WJ, Short FT, Williams SW, 2009. Accelerating loss of seagrass across the globe threatens coastal ecosystems. *Ecology* PNA 1 - 5.