Ecosystem Overview of the European Regional Seas

Annex 3

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AUTHORS (arranged in alphabetical order)

Olivier Beauchard (NIOZ), Torsten Berg (MariLim), Kemal Can Bizsel (DEU), Nihayet Bizsel (DEU), Ángel Borja (AZTI), Martynas Bucas (KUCORPI), Laura Carugati (CONISMA), Tanya Churilova (MHI-NASU), Sabine Cochrane (APN), Roberto Danovaro (CONISMA), Javier Franco (AZTI), Karin Fürhaupter (MariLim), Gokhan Kaboglu (DEU), Stelios Katsanevakis (JRC), Olga Kryvenko (MHI-NASU), Sally Little (UHULL), Krysia Mazik (UHULL), Snejana Moncheva (IO-BAS), Mairi Pantazi (HCMR), Nadia Papadopoulou (HCMR), Joana Patricio (JRC), Chiara Piroddi (JRC), Ana M Queirós (PML), Silje Ramsvatn (APN), Chris Smith (HCMR), Oihana Solaun (AZTI), Kremena Stefanova (IO-BAS), Heliana Teixeira (JRC), Laura Uusitalo (SYKE), Maria C. Uyarra (AZTI), Anastasija Zaiko (KUCORPI).

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1. Preface

The Annex 3 of Deliverable 1.4. - Report on SWOT analysis on monitoring provides a detailed description of the four marine regions (i.e. the Mediterranean Sea, the Baltic Sea, the Black Sea and the North Eastern Atlantic, including the waters surrounding the Azores, Madeira and the Canary Islands) (Figure 1), that have been covered in the DEVOTES Catalogue of Monitoring Networks (Annex 1), and therefore, over which the Gap and SWOT analysis have been carried out.

![Figure 1. Marine regions used in the DEVOTES GIS-based interactive pdfs.](image)

However, for practical reasons (e.g. certain ongoing monitoring programmes cover OSPAR/ICES areas that are not covered by the MSFD, literature review often have a wider geographical scope) the ecosystem overviews at times may cover non-EU marine waters. For example, the North Eastern Atlantic covers the North-East Atlantic Ocean, the waters around Azores, Madeira, and the Canary Islands, as well as additional OSPAR areas (Region I).

In this ecosystem overview, we have additionally included the Sea of Marmara because this non-EU waters are the connection between the Mediterranean and the Black Sea (for details see section 2.3.)

The overviews are carried out by Regional Sea and cover at least the following aspects: key characteristics and habitats, key biodiversity components, and human uses, pressures and impacts.
2. Ecosystem Overview per Regional Sea

2.1. North Eastern Atlantic

Introduction

For the purpose of providing an ecosystem overview of the North Eastern Atlantic, the five regions of the OSPAR Convention (Convention for the Protection of the Marine Environment of the North-East Atlantic) (i.e. Arctic Waters (Region I), Greater North Sea (Region II), Celtic Seas (Region III), Bay of Biscay and Iberian Coast (Region IV) and Wider Atlantic (Region V), which encompasses the Azores islands) (Figure 2) and the European part of the Macaronesia (which in addition to Madeira and Canary Archipelagos, it overlaps with OSPAR in the sense that it also includes the Azores) have been considered. Despite the Arctic Waters (Region I) are not covered by the MSFD, these have been included in the ecosystem overview as several monitoring programmes, carried out in the context of OSPAR and ICES, have been considered in the catalogue.

The North Eastern Atlantic includes a diverse range of environmental conditions and different ecosystems, which vary in diversity and sensitivity. These, together with the high coastal population densities, play a key role in the types and patterns of human activities in the area, and their impacts on the marine environment. In addition, impacts of climate change are becoming evident in the North Eastern Atlantic, especially in the northern areas. Therefore in order to manage, monitor and assess the many pressures on the diverse ecosystems of the North Eastern Atlantic, Contracting Parties of the OSPAR Convention cooperate through monitoring and assessment activities at a regional level. The overview of the current knowledge on trends in pressures and impacts, and the quality status of the North Eastern Atlantic is summarised in the OSPAR Quality Status Reports (OSPAR, 2000 and 2010), which are the main documents from which information has been extracted for developing the present Annex to DEVOTES Deliverable D1.4. These summary reports are based on collective monitoring and data collection undertaken by OSPAR countries, relevant scientific literature and information on sources, such as the International Council for the Exploration of the Sea (ICES) and organisations within the European Union (e.g., EUROSTAT and the European Environment Agency). Information regarding Regions I-IV included in this report integrates material from the ecosystem overview performed under DEVOTES Deliverable 3.1. (Teixeira et al., 2014).
Figure 2. The OSPAR Convention area is divided into five Regions for the purpose of assessment (source: OSPAR, 2010).

Key characteristics and habitats

The northern part of the North Eastern Atlantic, especially Region II (i.e. areas IVa, b, c of the North Sea and VIIId, e, h of the English Channel) is relatively shallow (Figure 3). For example, the average depth of the English Channel is 63 m, reaching only 174 m at its deepest point. Furthermore, most of the Celtic Sea (Region III) lies above the continental shelf, with depths ranging between 90 and 100 m, which contrasts with the Norwegian Sea (Region I), where the average depth is around 2000 m.

The major topographical features in the North Eastern Atlantic are the Mid-Atlantic Ridge (the Azores and Iceland are its highest points) and the Greenland-Scotland Ridge (which separates the Atlantic Basin from the Nordic Seas). Water depths range from around 5000 m on either side of the Mid-Atlantic Ridge and Macaronesia, to less than 200 m on the continental shelf along the European coast. In some places seamounts occur as submerged single mountains or chains of mountains along the ocean floor, especially close to Macaronesian islands. The most extensive continental shelf areas are found in the North Sea and Celtic Seas. Other shelf seas are found around Iceland, Greenland and in the Barents Sea. However, along

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1 Reference to subdivisions or “areas” (e.g. area IVa of the North Sea) refer to those provided by ICES (International Council for Exploration of the Seas) and are used throughout the text to provide examples. The use of the “Region” term refers to the OSPAR regions.
the Iberian coast, Macaronesia and the west of Norway the continental shelf breaks quite close to the coastline and rather steeply.

![Figure 3. Water depth (m) in the North Eastern Atlantic (source: OSPAR, 2010).](image)

The general ocean circulation in the North Eastern Atlantic is dominated by the north-eastward extension of the Gulf Stream, known as the North Atlantic Current (Figure 4). This is part of the global ocean circulation – the ‘Great Ocean Conveyor’ – which transports relatively warm, nutrient-rich and oxygen-rich water from the north-western Atlantic towards the European coasts. One of the factors driving this flow in the North Eastern Atlantic is the cooling and sinking of this water in the polar region, from where it flows southward at depth. This general pattern of northward flow at the surface and southward flow at depth can be affected by freshwater inputs from the European landmass. Inter-annual variations in the North Atlantic Current control the temperature and salinity regimes in the area.

Both the bathymetry of the seabed (Figure 3) and the ocean circulation (Figure 4) exert a strong control on the ecosystems of the area, including the occurrence of species and habitats and their interactions. The distinction between waters that are mixed (where most conditions are the same from the surface to the seabed) and waters that are stratified (where conditions vary stepwise with depth) is important biologically, influencing the distribution of habitats as well as the structure of pelagic and benthic...
ecosystems. The areas where these water types meet (‘fronts’) are regions of intense biological activity and often provide productive fishing grounds. In addition, the western part of the Iberian Peninsula and the area between Canary Islands and African coast experience upwelling events, which support specific habitats and important fishing resources.

During winter time most of the North Eastern Atlantic is well-mixed to depths of up to 600 m and there is a deep, permanent thermocline in deep oceanic waters. In spring, a strong vertical temperature gradient develops that separates warm surface water from cold deeper water. In shallow shelf areas, strong tidal currents keep the water mixed throughout the year. For example, the Irish Sea (Region III of OSPAR and area VIIa of ICES), which is predominantly shallow (< 100 m), is characterised by large tidal energy inputs. In other areas, like the Bristol Channel (Region III), where the second largest tidal range in the world (14 m) can be observed, the tidal input affects not only the water mix, but also the underlying habitats.

The coastline of the North Eastern Atlantic encompasses a great diversity of habitats, including rocky shores, marshes, estuaries, mud flats and sand flats in intertidal areas, etc. Similarly, coastal benthic communities of subtidal areas comprise both rocky and soft sediment communities. For example, the
southern parts of Region I are dominated by sand-dwelling communities. The English Channel, most of the Celtic Sea, and low energy environments of the Irish Sea, all in Region II, are also characterized by fine muds, sandy muds, sand and gravel.

In contrast, bedrock outcrops (e.g. North Channel, south-west and west of Isle of Man) and bedrock platforms with kelp (e.g. Bristol Channel) can also be found in the North Eastern Atlantic. The seabed at the Bristol Channel is varied. Extensive rock habitats are present in most of the inshore areas and further offshore along the northern half of the west coast and the north coast of Scotland (depth typically ranging from 200 m to >2000 m). Sponge and turf communities as well as kelp and seaweed communities can be found. Additionally, large areas of mixed sediments and coarse to muddy sands are present in this region. In the Bristol Channel, reef forming species like Ross worm (*Sabellaria spinulosa*) and blue mussel (*Mytilus edulis*), maerl (*Phymatoliton calcareum, Lithothamnion corallioides*) are common. In the Bay of Biscay canyons, seamounts, banks, pockmarks or ridges, channels, etc. can all be found. In this region (Region IV), deep-sea sponge aggregations, coral gardens and cold-water corals are some of the occurring habitats.

Offshore areas of the North Eastern Atlantic can be dominated by fine sands with brittle-stars (e.g. Region I) or encompass different habitats such as sand, mixed and coarse sediments (Regions II-IV). Macaronesian habitats, especially those from deeper parts, are less known and mapped. In addition to benthic habitats, pelagic habitats need consideration.

Several European projects have advanced in mapping seafloor habitats. Hence, EUSeaMap (Mapping European seabed habitats, [http://jncc.defra.gov.uk/page-6266](http://jncc.defra.gov.uk/page-6266)) is the results of MESH and BALANCE projects in the northern part of the Atlantic, whilst MeshAtlantic project ([www.meshatlantic.eu](http://www.meshatlantic.eu)) has mapped the southern part.

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**Key biodiversity components**

The organisms living in the North Eastern Atlantic area belong to a wide range of taxonomic and ecological groups. A recent publication (Narayanaswamy et al., 2013) suggests that there are more than than 26,000 species for all European Seas (excluding bacteria and viruses), of which around 16,000 are present on what they call the Western European margin (which highly correspond with the North Eastern Atlantic). However, organisms have restricted distributions, and the biogeographical regions give distinct characteristics in terms of biodiversity to various parts of the area. Knowledge on the different taxonomic groups varies across the different European seas; for the North Eastern Atlantic there is a good knowledge of some invertebrate groups (e.g. crustaceans and bryozoans) but limited knowledge on prokaryotic biodiversity (i.e. Bacteria and Archaea). In this section, a general description of the most important groups
(i.e. microorganisms, phytoplankton, zooplankton, benthic organisms, fish, marine reptiles, birds and mammals) is provided to deliver an overview of the different biodiversity components in the North Eastern Atlantic.

**Non phothosynthetic microorganisms**

Microorganisms, principally bacteria (but also yeasts, fungi and viruses), are constituents of the plankton as well as of the benthos. Planktonic bacterial production in the open sea is related to primary production and the abundance of bacteria increases following phytoplankton blooms.

In spite of their importance in the biogeochemical processes, ongoing monitoring programmes of microorganisms are rarely included in the North Eastern Atlantic.

**Phytoplankton**

Phytoplankton biomass shows considerable spatial variability in the North Eastern Atlantic region. In this area, plankton have a strong seasonal cycle, typical of temperate latitudes, with periods of high (often in spring) and low (often in winter or late summer) abundance or biomass. The spring bloom is generated mainly by diatoms (e.g., genera such as *Chaetoceros*, *Thalassiosira*, *Skeletonema*, *Rhizosolenia*, *Guinardia* and *Pseudo-nitzschia*; O’Brien et al., 2012) and are often closely linked with the developing water stratification). In the wider Atlantic (south of lat. 40° N), however, the biomass is lower and less variable throughout the seasons since the upper water column stays stratified throughout the year.

During summer months, recycling of nutrients occurs and other algal groups such as the dinoflagellates (e.g., *Ceratium*, *Prorocentrum*, *Protoperi dinium*, *Gymnodinium* and *Karenia*, O’Brien et al., 2012) dominate the phytoplankton. Diatoms may return again in the late autumn as stratification breaks down and nutrients are again mixed into surface waters.

A wide diversity of different phytoplankton species is found in the North Atlantic, with around 300 species in the Arctic and around 1000 in the Bay of Biscay and Iberian Coast subregion. However, it has to be noted that many species of phytoplankton have not yet been described. Total annual production of phytoplankton varies also from region to region, the highest being on the Galician shelf and in the Cantabrian Sea.

**Zooplankton**

In the epipelagic zone (0 – 200 m), the zooplankton is dominated by species with a size spectrum ranging from protozoans to crustacean euphausiids, and in shelf seas, by larval stages of benthic organisms (e.g. echinoderms), mainly in spring and summer. Although in the deep ocean waters of the Wider Atlantic the
maximum number of species occurs at around 1000 m depth, the biomass at this depth is an order of magnitude lower than that found in the epipelagic zone.

The herbivorous copepods of the genus *Calanus* play a key role in ecosystems of the North Eastern Atlantic. They are the most abundant form of zooplankton and may account for over 90% dry weight of the total zooplankton biomass in the northern and eastern part of the area. The main sub-Arctic species is *Calanus finmarchicus* which has its main centre of distribution in the Norwegian Sea, but extends south into the northern North Sea. Regarding temperate species group, the main representative is the copepod *Calanus helgolandicus*, which is most abundant in the Bay of Biscay and southwest approaches to the UK, but extends into the North Sea from the south and west. However, since the 1960s, the CPR (Continuous Plankton Recorder Survey’s marine monitoring programme) data show a northward retreat of the subarctic species and advance of the temperate species. While the abundance of *Calanus finmarchicus* in the northern North Sea, in the 1960s, was about 10 times that of *Calanus helgolandicus*, now the two have approximately the same abundance. This change has occurred in parallel with a progressive warming of sea temperatures and changes in ocean currents connected with global scale changes in climate.

**Benthos**

Similar to the other European regional seas, the microphytobenthos can be found on any substrate, whereas certain species of the macrophytobenthos may have special requirements. For example, red and brown macroalgae (e.g. *Gelidium, Fucus*) may require hard substrates (e.g. rock). The North Eastern Atlantic is highly diverse in macroalgae. Seagrass species, such *Zostera* and *Ruppia* may prefer soft sediments.

As we descend on depth, phyto-benthic abundance decreases (i.e. due to light dependence) while zoobenthic abundance increases. Furthermore, and although it is not specific to the North Eastern Atlantic, species size decreases with depth.

It has been observed that “frontal regions”, areas where different ocean currents meet, normally have a high primary production, which results in productive benthic communities. Some frontal areas in the North Eastern Atlantic include in the North Sea, in the Kattegat/Skagerrak area and the Irish shelf front, to the west of Ireland.

Interesting structural species, such as *Lophelia* occur in large coral banks near the continental shelf break off Ireland, Scotland, the Faroe Islands, Norway, and off the south coast of Iceland. Other special assemblages are also present in the North Eastern Atlantic: deep-water sponge assemblages, such as *Geodia* and *Aplysilla* and coral gardens (Region I), biogenic reef features such as *Modiolus modiolus*, Ross
worm (*Sabellaria spinulosa*), blue mussel (*Mytilus edulis*), maerl (*Phymatolithon calcareum, Lithothamnion corallioides*) (Region III), etc.

The northern and north-western Spain and on the Portuguese shores are dominated by hard substrata, which in turn are primarily colonized by sessile and slow moving macrofauna. In contrast, their intertidal and subtidal soft bottoms are dominated by infauna. The western side of the Portuguese shoreline, is dominated by soft bottoms, with less abundant fauna associated.

The Macaronesia, with several volcanic areas, provide upwelling currents that support rich and interesting benthic species and communities (Couto et al., 2012). Indeed, research continues providing new additions to benthic marine algae species.

**Fish**

The North Eastern Atlantic includes a wide range of fish species, many of which are of high value to people, providing food and livelihoods. Indeed, the Norwegian Sea (Region I) is an important spawning area for the North Atlantic cod stock. The winter fishery for stock fish in the Lofoten archipelago is one of the most culturally and economically important events in northern European marine history. The spring spawning herring (*Clupea harengus*) represents another commercially important fishery in the Norwegian Sea. This fishery has displayed enormous fluctuations and from 1968 was believed to have been fished out, before it re-established and started to increase after a moratorium in the early 1980s. There is a close link between herring and cod as herring larvae are important food for cod juveniles.

In Region II, flatfish are important commercial species (e.g. North Sea). Furthermore, the burrowing sandeel (*Ammodytes marinus*) is a very important prey species for many seabirds and commercial fish, and in recent years the management of sandeel has attained increased focus. The English Channel itself offers key nursery grounds to several important North Sea species of commercial interest, including plaice and other flatfish. This area represents an important southern boundary for cold water species which have been observed to be losing suitable habitat due to global warming, while few warm water species have been expanding their range posing new challenges to local biodiversity.

Region III includes species like cod (*Gadus morhua*). The Bay of Biscay (region IV) is an important area for fisheries, providing home to important fish stocks, including those of Atlantic mackerel (*Scomber scombrus*), Atlantic horse mackerel (*Trachurus trachurus*), blue whiting (*Micromesistius potassou*), albacore tuna (*Thunnus alalunga*) and hake (*Merluccius merluccius*).

**Birds**

The highly productive North Eastern Atlantic area supports important breeding and migratory birds’ populations dependent on the sea. Proportionately, the coasts of Arctic waters and the North Sea hold
the highest numbers of nesting species as well as the greatest populations. Total numbers of individuals in these northern areas are several orders of magnitude greater than those in the southern regions of the area. The total seabird breeding population in the area has been estimated in around 25 million pairs.

On an annual basis, many of these species exhibit varying periods of residence in different oceanographic regions and areas. Some migrate into breeding areas in spring and summer, and out of them during autumn and winter. Other visitors move into regions after breeding elsewhere.

The seabird groups in this area are fulmars, shearwaters, petrels, storm-petrels, gannets, cormorants, skuas, terns, gulls and auks. The auks (six species) make up more than 60% (by number) of the total seabird populations in the area. Regarding food consumption, piscivores seabird species dominate the breeding community in the area, primarily guillemots (Uria aalge) and Atlantic puffins (Fratercula arctica) that feed almost exclusively on schooling forage fish such as sandeels, herring, pilchard, young gadoids, and sprat.

Surveys of distribution of seabirds at sea have shown that shelf areas hold substantially higher densities than oceanic waters. Large intertidal flats, such as in estuaries and in the Wadden Sea, are particularly important for wading birds.

Turtles
Turtles typically inhabit tropical and subtropical waters. Therefore, within the North Eastern Atlantic, it is the Macaronesia area where they are most abundant. In addition, and as a result of their long migrations, sightings and interactions with fisheries have also been recorded in the Bay of Biscay. The main species sighted in the North Eastern Atlantic are: Leatherback sea turtle (Dermochelys coriacea), Loggerhead turtle (Caretta caretta), Green turtle (Chelonia mydas), Atlantic ridley sea turtle (Lepidochelys kempii) and the Hawksbill turtle (Eretmochelys imbricata). Of these species, the Loggerhead turtle and the Green turtle are frequently found in the North Eastern Atlantic in general and in the Macaronesia, respectively (Plereguezuelos et al., 2002). The Atlantic ridley sea turtle is rarely seen.

Mammals
The North Eastern Atlantic supports a large diversity of cetaceans, with more than 30 species. The Macaronesia, Bay of Biscay and the English Channel are amongst the richest areas of the North Eastern Atlantic, in terms of the number of different species that they support. Indeed, in the waters surrounding the Canary Islands in the Macaronesia, as well as in the Bay of Biscay, more than 20 species of cetaceans have been recorded (Ritter, 2003).

Other areas of the North Eastern Atlantic are also important for other marine mammals; charismatic polar bears occur in the furthest northern parts of the the Arctic. In addition, the North Sea support around
30% of the world’s Harbour porpoise (*Phocoena phocoena*) and around 40% of the world’s population of grey seals (*Halichoerus grypus*) breed in European waters.

Despite anthropogenic pressures and diseases (e.g. phocine distemper virus that largely affected the population of seals around the 80s and 90s) different international conventions that enhance the protection of marine mammal species and the moratorium on commercial whaling have helped the recovery of many marine mammal species.

**Conservation measures**

Since 1998, OSPAR has been working under its Biodiversity and Ecosystems Strategy to identify, protect and conserve those species, habitats, and ecosystem processes in the North Eastern Atlantic which are most vulnerable to harm. In fact, available information on threatened and/or declining species and habitats has been collected, and a list (based on criteria for decline and threat) was agreed in 2003 and extended in 2008 (Table 1).

Furthermore, OSPAR is developing a network of marine protected areas (MPAs) for the North Eastern Atlantic in order to make a significant contribution to the sustainable use, protection and conservation of marine biodiversity, as a response to its commitment to establish “an ecologically coherent network of well-managed MPAs in the North-East Atlantic by 2010”. As of the 31st of December 2012, the OSPAR Network of MPAs comprised a total of 333 sites, including 324 MPAs situated within national waters of Contracting Parties (CPs) and nine MPAs outside of CPs national waters with different jurisdictional protective regimes. Collectively, these sites cover ca. 700,600 km² or 5.17% of the OSPAR maritime area in the North Eastern Atlantic (Figure 5, Table 2).

Although a wide range of biological monitoring programmes are undertaken within the North Eastern Atlantic, there is a need for improved coordination. These programmes mostly focus on protected sites or features rather than the functional aspects of the ecosystem. For example, in the Norwegian Sea (Region I), cold water coral reefs, specifically *Lophelia pertusa*, has become a major priority for conservation, as they provide very important nursing grounds for many commercial fish stocks and creating three dimensional habitats, which have high effect on the biodiversity.
Table 1. OSPAR List of threatened and/or declining species adopted in 2003 (species added in 2008) and the current key pressures with impacts on the species listed (source: OSPAR, 2010).

<table>
<thead>
<tr>
<th>Species</th>
<th>Scientific name</th>
<th>Regions where species occurs and has been recognised by OSPAR to be threatened and/or declining</th>
<th>Key pressures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean quahog</td>
<td>Arctica islandica</td>
<td>I</td>
<td></td>
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<tr>
<td>Atlantic herring</td>
<td>Megalopsis archiasis</td>
<td>II</td>
<td></td>
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<tr>
<td>Dog whelk</td>
<td>Nucella lapillus</td>
<td>III, IV</td>
<td></td>
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<tr>
<td>Flat oyster</td>
<td>Ostrea edulis</td>
<td>I</td>
<td></td>
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<tr>
<td>American lampel</td>
<td>Perna viridis</td>
<td>II</td>
<td></td>
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<tr>
<td>Lesser black backed pike</td>
<td>Lota lota</td>
<td>I</td>
<td></td>
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<tr>
<td>Ivory goby</td>
<td>Pagophilus citreus</td>
<td>I</td>
<td></td>
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<tr>
<td>Scallop's scallop</td>
<td>Arctica islandica</td>
<td>I</td>
<td></td>
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<tr>
<td>Little shrimper</td>
<td>Pagophilus citreus</td>
<td>I</td>
<td></td>
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<tr>
<td>Bimaleric shrimper*</td>
<td>Pagophilus citreus</td>
<td>I</td>
<td></td>
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<td>Black-legged kelpfish*</td>
<td>Hassia tridens</td>
<td>I</td>
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<td>Rosebud tern</td>
<td>Stirna longica</td>
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<td>Brenta gullioniset</td>
<td>Unio edulis - borean population</td>
<td>I</td>
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<td>Thick killed salmon*</td>
<td>Harex coffele</td>
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<tr>
<td>European eel</td>
<td>Anguilla anguilla</td>
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<td>Dogfish</td>
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<td>European eel*</td>
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<td>Herring</td>
<td>Conger conger</td>
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<td>Scombroid</td>
<td>Scombroide sp.</td>
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<td>Sea turbot</td>
<td>Psetta maxima</td>
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<td>Portuguese electric eel</td>
<td>Centrophorus coelatus</td>
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<td>Baltic eel</td>
<td>Centrophorus electricus</td>
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<td>Ladrocked gulf eel</td>
<td>Centrophorus squamosus</td>
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<td>Basking shark</td>
<td>Centrophorus squamosus</td>
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<td>Common skate</td>
<td>Dicentrarchus labrax</td>
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<td>Spotted ray</td>
<td>Rajus montagui</td>
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<td>Striped eel</td>
<td>Syngnathus scolopinus</td>
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<td>Porbeagle*</td>
<td>Lutjanus argenticeps</td>
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<td>Thornback tuna/ray*</td>
<td>Raja clavata</td>
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<td>White saeta</td>
<td>Neosaura vriab</td>
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<td>Angel saeta*</td>
<td>Syngnathus japonicus</td>
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<td>Cod</td>
<td>Gadus morhua</td>
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<td>Orange roughy</td>
<td>Holocentrus violaceus</td>
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<td>Blenny fish</td>
<td>Blennius scorpiatus</td>
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<td>Long-nosed saletine</td>
<td>Neosaura vriab</td>
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<td>Short-nosed saletine</td>
<td>Neosaura vriab</td>
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<tr>
<td>Loggerhead turtle</td>
<td>Caretta caretta</td>
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<td>Leatherback turtle</td>
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<tr>
<td>Broadhead whale</td>
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<tr>
<td>Sea whitefish</td>
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<tr>
<td>Northern right whale</td>
<td>Echidna nevado</td>
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<tr>
<td>North Pacific salmon</td>
<td>Oncorhynchus keta</td>
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</tbody>
</table>

**KEY TO TABLES 1.2 AND 1.3:** Climate change, pH, pH changes, Hydrological changes, Nutrient and organic enrichment, Herbivory, Barriers to species movement, Mortality or injury by ships strikes, Habitat damage, Habitat loss, Introduction of nonindigenous species and translocations, Removal of target and non-target species, Predation, Loss of prey species, Threaten outside the OSPAR area.
**Table 1.** Marine protected areas (MPAs) nominated to OSPAR by December 2012 (source: OSPAR, 2013).

<table>
<thead>
<tr>
<th>OSPAR country</th>
<th>MPAs</th>
<th>Coverage, km²</th>
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<tbody>
<tr>
<td>Belgium</td>
<td>2</td>
<td>1,239</td>
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<tr>
<td>Denmark</td>
<td>34</td>
<td>12,472</td>
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<tr>
<td>France</td>
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<td>Germany</td>
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<td>Ireland</td>
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<td>Netherlands</td>
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<tr>
<td>Norway</td>
<td>12</td>
<td>85,416</td>
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<tr>
<td>Portugal</td>
<td>8**</td>
<td>5,678</td>
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<tr>
<td>Spain</td>
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<tr>
<td>Sweden</td>
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<td>2,484</td>
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<tr>
<td>UK</td>
<td>183</td>
<td>47,676</td>
</tr>
<tr>
<td>High Seas/ABNJ/ECS*</td>
<td>7</td>
<td>496,935</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>333</td>
<td>700,593</td>
</tr>
</tbody>
</table>

* ABNJ = Areas beyond National Jurisdiction; ECS = Extended Continental Shelf subject to a submission by a Contracting Party to the UN CLCS

** Portugal has altogether nominated 12 MPAs to OSPAR. Four of the areas however are encompassed by a Portuguese submission to the UN CLCS on the outer limits of its extended continental shelf, and have therefore been assigned to the category “High Seas/ABNJ”.

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**Table 2.** Marine protected areas (MPAs) nominated to OSPAR by December 2012 (source: OSPAR, 2013).

<table>
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<tr>
<th>MPAs</th>
<th>Coverage, km²</th>
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In the Greater North Sea (Region II) much conservation efforts have been placed in protecting the mussel beds habitats in the largest intertidal mudflat in the world, located in the Wadden Sea, off the coast of the Netherlands, which serves as an important feeding ground for millions of migrating seabirds that depends on of this habitat. The recognition of the need to preserve Channel habitats has led to large efforts to raise the protection status of the region, parts of which now represent approximately half of the 28 recently designated UK Marine Conservation Zones.

Within the Celtic Seas (Region III), conservation priorities in the Irish Sea include the inclusion of a large area of mud substrata and several offshore rock outcrops the expansion of the UK offshore Marine Protected Area network, as well as the protection of sheltered sea loughs, biogenic reef features (*Modiolus modiolus*) and rock outcrops, which typically have a high biodiversity and hence conservation value. At Bristol Channel, species like the short snouted seahorse (*Hippocampus hippocampus*), various Cnidaria, the pink seafan (*Eunicella verrucosa*) and seagrasses have granted several areas of the region international and national conservation designations (SAC, SPA, MCZ, SSSI). As in the Norwegian Sea,
the Northwest coast of Scotland and Northern Ireland, the cold water coral (*Lophelia pertusa*) is also present and conservation efforts have been put into place for protecting this long-lived and slow growing species.

In the Bay of Biscay and the Atlantic Iberian coast (Region IV) the following (and other) species from the OSPAR list are present: birds (e.g., black-legged kittiwake or roseate tern), fishes (e.g., European eel (*Anguilla anguilla*), Portuguese dogfish (*Centroscymnus coelolepis*) or bluefin tuna (*Thunnus thynnus*)), reptiles (e.g., loggerhead turtle (*Caretta caretta*) and leatherback turtle (*Dermochelys coriacea*) and mammals (e.g., blue whale (*Balaenoptera musculus*) and Northern right whale (*Eubalaena glacialis*)). Within this region different categories/levels of protection and management are in place. However, they are often focused on maintaining the biodiversity of charismatic species or rare habitats. As an example, one of the biggest MPAs in the area, El Cachucho (Banco Le Danois), is a highly vulnerable and important ecosystem for the breeding of commercial fish species (including blue whiting, white hake, monkfish and bluemouth). Moreover, this MPA includes four out of the fourteen threatened habitats listed by OSPAR Convention (i.e. deep-sea sponge aggregations, cold-water coral reefs, seamounts and, sea-pen and burrowing megafauna communities).

In future work, it will be important to give more emphasis to monitoring and assessing status and impacts at an ecosystem scale, as in the work done in the North Sea on Ecological Quality Objectives (EcoQOs).

**Main human uses, pressures and impacts**

A range of human uses of the sea (e.g. fishing, mariculture, shipping, tourism and recreational activities, sand and gravel extraction) provide goods and services for coastal countries. The main pressures, in terms of their spatial extent and impact on biodiversity, are those associated with physical disturbance and include abrasion, changes in siltation and, in some cases, substratum loss and smothering. Selective extraction of non-living resources (e.g. aggregate extraction) is widespread in the southern North Sea and Celtic Sea. Selective extraction of target and non-target species, together with death or injury by collision, associated with fishing, are widespread pressures throughout the North East Atlantic region.

Many of the coastal states bordering the North Eastern Atlantic are densely populated, highly industrialised and/or use land intensively for agriculture. As a consequence, the region is affected by inputs of nutrients and organic matter and the introduction of synthetic and non-synthetic compounds through rivers, estuaries the atmosphere and coastal discharges of domestic and industrial discharges. However, the degree of pressure from the different human activities varies between and within regions. The much greater concentrations of human population in catchments draining into the greater North Sea (with over 500 inhabitants per km²) produce a significantly different level of pressure to that affecting the
wider Atlantic region, where the only human populations are associated with the Macaronesian archipelagos. Nevertheless, some pressures are of concern in all regions of the North Eastern Atlantic. In fact, the most widespread impacts on ecosystems result from fishing and the emerging impacts of climate change (e.g. changes to the temperature, salinity, pH, water flow patterns and emergence regime), which are a cause for serious concern.

_use of living marine resources_

Human use of living marine resources provides a wide range of goods and services of economic value. However, these uses exert pressure on the coastal and offshore environment which can have a wide range of impacts on marine ecosystems. Use of living marine resources covers the exploitation of marine species by man for food, feed, fertilizer or the production of other products of value or use, and includes activities such as fishing, mariculture and hunting. These activities are of high economic significance in some European countries and in some regions within countries.

The North Eastern Atlantic is an important area for fisheries. Areas like the English channel (Region II), which connects the North Sea to the Atlantic and the Norwegian Sea (Region I), with a varying topography and relatively warm water temperatures, provide good fishing grounds and spawning areas for the North Atlantic cod stock, respectively. However, fishing pressure continues to have a considerable impact on marine ecosystems (e.g. death of many species, seabed disturbance). For some areas like the Norwegian Sea (Region I), the selective extraction of species from a high fishing pressure is considered the most important pressure on biodiversity. In the North Sea (Areas IVa, b and c) the selective removal of target and non-target species is one of the main pressures, and has led to 29 species classified as ‘under threat’. In addition to the direct effects of species removal, the physical impacts associated with fishing gear on the seabed are also widely spread. Abrasion and changes in turbidity are some of the side (but very important) effects of using mobile-bottom fishing gear (e.g. beam trawling, scallop dredging, etc.). Despite the positive effects of improved management strategies for fisheries, intensive efforts are still required to reduce this pressure. OSPAR recommends cooperation between European countries to improve monitoring and assessment of fisheries, by-catch and vulnerable habitats, particularly in the Wider Atlantic where knowledge is poor.

Mariculture (the cultivation of marine organisms such as fish and shellfish for food and other products) is a growing activity in the North Eastern Atlantic (widespread in areas like the West Scotland), with potential to cause substantial environmental damage if not properly managed. In fact, there are many pressures of concern linked to mariculture, such as introduction/spread of non-indigenous species, siltation, deoxygenation, accumulation of organic matter, genetic modification, habitat damage and/or
contamination. Therefore, the implementation of measures to mitigate impact from this activity should continue.

Hunting of marine mammals is carried out only by northern countries (Norway, Iceland, Faroe Islands, Greenland) and the Russian Federation and is subject to management measures and monitoring. There is no evidence of major environmental problems if these activities are properly carried out within the relevant management plans.

**Eutrophication**

A healthy marine environment, where no human-induced eutrophication occurs, was not achieved in the period 2001–2005. While eutrophication is not a problem in the Arctic waters (Region I) and the wider Atlantic (Region V), many areas of the North Sea (Region II), including areas in the Channel, Skagerrak and Kattegat, and some small coastal embayments and estuaries within the Celtic Seas (Region III) and the Bay of Biscay and the Iberian Coast (Region IV) are still affected by eutrophication. Eutrophication is a more prominent problem in coastal areas than in offshore waters.

Regarding monitoring, in order to achieve a status where eutrophication does not occur, OSPAR recommends improving the monitoring framework through coordinated use of novel observation tools and coordination of data collection on sources, inputs and environmental status.

**Contaminants**

Although inputs of metals and some organic contaminants to the sea have fallen considerably over the past 20 years, most priority chemicals are still being released into the environment. Environmental concentrations of monitored chemicals have generally fallen, but are still above acceptable concentrations, especially in coastal areas near the main sources of pollution in the North Sea (Region II), the Celtic Seas (Region III) and the Bay of Biscay and the Iberian Coast (Region IV). Indeed in the North Sea, the introduction of non-synthetic compounds (i.e. mercury and PAHs) as a result of the high human population density in the adjacent areas is a matter of concern. Contamination with persistent organic pollutants is widespread and their long-range air transport to the North Eastern Atlantic, especially to the Arctic Waters (Region I), is also problematic.

OSPAR recommends further development of chemical monitoring, supported by the following:

- Improved understanding of the effects of hazardous substances, particularly cumulative effects and endocrine disruption.
- Improved biological effects monitoring, integrated, where appropriate, with chemical monitoring.
- Extending datasets further offshore beyond the densely populated and industrialised coasts.
• Improved information collection on the production, uses and pathways to the marine environment, especially for substances which are not deemed suitable candidates for marine monitoring.

• Use of research results on concentrations and effects of hazardous substances on deep-sea species and ecosystems.

Concurrently discharges of radionuclides from nuclear installations have fallen and radiation doses to humans and marine life from this pollution are low in the North Eastern Atlantic. However, in places like the Bristol Channel, where two nuclear stations are located (with proposed expansion), pressures such as localised thermal regime change and the introduction of some radionuclides occur. Therefore, OSPAR recommends to continue monitoring programmes, to improve the assessment tools and to develop environmental quality criteria in order to evaluate the impacts of discharges of radioactive substances on the marine environment.

In addition, marine litter is also a threat, especially to seabirds and mammals, through suffocation, entanglement and ingestion (OSPAR, 2010).

**Offshore industry**

Offshore oil and gas activities have developed in the North Eastern Atlantic over the past 40 years. However, production is at different stages and intensities in the regions. The major offshore oil and gas developments are in the North Sea and Norwegian Sea; oil and gas in the northern North Sea and Norwegian Sea, and mostly gas in the southern North Sea. Some production also takes place in the Irish Sea and Celtic Sea (gas only), the Bay of Biscay, the Gulf of Cadiz (gas only), and the Barents Sea.

Concerns over impacts of the offshore industry on the marine environment continue, especially those relating to oil and chemicals discharged with produced water, impacts from historic cuttings piles, smothering of macrofauna with drill cuttings and atmospheric emissions. Therefore, OSPAR recommends to continue monitoring and assessment and to improve the evidence base for future assessments of the impacts of the offshore industry on marine ecosystems.

**Other human uses and impacts**

A range of other human uses of the sea provide goods and services for OSPAR countries. These include: maritime transportation (e.g. the English Channel being one of the busiest shipping routes in the world); tourism and recreational activities (e.g. in the Celtic and Cantabrian Seas); increasing installations of wind farms (e.g. currently expanding in the English Channel); cables; land reclamation, coastal defence and other structures; artificial reefs; mineral extraction; and dredging and dumping (including dumped
munitions). Many of these activities are concentrated in the coastal waters of the North Sea (Region II), the Celtic Seas (Region III) and the Bay of Biscay and the Iberian Coast (Region IV), and have increased in intensity since 2000.

There are specific impacts which result from more than one activity, such as marine litter, microbiological contamination, non-indigenous species and underwater noise. Integrated management based on an ecosystem approach to management is essential for balancing the demands of different uses of the sea and nature conservation interests. In fact, OSPAR recommends to monitor the impacts from growing human uses of the sea and to agree on methods for cumulative impact assessment and socio-economic evaluation.

**Climate change**

Impacts of climate change are now becoming evident, although the nature, rate and impacts of climate change differ across the North Eastern Atlantic. The increase in temperature and acidification will be higher in northern areas (the Arctic Waters and the North Sea) than southern areas (e.g. the Bay of Biscay and the Iberian Coast). Threats to Arctic biodiversity are particularly imminent with sea-ice loss, which profoundly affects ice-associated marine life, and projected rates of acidification, suggesting adverse ecosystem impacts within the next decade. The differences between the Regions imply a need to understand better the potential climate change impacts at both the regional and local level.

Regarding monitoring, and in order to get better links between science and the development of local policy on risk assessment, OSPAR recommends cooperating internationally to monitor the effects of climate change and ocean acidification.
2.2. Baltic Sea

Introduction

This ecosystem overview aims to outline the main features of the Baltic Sea ecosystem from the point of view of biodiversity, food webs, sea-floor integrity and non-indigenous species. The overview relies heavily on previous work; mainly, on the Baltic Sea Ecosystem Overview by ICES (2008), the HELCOM Red List assessment (HELCOM, 2013) and by Ojaveer et al. (2010) and the food web focused report produced by the EU-funded Interreg IVA project GES-REG (Uusitalo et al., 2013), which tried to identify key or representative species from all the trophic levels of the food web. They proceeded to review literature on effects of various pressures on key food web components, aiming to identify which pressures are most often cited as having an effect on these species.

Key characteristics and habitats

The Baltic Sea is a large brackish-water pool, characterized by narrow and shallow straits connecting it to the North Sea, and a large drainage basin bringing a large amount of fresh water runoff into the sea. The mean annual freshwater inflow of about 481 km\(^3\) almost equals the volume of saline water inflows from the North Sea (Ojaveer et al., 2010). The water exhibits a strong east-west and north-south salinity gradient, with the most saline water in the western bays and belts and least saline in the northern bays. The Baltic Sea is shallow, with ca. 30% of its area being less than 25 m deep. The mean depth is 60 m and the maximum depth is 459 m (ICES, 2008). The northern parts of the sea experience annual ice cover, the extent and duration of which vary according to the severity of the winter. In summer, the water temperature in some coastal areas can exceed 25°C (Ojaveer et al., 2010).

The coastal habitat types vary in different parts of the sea. The northern and western shores (Scandinavian) are rocky with extended archipelagos which are still experiencing isostatic rebound following glacial retreat, while the eastern and southern coasts are dominated by fine sediments, and are prone to inundation by rising sea levels (ICES, 2008). Intensive agriculture, high-nutrient runoff, and poor sewage treatment in eastern European countries have caused significant eutrophication in coastal regions of the Baltic Sea, especially in the three coastal lagoons: Odra lagoon, Vistula lagoon and the Curonian Lagoon and, to a lesser extent, the eastern lagoons and inlets of Germany (Small Haff, Bodden of Rügen, Darß-Zingst Bodden Chain, Peene estuary). Eutrophication has led to an excessive increase in suspended organic material, which causes organic enrichment of sediments. In combination with the natural slow water flow in coastal lagoons, this nutrient enrichment results in very soft and unstable sediments (Fenske et al., 2013) and a conspicuously reduced light penetration. The high eutrophication levels resulted in an
ecosystem shift in shallow bays and lagoons from comparatively stable conditions with dominance of rooted macrophytes (angiosperms and charophytes), to unstable conditions dominated and driven by intensive phytoplankton blooms. The Baltic Sea coastal lagoons and inlets are also characterized by well-emphasized salinity gradients resulting in varying community structure (from brackish to freshwater species dominance).

The upper water layer is separated from the more saline deep water layer by a permanent halocline located at depths of about 70–100 m. There is no halocline in the shallower areas in the north-eastern Baltic (for example, the Gulf of Bothnia and Gulf of Riga) or the Western Baltic (for example, the Kiel Bight or Belt Sea). A strong permanent halocline and seasonal thermocline in summer (occurs also in shallow areas) substantially hamper vertical mixing of water column, which induces formation of oxygen-depleted zones in several locations, essentially in the deep areas of the central Baltic (Ojaveer et al., 2010).

The oxygen-deficient waters are replaced occasionally through inflow of saline water from the North Sea through the straits; this, however, requires specific weather conditions. These strong inflows were frequent prior to mid-1970s (ICES, 2008), but have been much scarcer since. The estimated residence time of the Baltic Sea water is 25-35 years (Ojaveer et al., 2010). The oxygen deficiency leads to phosphorus being released from the sediments and being recycled back to the water column, thus feeding the primary production. The recurring oxygen deficiency and other hydrographic factors affect the deep water soft bottom fauna, which tends to be dominated by few species (Laine, 2003), and has shown high variability and significant changes over time (Laine, 2003 and references therein).

Key biodiversity components

Plankton

The primary production features a strong seasonal variation, with an intense spring bloom and a late-summer maximum. The species composition of the phytoplankton community varies between seasons and areas. The highest phytoplankton species diversity (1565 species) was recorded from the Gulf of Finland (Ojaveer et al., 2010), probably partly due to long-term dedicated taxonomic efforts in the area. Planktonic algae produce the majority of energy entering the Baltic Sea pelagic food webs (Furman et al., 1998), and the phytoplankton composition has implications to the functioning of the food web, both in reference to their edibility, and due to the toxins produced by some of the taxa. In addition, the microbes decomposing the soluble organic matter are particularly crucial for the functioning pelagic ecosystem (Furman et al., 1998). Mass occurrences of nitrogen-fixing cyanobacteria are a recurring phenomenon in the central Baltic Sea, Bothnian Sea, Gulf of Finland and Gulf of Riga (ICES, 2008). A list of potentially harmful phytoplankton in the Baltic Sea contains over 60 species with effects connected to toxicity, mechanical disturbance, bloom formation and water coloration (Ojaveer et al., 2010). It has been
proposed that many recent changes in the phytoplankton could be related to climate variation, which directly and indirectly influences water temperature, salinity, and nutrient loading from the catchment in the Baltic Sea area.

According to present-day knowledge, the most species-rich component of the Baltic Sea zooplankton is microplankton (ciliates and rotifers) (Ojaveer et al., 2010). The mesozoo plankton community is dominated by calanoid copepods and cladocerans, and varies along the salinity gradient. Changes in the zooplankton community have been attributed to changes in salinity and temperature (Viitasalo et al., 1995; Vuorinen et al., 1998; Ojaveer et al., 1998, Möllmann et al., 2000, 2003; Schmidt et al., 2003; Alheit et al., 2005; Möllmann et al., 2005). The copepods *Pseudocalanus elongatus*, *Temora longicornis*, and *Acartia* spp. are considered to be the main prey items of the dominating pelagic fish species sprat (*Sprattus sprattus*) and small-sized individuals of Baltic herring (*Clupea harengus membras*) (e.g. Szypula et al., 1997; Flinkman et al., 1998; Möllmann and Köster, 1999, 2002; Viitasalo et al., 2001; Casini et al., 2004; Rönkkönen et al., 2004; Casini et al., 2006). These zooplankton taxa were therefore also identified as key species in the food web. The only native macroplanktonic predator occurring in this relatively hostile environment is the scyphozoan *Aurelia aurita*, of which polyps and ephyrae are found in the southwestern Finnish archipelago (Palmén, 1953). Late summer and autumn occurrences of *A. aurita* are a known northern Baltic phenomenon (Wikström, 1932), but to what extent these autumnal congregations result from local reproduction or advection from further south is not documented, and may alter with changes in salinity (Segerstråle, 1951, 1952).

**Benthos**

The benthic invertebrate composition depends on salinity, water depth as well as the substratum type; on hard substrata in shallow waters, suspension-feeding mussels are dominant, while on soft bottoms and in deeper waters, deposit feeders and burrowing forms dominate (ICES, 2008). The most diverse groups are the polychaetes, crustaceans and molluscs. Some taxonomic sub groups like sea squirts, echinoderms, sponges, sea anemones and corals are nearly exclusively restricted to the high salinity areas of the western and southern Baltic Sea (HELCOM, 2013). However the number of freshwater species increases along the same gradient. Especially in the more or less freshwater inshore waters (e.g., Curonian Lagoon) and in the shallow offshore waters of the northeast, the number of freshwater species (mainly insects but also oligochaetes and molluscs) increases dramatically. Oxygen availability also limits species distribution because most benthic organisms are sensitive to long-term low-oxygen conditions. Therefore, macrobenthic life is often absent in the deeper basins below the halocline, particularly after longer periods without saline water inflows. On the anoxic bottom of the Baltic Proper, only members of the meio benthos that are able to withstand the stress exerted by the lack of oxygen inhabit these areas.
The blue mussel (*Mytilus trossulus* x *M. edulis*) is a key zoobenthic species in the coastal food web as well as a habitat-forming species (HELCOM, 2010; Koivisto, 2011). Overall 1898 benthic invertebrate taxa occur within the Baltic Sea (HELCOM, 2013) of which 19 are considered threatened (e.g. the bivalve *Macoma calcarea* or the snail *Lunatia pallida*) and nine near threatened (e.g. the bivalve *Mya truncata* or the amphipod *Corophium multisetosum*). The main threats for benthic invertebrates are eutrophication, and as a consequence the increasing oxygen depletion and number of anoxia events, as well as seabed damage due to bottom trawling and construction activities (HELCOM, 2013).

Salinity is also the main environmental factor controlling the wide-scale distribution of phytobenthic species in the Baltic Sea, while exposure, substratum type, and light availability determine the structure of vegetation communities on the local scale. Macroalgae are the most diverse macrophyte subgroup, they need a hard bottom for attachment, which is scarce in some subregions (e.g. southern Arkona and Bornholm Basin). The most important habitat-forming phytobenthic species on hard bottoms are bladder wrack algae (*Fucus* spp.) and clawed fork weed (*Furcellaria lumbricalis*) and in the Western Baltic also red algae like *Coccolithys/Phyllophora* and *Delesseria sanguinea*. Higher plants and charophytes are distributed on soft bottom. Although this subgroup has a much lower diversity than macroalgae, the brackish environment, soft bottom dominance and high areal extent of shallow bays and lagoons in the Baltic thrive the occurrence and diversity of those subgroups. Eelgrass (*Zostera marina*) is the most important habitat-forming phytobenthos species on soft bottoms (HELCOM, 2010) of moderate exposure levels. In coastal lagoons vegetation communities are characterized by tasselweed (*Ruppia* sp.), pondweed (*Potamogeton* spp.), milfoil (*Myriophyllum* spp.) and stoneworts (*Chara* spp.). These species serve a key role in structuring the coastal ecosystems. Overall 531 macrophyte taxa have been recorded the Baltic Sea (HELCOM, 2013) of which three were regarded as endangered, four as vulnerable and also four as near threatened. The threatened species are characteristic of coastal lagoons and bays reflecting the high anthropogenic pressures (eutrophication, siltation, habitat alteration due to ditching) in these areas (HELCOM, 2013).

**Fish**

The Baltic Sea fish fauna comprises about 70% marine, 20% freshwater and 10% migratory species. The fish and lamprey checklist of the Baltic Sea includes about 239 species, which is a comparable low number (HELCOM, 2013). The dominating fish species in the pelagic/benthic ecosystem are cod (*Gadus morhua*), Baltic herring (*Clupea harengus membras*), and sprat (*Sprattus sprattus*), which together comprise approximately 80% of the total fish biomass. Some flatfish species are commercially important and the biomass appears to be moderately high e.g. flounder (*Platichthys flesus*). Several migratory species, such
as salmon (Salmo salar), trout (Salmo trutta), eel (Anguilla anguilla), vimba bream (Vimba vimba), smelt (Osmerus eperlanus) are of high commercial value too (Ojaveer et al., 2010). Cod feeds on benthic meio- and macrofauna and fish (e.g. Uzars, 1994; Harvey et al., 2003), and is the main predator of sprat and herring (Köster et al., 2003). Large herring feed on zooplankton and nektobenthos (Casini et al., 2004; Möllmann et al., 2004), while sprat and small herring are zooplanktivorous; the copepods Pseudocalanus elongatus, Temora longicornis, and Acartia spp. are considered to be their main zooplankton prey (e.g. Szypula et al., 1997; Flinkman et al., 1998; Möllmann and Köster, 1999, 2002; Viitasalo et al., 2001; Casini et al., 2004; Rönkkönen et al., 2004; Casini et al., 2006). In the coastal zone, the distribution of fish species is largely governed by salinity. The most common and abundant freshwater species found in a majority of coastal areas of the Baltic Sea are perch (Perca fluviatilis), roach (Rutilus rutilus), bream (Abramis brama), bleak (Alburnus alburnus), ruffe (Gymnocephalus cernuus), ide (Leuciscus idus), pike (Esox lucius), and whitebream (Blicca bjoerkna). These fish are more abundant in areas where salinity is lower, such as in the northeastern Baltic Sea, including large gulfs and lagoons (Ojaveer et al., 2010). Of the 239 fish species of the Baltic Sea, two species are regarded as regionally extinct (American Atlantic sturgeon – Acipenser oxyrinchus, common skate – Dipturus batis), four species as critically endangered (e.g. eel – Anguilla anguilla, spurdog – Squalus acanthias), three as endangered (e.g. Atlantic wolf-fish – Anarhichas lupus, whitefish – Coregonus maraena), seven as vulnerable (e.g. salmon – Salmo salar, trout – Salmo trutta), and nine as near threatened. Main threats for fish are fishing – either targeted commercial, recreational or as by-catch – eutrophication and climate change. For migrating fish also barriers in estuaries and rivers are forming a major threat (HELCOM, 2013).

**Birds**

The Baltic Sea hosts a variety of sea birds feeding from the sea (Furman et al., 1998), and it is an important wintering area for many bird species (ICES, 2008) like divers, grebes and sea ducks, which are the most characteristic species in the Baltic Sea (HELCOM, 2013). The high variety of coastal habitats results in a high diversity of sea birds: for example dabbling ducks breed in brackish lagoons, sea ducks preferring rocky coasts, wading birds favour sandy open coasts and auks breed on rocky coasts. Common eider (Somateria mollissima), a common species breeding on the offshore islands, can be considered as keystone species according to HELCOM (2010). Common eider feeds mainly on blue mussel and has been assessed as vulnerable in the HELCOM Red List assessment. A total of 58 breeding birds have been assessed in the HELCOM Red List Project and 23 were red-listed. For wintering birds 63 species have been assessed of which 16 are regarded as threatened or near threatened. The main threats for sea birds are habitat destruction (breeding and feeding grounds), incidental by-catch in fishing gear but also environmental pollution (contaminants) as well as anthropogenic disturbance (noise, light, traffic; HELCOM, 2013).
Mammals

The marine mammals occurring in the Baltic Sea are grey seal (*Halichoerus grypus*), ringed seal (*Phoca hispida*), harbour seal (*Phoca vitulina*), and a small population of harbour porpoise (*Phocoena phocoena*). Along with man and piscivorous birds, these species are the top predators of the Baltic Sea ecosystem, feeding on available fish species (Routti *et al.*, 2005; Suuronen and Lehtonen, 2012). The latest HELCOM Red List assessment has verified a threat status for all Baltic Sea marine mammals (VU = vulnerable, CR = critically endangered) beside the grey seal and a subpopulation of the harbour seal in the southern Baltic Sea (LC = Least concern). The main threats for marine mammals are incidental by-catch in fishing gear but also environmental pollution (contaminants) which negatively affects health and fertility as well as anthropogenic disturbance (noise, traffic) at their nursing, moulting and feeding grounds (HELCOM, 2013).

Main human uses, pressures and impacts

Based on published literature, changes of salinity and thermal regime were identified as the main factors behind many of the changes in the Baltic Sea food web (Uusitalo *et al.*, 2013). The most recent overview on threats to the biodiversity of the Baltic Sea (i.e. HELCOM, 2009) includes 10 major categories: fisheries, maritime activities (including shipping), physical damage and disturbance, recreational activities, eutrophication, hazardous substances, alien species, noise pollution, hunting, and climate change. Overfishing, eutrophication, and drastic decline of marine mammals have been the most prominent changes in the Baltic Sea during the twentieth century. Pressures specifically associated with these factors include selective extraction of target and non-target species, death or injury by collision, abrasion and the potential for siltation rate changes and, in relation to eutrophication, input of nutrients and organic matter. However, it is possible that the results are biased, since eutrophication has also been extensively studied in the last decade. The literature review does not indicate physical damage, physical loss, or man-made changes in hydrological regime as relevant pressures for the Baltic Sea ecosystem.

All the other factors affecting the Baltic biodiversity are of relatively recent concern and have localized impact, or information on their impact is poorly documented.

There are several human activities that have increased significantly during the last decades. These include human-mediated bioinvasions, maritime transport (with increased risk of oil spills), extraction and disposal activities, a variety of technical installations in coastal areas and on the seabed (including sea cables and pipelines), and recreational activities. Elmgren (2001) pointed out that the scientific understanding of the ecosystem changes and their causes, as well as the importance of various pressures, tends to change and develop with time, and it may take decades to reach agreement. Therefore, the current view of main pressures should not be taken as an exclusive list.
**Non-indigenous species**

Although the first human-mediated introduction of species in the Baltic Sea occurred in the eleventh to twelfth century, species invasions have become a problem during the past two decades, especially with intensified invasion of alien species from the Ponto-Caspian region. Since the early 1980s, over 100 aliens have been recorded in the Baltic Sea (the Kattegat included) most of them being introduced by shipping (ballast water or hull fouling), or spread from their primary sites of introduction in adjacent freshwater bodies. It is assumed that some 70 species have been able to establish and maintain self-sustaining population (Zaiko et al., 2007). Alien species are abundant and even dominant throughout the shallow benthic and fouling communities of the Baltic Sea—at present, no shallow-water habitat is entirely free of human mediated invaders. Their numbers are lowest in Bothnian Bay and highest in the high-salinity Kattegat area (Ojaveer et al., 2010).

Alien species have no direct value as food resources in the Baltic, as none of them supports commercial fisheries and invertebrates are not harvested for food because of their small size. However, on the basis of existing knowledge, approximately 30 non-indigenous species (i.e. less than 30% of all introduced species) can be classified as nuisance organisms in the Baltic; only 9 of them have caused measurable damage. These are four Ponto-Caspian species (*Cercopagis pengoi*, *Cardylophora caspia*, *Dreissena polymorpha* and *Neogobius melanostomus*), three North-American species (*Balanus improvisus*, *Gammarus tigrinus* and the American mink *Mustela vison*), the Japanese swim-bladder nematode *Anguillicola crassus* and the “shipworm” mollusk *Teredo navalis*, believed to be of Indo-Pacific origin.

The influence of the most recent and potentially harmful invader—the alien ctenophore *Mnemiopsis leidyi*—on the pelagic food web of the Baltic Sea seems to be spatially restricted to the southern Baltic Sea (Gorokhova et al., 2009).
2.3. Black Sea and the Sea of Marmara

In the DEVOTES Deliverable 1.4, the Black Sea monitoring networks are analysed considering two geographical areas: EU and non-EU waters (Figure 30 from the main D1.4 report). In addition, the monitoring networks covering the Sea of Marmara (currently included in the non-EU Seas) are also included in the analysis. The Sea of Marmara connects two EU Seas (the Black Sea and the Mediterranean Sea) and is under the sovereignty of Turkey (a candidate EU country). It is therefore deemed relevant within this deliverable to consider and assess the marine monitoring undertaken in the Sea of Marmara in association with monitoring undertaken in the Black Sea.

2.3.1. Black Sea

Introduction

This ecosystem overview aims to outline the main features of the Black Sea ecosystem from the point of view of the Descriptors included in DEVOTES (i.e. biological diversity, food webs, non-indigenous species and sea-floor integrity).

Key characteristics and habitats

The Black Sea is an almost enclosed basin connected to the Aegean and Mediterranean Seas via the narrow Bosphorus Strait only. It has a total coastline length of 4,869 km, covers an area of 436,000 km², has a volume of 555,000 km³, and maximum depth of 2,258 m with variable topography. Low salinity (average salinity 18; maximum 22), the presence of hydrogen sulphide (H₂S) at depths below 150 m (about 87% of the volume) and high vertical stratification are unique features that precondition high productivity and low biodiversity of the basin, compared to the Mediterranean Sea. Shelf seas (sea depths of 100–200 m) occupy up to 25% of the total area of the seafloor with the greatest width (more than 200 km) being in the northwestern part of the sea. Here, the maximum width is tens of kilometres compared to just a few kilometers along the eastern and southern coasts.

River discharge is an essential input to the Black Sea ecosystem. Major rivers draining into the Black Sea include the Rioni, Kodori, Inguri Chorokh, Kizilirmak, Yesilirmak, Sakarya, Southern Bug, Dnister, Danube, Dnieper and Don (BSC, 2008). The drainage basin of the Black Sea is over five times the area of the sea itself (Ludwig et al., 2009). The river’s discharge is a key driver of ecosystem function on the shelf that results in high abundances of the main commercial fish due to high productivity of the near-shore waters. The shelf environment provides vital habitat of the majority of the Black Sea benthic organisms.
The Black Sea is an isolated and unique inland sea, which contains the Earth’s largest permanent anoxic sulphidic water body, as well as the world’s only known active undersea river (Gray, 2010). Researchers working in the Black Sea have found currents of water 350 times greater than the River Thames flowing along the sea bed, carving out channels much like a river on the land.

Deeper waters are mostly isolated from the direct influence of river’s discharge and have a unique hydrographic regime. A sharp and permanent pycnocline lies between the low salinity surface waters of river origin and high-salinity deep waters of Mediterranean origin that restricts the penetration of vertical mixing depth up to 100–150 m. As a result, a two-layer chemical structure is formed with oxygen only in the upper 150-200 m. The signature of the Mediterranean inflow within the interior parts of the basin is best monitored within the uppermost 500 m depth, where the residence time of the sinking plume varies from ~10 years at 100 m depth to ~400 years at 500 m (Ivanov and Samodurov, 2001).

Anoxic conditions in the deeper waters bounds the distribution of flora and fauna, with the exception of sulphate reducing bacteria that are the only population of bacteria known in the deep-sea bed and water column habitats below the 200 m isobaths.

From the 18 benthic habitats that have been outlined in the MFSD, only 12 (from littoral to shelf sublittoral) are inhabited by oxygenic flora and fauna in the Black Sea. Existing information for the majority of the BS seabed biotopes have been compiled and analysed according to EUNIS classification in the frame of MESMA project (MESMA, 2010). Due to its deep-continental location there are no appreciable tides in the Black Sea, as for example in the NE Atlantic, where the extent of the littoral, infralittoral and circalittoral habitats are largely determined by gravitational forcing (MESMA, 2010). Consequently, comparison of a bathymetry map with a map of seabed sediment distribution could be employed to provide a generic overview about habitats distribution in the sea.

The littoral zone in the Black Sea is rather narrow. Typology of the sea coast could be used for designating the spatial distribution of littoral rock and littoral sediment habitat types. In mountainous areas (eastern and southern coasts, southern coast of Crimea), abrasive coasts dominate. In plain and low areas, the coasts are mostly accumulative. Lagoon and deltaic coasts are confined to the areas near river mouths. The marginal zone of the delta of the Danube River is rimmed by lagoon sandy bars and low marine terraces (about 2 m high). Coastal bars (sandy and sandy–coquina) are low with feature widths of 40–100 m. At present, accumulative coasts are gradually receding (Ignatov, 2008).

Shallow sublittoral habitats in the Black Sea could be extended from the coastline down to 50 m isobath. In association with *Cystoseira spp.* and *Phyllophora* beds, *Mytilus galloprovincialis* mussel beds on bedrock and boulders are the most important biotopes on shallow sublittoral rock (Sekercioglu et al., 2011). Sublittoral seagrass beds, *Phyllophora nervosa* on shell gravel, *Donax trunculus*, *Chamelea gallina,*
*Lentidium mediterraneum* and *Lucinella divaricata* in infralittoral sands are the main biotopes of shallow sublittoral sediments habitats in the Black Sea (MESMA, 2010).

Shelf sublittoral habitats occupy seabed between 50 m down to upper border of H$_2$S zone (125 – 140 m). They are characterized by decreased dissolved oxygen, increased salinity and decreased species richness compared to the coastal habitats. In these shelf sublittoral habitats, *Modiolula phaseolina* and *Mytilus galloprovincialis* are the most important habitat-forming species. The higher salinity (18.5) of deeper waters enables the development of small echinoderms. In the Black Sea these species only occur in this biotope (MESMA, 2010).

In the Black Sea, the physical, chemical and hydrographical conditions of pelagic water column habitats have not been described. It is however clear that in the close vicinity of river mouths, physical and chemical conditions are strongly influenced by freshwater input, low salinity, high nutrient levels and low transparency that are reflected in the pelagic community composition (plankton). Hydrographic, altimeter, CZCS and SeaWIFS data reveal quasi-persistent and/or recurrent features of the circulation system. These include the meandering Rim Current system with several anticyclonic eddies on the coastal side of the Rim Current zone, bifurcation of the Rim Current near the southern tip of the Crimea and the presence of a large anticyclonic eddy within the northern part of the northwestern shelf that determine the cross coastal-open sea water exchange driven mainly by the freshwater plume (Korotaev et al., 2003).

Monitoring by profiling floats shed new light into the seasonal variability of the subsurface oxygen maximum and mesoscale variability (e.g. Korotaev et al., 2006).

Black Sea coastal waters and the continental shelf are predominantly eutrophic (rich in nutrients). Central areas are characterized by mesotrophic conditions (medium level of nutrients) and significant parts are hypertrophic (high level of nutrients). The largest hypertrophic areas are located in the northwestern Black Sea, in the zone influenced by inflow from the Danube, Dniester and Dnieper rivers, which contain high levels of chlorophyll. Changes to the composition and abundance of phytoplankton species (and the timing and duration of blooming events) have been observed in response to anthropogenic impacts.

**Key biodiversity components**

The most recent figure for the total number of species in the Black Sea provided by Zaitsev (2008) is relatively small and stands at ~3,770 spp. The majority of the biota are composed of species of Atlantic-Mediterranean origin (80%), and the rest have freshwater or Ponto-Caspian origin (Shiganova and Ozturk, 2009).
**Phytoplankton**

Much of the diversity of the Black Sea phtoplankton flora can be attributed to unicellular algae. So far in the Black Sea checklist are about 1608 species belonging to 24 classes. Among them Bacillariophyceae and Dinophyceae contribute up to 80% of the total number of phytoplankton species. High nutrient levels provide a competitive advantage for mixo- or heterotrophic dinoflagellates against autotrophic diatoms, as indicated by high dinoflagellate to diatom ratio (Humborg et al., 1997). In the western Black Sea shelf, the revision of the phytoplankton check-list in 1980-2005 documented 544 species, which was more than a two-fold increase when compared to the 1954-1980 survey period (where 230 species were identified). This way likely due to improved sampling strategy, microscope quality, sampling frequency, changing environmental conditions and introduction of Non-indigenous species (NIS). In the Southern Black Sea, the most important change observed over the last 10 years has been the slight domination of dinoflagellate and other micro-nanoplankton species. This recorded increase in the ratio of dinoflagellates could be related to changes in the nutrient balance and temperature of the sea water (BSC, 2008).

Included within the phytoplankton taxa are more than 200 potentially toxic dinoflagellate species (Sournia, 1995). Approximately 20 species are listed as potentially toxic, but only a small number of toxicity cases have been reported (Bargu et al., 2002; Vershinin et al., 2005; Ryabushko et al., 2008; Alexandrov et al., 2012), with harmful effects mainly related to hypoxia conditions during bloom events (BSC, 2008). Some dinoflagellates produce resting stages, called dinoflagellate cysts. These stages could favour invasive species (i.e. via ballast waters). Phytoplankton communities manifest high seasonal and spatial variability in species composition and abundance. Dramatic biodiversity / successional alterations especially during the period of intensive eutrophication have been documented, with shifts in Bacillariophyceae/Dinophyceae biomass ratio in spring and additional phytoplankton blooms in late spring-summer. Whilst the period after the year 2000 marked further changes related to both the climatic signal and reduction of anthropogenic pressure, blooms of the prymnesiophyte species *Emiliania huxleyi* have emerged as a recent recurrent feature of the ecosystem (BSC, 2008; Finenko, 2008; Mikaelyan et al., 2011; Moncheva et al., 2012).

**Benthic flora**

Microphytobenthos is represented by ~800 unicellular algae species, dominated by diatoms. In contrast, the species list of macrophytes is restricted to ~330 species from Chlorophyta, Phaeophyceae and Rhodophyta division (Milchakova, 2007) and *Zostera marina* Linnaeus, *Z. noltii* Horneman, *Ruppia spiralis*, *Potamogeton pectinatus* Linnaeus ve *Cymodocea nodosa* (Ucria) Ascherson) (Aysel et al., 2004; 2005a, 2005b, 2008; Gonlugur-Demirci and Karakan, 2006) from division of the higher flowering plants. *Cystoseira*, *Phyllophora* and *Zostera* genera in the Black Sea form the main shelf biocoenoses and their status defines the coastal ecosystems function. The most drastic change in the ecosystem in the 1980s
was related to the sharp decrease in diversity of macrophytes and almost total disappearance of perennial algae (BSC, 2008). The major features of macrophytobenthos during the last several decades have been decreasing species numbers, dominance of small-size species with fast growth rates, decrease of community biomass, and reduction of the *Cystoseira* zone to a narrow inshore strip shallower than 10 m. As *Cystoseira* biomass decreased markedly, macroalgae blooms were dominated by opportunistic species (mainly epiphytic filamentous algae). In addition, a sign of the transformations in the macrophytobenthos community was the loss of Phyllophora in the region of Zernov’s *Phyllophora* Field in the northwestern Black Sea (BSC, 2008).

In total 258 taxa were identified in the Turkish Black Sea region from five classes: Cyanophyceae with 13 species, Rhodophyceae with 140 species, Phaeophyceae with 53 species, Chlorophyceae with 50 species and Charophyceae with two species (Aysel et al., 1996, 2000, 2004, 2005; Erdugan et al., 1996). With new additions of algal taxa, this number later increased to 297 (Aysel et al., 2004).

**Zooplankton**

Ciliates and other protozoans compose a significant part of the plankton fauna. The species list of meso- and macroplankton consists of ~250 species (or ~190 marine species if freshwater ones are excluded) nearly a quarter of which are meroplankton. Copepoda and Cladocera are the most diverse groups of the edible zooplankton which are crucial for the Black Sea food web functioning. The Black Sea zooplankton community has greater productivity but lower species diversity when compared to the adjacent Mediterranean Sea. Many taxonomic groups such as Doliolids, Salps, Pteropods, Siphonophors, and Euphausiids that are wide-spread in the Mediterranean Sea are absent or rarely recorded in the Black Sea.

The most important feature of the zooplankton community after the 1970s eutrophication period was the change in species composition between various zooplankton groups. Some of them disappeared (e.g. *Oithona nana* and *Acartia margalefi*) or decreased dramatically (e.g. *Anomalocera patersoni*, *Pontella mediterranea*, *Centropages ponticus*), whereas others increased in abundance, such as the outbursts of gelatinous planktonic species *Aurelia aurita*, *Rhizostoma pulmo* and *Noctiluca scintillans*, which dominated the total zooplankton biomass throughout the 1980s (Shiganova et al., 2008). The zooplankton community has also been strongly affected by the population outburst of the alien ctenophore species *Mnemiopsis leidyi* after 1988 due to their intensive preying on edible zooplankton (Vinogradov et al., 1989; Shiganova, 1998). For example, after 1998 *Mnemiopsis* biomass decreased following population control by the predator *Beroe ovata* when it settled in the Black Sea (Kamburska et al. 2006; Shiganova et al., 2008). Also, new copepod species were established in the plankton fauna: *Acartia tonsa* and *Oithona davisae*, which are currently well represented in the Black Sea.
**Benthic Fauna**

The fauna of the Black Sea includes more than 2000 species referring to 22 phyla (Zaitsev, 2008). In comparison with the Mediterranean Sea, the fauna is remarkably different with its low number of species and the decline in diversity of many oceanic groups, such as Sponges, Salps, Pteropods, Euphausiids, Nemertini, etc. (Shiganova and Ozturk, 2009). Low salinity and the existence of an anoxic zone are largely responsible for the faunal impoverishment of the Black Sea. However, the low species diversity combined with high habitat diversity can provide favorable conditions for the introduction of alien species (Shiganova and Ozturk, 2009; BSC, 2010).

The number of benthic invertebrate species is several times as higher than for zooplankton. Sea worms Turbellaria, Nematodes, and Polychaetes are represented by 450 species. There are approximately 100 Bivalvia species, most of which are sandy-bottom inhabitants with *Modiolus phaseolinus* as the most abundant. A few species live on hard substrates such as wide-spread *Mytilus galloprovincialis* and *Mytilaster lineatus*. Two alien mollusc species, *Anadara inaequivalvis* and *Rapana thomaisiana* have major effects on the native fauna of the Black Sea. *Rapana* is a predator on other mollusks while Anadara is in competition with other native species for the food and space (Sahin et al., 2009). Mollusc diversity in the Black Sea has declined about two-fold since the *Rapana* invasion in 1947. Gastropods in the Black Sea are represented by 115 species.

Among crustaceans, species of the Isopoda (30 species), Decapoda (40 species), and Amphipoda (110 species) orders are the most widespread (Kiseleva, 1979). The most notable changes in zoobenthos community of the 1980s and 1990s were in response to intensifying eutrophication and sustained organic enrichment of sediments, and resulted in lower species diversity, reduced abundance and biomass of benthic populations. Thus a more simplified community structure developed, which were mostly dominated by opportunistic and invasive species with high total abundance but low total biomass, increasing role of hypoxia-tolerant groups (bivalve molluscs) along with high fluctuations of populations (BSC, 2008).

Along the Turkish coasts of the Black Sea, which is the longest segment, diversity of zoobenthos is not known well. Bat et al. (2011) recorded 421 zoobenthic species, belonging 13 taxonomic groups present in the Turkish coast of the Black Sea.

The number of crustacean species found in the Turkish Black Sea comprises 69.8% of the total number of Black Sea species (Gonlugur et al., 2004). *Ulva rigida* facies, distributed along the Black Sea coastline, represents a habitat for 115 faunal species (Gonlugur and Katagan, 2004). Besides Ulva facies, the other suitable biotopes are *Cystoseira barbata* and *Mytilus galloprovincialis* for polychaetes (Cinar and Gonlugur, 2005). The review by Kurt Sahin and Cınar (2011) is an important study for the Black Sea as the authors discuss polychaete species distributions along all coasts of the Black Sea.
Fish

The Black Sea ichthyofauna includes nearly 200 species of cartilage and bony fish. Approximately three quarters of these are fully marine species of Atlantic, Mediterranean and Boreal Atlantic origin. This group includes important commercial pelagic planktivorous (e.g. sprat, anchovy) and predator (e.g. whiting, mackerel) species and demersal fish (e.g. turbot). The group of brackish-water fish includes 22 endemic and relicts that inhabit mainly the northwestern shelf waters and/or waters near the Kerch Strait. Diadromous and semi-diadromous fish comprise 25 species and all have been affected by human activity. The loss of spawning and nursery habitats, introduction of barriers to migration routes and over-exploitation has resulted in unfavourable status of many valuable species including sturgeon, salmon and herring. Overharvesting of Black Sea fish stocks, combined with the introduction of the predatory ctenophore *Mnemiopsis*, have made the Black Sea a classic study of fishery collapse, though there are recent signs of recovery (Kideys, 2002). Fishing bans in Turkey are often ignored or cut short as there are not enough qualified fisheries inspectors, and fish stocks risk being exhausted in a few decades (Senerdem, 2011).

Marine mammals

There are only four species of mammal in the Black Sea: three Cetacean (Odontocete) species - the bottlenose dolphin (*Tursiops truncatus ponticus*), the common dolphin (*Delphinus delphis ponticus*) and the harbour porpoise (*Phocaena phocaena relicta*) and one pinniped species, the monk seal (*Monachus monachus*) that is on the verge of extinction. The population of dolphins in the Black Sea decreased from 1 million in the 1950s to less than 50,000 – 100,000 by the end of the 1980s and has not recovered. Currently, the clearest threats affecting cetacean populations are accidental mortality in fishing gear; habitat degradation causing the reduction of prey resources; water pollution and epizootics resulting in cetacean mass mortality events (ACCOBAMS, 2012).

Sea Birds

The Black Sea is located on the intensive East European migratory bird route, which makes the ornithofauna very diverse. The river deltas, the numerous coastal swamps and lakes, the sea bays and the scattered islands in addition to the salubrious climate and the abundance of food provide conditions for nesting, migration and wintering of thousands of seabirds (Nankinov, 1996). The region’s seabird fauna includes gulls (*Larus*) and terns (*Sterna*), which is enriched by numerous species of sandpipers and ducks during migration seasons (BSC, 2007). More than 75% of the Black Sea birds are concentrated in the coastal area of Romania, Ukraine and the Russian Federation from the Danube Delta to the Tamansky
Peninsula in the Kerch Strait, and one third of their number inhabit the Danube Delta (BSC, 2007). In the Danube Delta there are 320 bird species including the most important species, the pygmy cormorant *Phalacrocorax pygmeus*, the red-breasted goose *Branta ruficollis*, the white pelican *Pelecanus onocrotalus* and the Dalmatian pelican *Pelecanus crispus*. Seabirds in the Black Sea region are protected in 22 parks and reserves [in Bulgaria (6), Romania (1), Russia (1), Ukraine (9), Georgia (2) and Turkey (3)] covering an area of 10,000 km² (Nankinov, 1996). The Southern Black Sea coast also holds internationally important populations of Yelkouan Shearwater (*Puffinus yelkouan*), and the Mediterranean sub-species of the European Shag (*Phalacrocorax aristotelis desmarestii*). *Puffinus yelkouan* has recently been upgraded on the IUCN Red List to ‘Near Threatened’. These two species are listed as Annex 1 species under the EU Birds Directive.

**Main human uses, pressures and impacts**

Six countries surround the Black Sea: Bulgaria, Georgia, Romania, Russia, Turkey and the Ukraine. Nearly 18 sectors operate within the region that are exploiting the marine resources and are contributing to the current status of the ecological components. Among them shipping, fishing, agriculture, tourism, land based industry and infrastructure are the most important human uses for an economic development of the region (Knight et al., 2011). Physical pressures associated with these activities include abrasion, substratum loss and the potential for smothering and underwater noise. Biological pressures include the introduction of non-indigenous species and translocations, selective extraction of target and non-target species and death or injury by collision. The main anthropogenic impacts are eutrophication resulting from agriculture and industrial activity which give rise to inputs of nitrogen, phosphorus and organic matter, inputs of synthetic compounds and particularly, inputs of non-synthetic compounds (BSC, 2008).

The northwestern shelf is the most impacted region of the Black Sea mainly because of discharges of the Danube, Dniepr and Dniester, which collect industrial, domestic, and agricultural runoff from catchments which are home to 162 million people (Mee, 1992). Nutrient surplus could lead to undesirable effects through eutrophication, which can result in ecosystem disturbance and loss of biodiversity (BSC, 2008). The discharges from rivers also deliver contaminants that accumulate in shallow sediments, which results in additional stress on the biota.

Alterations in nutrient ratios have led to a change in community structure of the phytoplankton. Intense and unregulated fishing has led to over-exploitation of major fish stocks with several commercial and non-commercial species in unfavourable status and/or declining in abundance. Some recovery of populations has been seen since the mid-1990s. Several marine mammal species in the Black Sea are endangered in terms of population size and distribution and have the potential to become extinct within the next 10 - 20 yr.
Much of the coastline has been subject to anthropogenic impacts resulting in a decline in diversity and reduction in status (despite extensive protection) of habitats and management plans.

Destructive fishing practices and over-exploitation have led to the decline of many benthic and pelagic fish species with stocks collapsing in the 1980s. Stocks have been slow to recover with several species under threat. Commercial fishing led to mass destabilization of the marine food web with the removal of important top predator fish species, which along with the anthropogenic eutrophication drive the cascading alterations in the ecosystem (Llope et al., 2011). This was a factor in the rapid expansion of the geographic range of the invasive ctenophore, *Mnemiopsis leidyi* and reductions in native plankton species (Knight et al., 2011).

In addition, the entire planktonic system has been affected by climatic signals (i.e. the severe climatic cooling regime of the 1980s followed by similarly strong warming regime of the 1990s and the early 2000s; Oguz et al., 2006, Moncheva et al., 2012). Climate records dating from the 1950s indicate that winter temperatures have decreased along the Black Sea coast since 1951, but summer temperatures have increased in the western and southeastern regions (Tayanc et al., 2009). Since the 1960s, heat wave intensity, length, and number have increased six to seven-fold (Kuglitsch et al., 2010). Autumn precipitation has increased in the interior and winter precipitation has declined in the more populated west.

A potential future threat is nuclear contamination (i.e. inputs of radionuclides) and thermal pollution (local change to the thermal regime) from Turkey’s first nuclear power plant to be constructed at Akkuyu, a seismically active area on the Mediterranean coast (Ozyurt et al., 2001; Cigna et al., 2002). A second plant is planned for Sinop on the Black Sea coast.

**Non-Indigenous Species**

Among the NIS of the Black Sea, more than two-thirds (68%) originate from the North Atlantic, 13% originate from the Indo-Pacific and 8% originate from the Western Pacific. The main entry point is through ship ballast waters (Zaitsev and Ozturk, 2001). The main negative ecological effects of NIS in the Black Sea ecosystem are:

- Competition with other organisms,
- Predation,
- Hybridisation,
- Providing a reservoir/vector for parasites and pathogens,
- Altering energy and nutrient flows (via nitrogen fixing),
- Altering the local food web (i.e. shifting from suspension-feeding to deposit feeding)
- Altering the composition and functioning of habitats and ecosystems (i.e. over growing and blocking water bodies).

Global Invasive Species (GISD) and the EU funded DAISIE are international and regional Invasive Alien Species (IAS) databases with considerable coverage. Each has the list of “Top 100 of the world’s worst invasive alien species”, however, the difference in the contents of these lists is considerable. A striking example is the comparison of marine species listed for the Black Sea. GISD lists only two marine species, the macroalgae *Polysiphonia brodie* (Rhodophyceae) and the microalgae *Alexandrium minutum* (Dinophyceae). Whereas DAISIE list five species, the barnacle *Balanus improvises*, the oyster *Crassostrea gigas*, the jellyfish *Mnemiopsis leidyi* nd Rapana venosa, and the mollusk rapa whelk.

Two non-native invasive species, *Rapana venosa* and *Mnemiopsis leidyi* have historically caused widespread problems in the region. The ctenophore *M. leidyi* affected the physical properties by reducing the water transparency, and more significantly the biological properties by causing a cascade effect up all trophic levels. Their strong grazing on zooplankton populations reduced food resources for planktivorous and predatory fishes, and favoured phytoplankton growth. It also supported microplankton growth through mucous excretion, which then led to more abundant bacteria population and thus its predator ciliates and zooflagellates (Shiganov et al., 2004). Despite a reduction in *Mnemiopsis leidyi* abundance after the introduction of *Beroe ovata*, the density and distribution of the species continue to cause impacts in the region.

According to Cinar et al. (2011), the list of alien macroalgae species from the Turkish coasts of the Black Sea are; from Rhodophyta *Asparagopsis armata*, *Colaconema codicola*, *Ganonema farinosum*, *Polysiphonia fucoides*, *Polysiphonia paniculata* from Heterokontophyta *Ectocarpus siliculosus* var. *hiemalis*, *Halothrix lumbricalis*, *Pylaiella littoralis*, *Punctaria tenuissima*, from Chlorophyta *Codium fragile* subsp. *Fragile*, *Ulva fasciata*.

### 2.3.2. The Sea of Marmara

Although the Sea of Marmara is not currently considered an EU marine area, and thus not legally obliged to implement the MSFD, it is of extreme ecological importance for both the Mediterranean and Black Sea to which it is connected. Therefore an overview was also included in this annex.

The Turkish Straits System (TSS, including the Bosphorus Straits, Sea of Marmara and Dardanelles Straits), together with the northeastern Aegean area, which is naturally connected, forms a “natural laboratory” with different water masses (Zervakis and Georgopoulos, 2002) (Figure 6).
Figure 6. Sea of Marmara.

The less saline, colder and lighter, mesotrophic Black Sea waters (BSW) are exported southwardly to the upper layer of the Sea of Marmara. The dense Mediterranean waters originate from the Levantine basin (Levantine Water, LW) of Aegean Sea and enter the Sea of Marmara basin through the Dardanelles Straits. These waters sink to a depth corresponding to its modified density and expand northwardly to the Black Sea, as a function of seasonal input flux variations and interior stratification (Besiktepe et al., 1994). As a result, the Sea of Marmara presents a two-layer stratification system, driven by the density difference between the Black Sea and the Aegean Sea waters. In the Black Sea, fresh water sources are of paramount importance for the two-layer stratification system. This is because in the Black Sea, the Danube itself contributes about 210 km$^3$ yr$^{-1}$ of water discharge, which is more than the entire freshwater supply to the North Sea. The Dnieper and Dniester additionally deliver approximately 60 km$^3$ yr$^{-1}$. In the opposite direction a halocline (of a thickness of 10–20 m) separates cool, nutrient rich, brackish waters (22–26) in the thin upper layer of the Sea of Marmara (15–20 m) from the saltier, warmer and nutrient poor waters (38.5–38.6) in the larger lower layer throughout the year (Bizsel, 1988; Besiktepe et al., 1994). The net inflow of fresh water to the Black Sea provides a barotropic pressure gradient across the Bosphorus, leading to southerly flow of less dense surface water. In the opposite direction an underflow of dense water arises due to baroclinic pressure difference caused by the salinity difference between the Sea of Marmara and the Black Sea. Along the way, the properties of the surface Black Sea water progressively change through diffusive mixing with the deeper layers of Levantine origin; referred to as modified Black Sea Water (MBSW).
The brackish Black Sea flow spends 4–5 months (on average) in the productive upper layer of the Sea of Marmara during its transit to the Aegean Sea. The underflow spends about 6–7 years in the deeper layers of the Marmara basin (Besiktepe et al., 1994).

The Sea of Marmara is an intercontinental basin with a complicated bathymetry, with some 11,500 km² and in area and total volume of 3,378 km³, in addition to the Bosphorus (average depth 35 m) which connects it to the Black Sea, and the Dardanelles (average depth about 50 m), which connects it to the Aegean Sea. There is a wide continental shelf (< 100 m depth) in the south, while in the north there are three depressions over 1000 m deep (maximum depth 1273 m in the central basin), separated by sills at around 700 m. The length of the Bosphorus strait is approximately 31.7 km. The width varies from 0.7 km to 3.5 km and the depth ranges from 25 m to 100 m (Yuksel et al., 2008). The water level difference between the Black Sea and the Sea of Marmara is on average 0.33 m. When the water level difference of Bosphorus Strait exceeds approximately 0.45 m, the lower layer flow will be blocked by the barotropic pressure gradient, whereas the upper layer flow will increase considerably and the velocity can reach 2.5 m/s in some parts of the strait. Where water level differences fall below ~0.10 m, (which typically occur during strong SW winds), the upper layer flow may be blocked (Besiktepe et al., 1994).

Studies carried out during 1990-1998 in the Sea of Marmara revealed that the average phosphate and nitrate concentration ranges in upper layers were respectively 0.02-0.25 μM and 0.02-4.10 μM (Coban-Yildiz et al., 2000). This is not only because of nutrient richness in the Black Sea originated upper layer waters during the period between the months of November and April, but also because of winter vertical mixing and seasonal deficiency in solar radiation. The average phosphate nitrate and reactive silicate concentration ranges in the lower layer were 0.7-1.1 μM, 7.8-10.7 μM and 32-39 μM respectively (Polat et al., 1998). The minimum values were usually recorded in the southern areas close to Dardanelles Strait while the maximums were recorded in the northern areas close to Bosphorus Strait.

Regarding particulate organic matter (POM) in the upper layer, the ranges of POC, PON and PP ranged between 10-35 μM, 0.4-4.5 μM and 0.05-0.45 μM during the period from 1990 to 1998 (Coban-Yildiz et al., 2000). The width (15-20 m) of the euphotic upper layer does not restrict POM content, instead it enriches POM as a storage unit or as a trap for sinking particles. The POM of the lower layer is mainly composed of the particles that penetrated and sunk from the upper layer and the bacteria that use these particles as substrates. The N:P ratio of the upper layer ranges between 7-12, which is similar for the lower layer, however with a slightly smaller range. The ratio is reasonably in balance with those of the Mediterranean (Polat et al., 1998; Coban-Yildiz et al., 2000). This reveals that primary production is limited by the nitrate and the low quantity of nitrogen content of the POM in the the lower layer. The annual flows of TN and TOC into the Sea of Marmara from the Black Sea (mainly river-borne C and N) are about three times of those flowing in opposite direction.
The depth of 1% surface irradiance in the NE Aegean Sea reaches the 80–100 m depth (Ignatiades et al., 2002) whereas in the Sea of Marmara the light penetration hardly exceeds 30 m (Ediger and Yilmaz, 1996). Solar radiation can only penetrate down to the depth of permanent halocline and thus, photosynthesis and related POM production are restricted to this depth. In the two-layered eutrophic system, the phytoplankton and detritus in the upper layer will gradually settle to the bottom layer and be degraded.

Although the Mediterranean originated lower layer of the Sea of Marmara is oxygen rich (7-9 mg L$^{-1}$) and has an average residence time of 6-7 years, the bacterial degradation of organic matter sinking from the upper layer causes rapid consumption of oxygen, resulting in persistent depression of oxygen to a concentration of 1-3 mg L$^{-1}$ in the lower layer of the Sea of Marmara (fish begin to escape at about 4 mg L$^{-1}$). The oxygen concentration can drop down to less than 1 mg L$^{-1}$ in the warmer waters along coastal areas particularly during the summer period. Despite the increase in biological production in the surface waters of the Sea of Marmara as result of the escalation in organic pollution level for last 30 years, dissolved oxygen levels are not significantly different from the levels observed in 1970’s and 1980’s (Bizsel, 1988).

The impact of pollution is more prominent in the upper layer of the Sea of Marmara, resulting in a decrease in the thickness of the euphotic layer and sudden drops in dissolved oxygen concentrations at depths just below the halocline (referred to as the “oxycline”; Tugrul et al., 2000). The level of pollution is briefly summarized below:

- The main sources of the pollution are untreated domestic and industrial discharges.
- Over 10,000 industrial establishments and human population over 25*10^6 are the main drivers creating intensive pressures on the ecosystem of the Sea of Marmara. Within the frame of domestic discharges, it has been noted that 32% of the municipalities around the Sea of Marmara do not currently have a sewage system. The very same ratio is also valid for the all along the Turkish coastlines, which comprises 1257 municipalities within 28 provinces.
- This ratio means that 537*10^6 m$^3$ untreated wastewater (~1.5*10^6 m$^3$ per day) out of 2*10^9 m$^3$ total wastewater (~56.7*10^6 m$^3$ per day) is discharged annually to the marine environments surrounding Turkey.
- In the Istanbul province, 4500-5000 industrial establishments discharge 3*10^5 m$^3$ wastewater per year, and 50% of this annual total is untreated.
- According to recent studies (Pekey et al., 2004; Pekey, 2006), Izmit Bay is the most prominent pollution hotspot in the Sea of Marmara.
- Moreover, the Sea of Marmara recieves daily inputs of heavy metals in high quantities such as 6.6 kg lead (Pb), 43.2 kg zinc (Zn), 1.9 kg copper (Cu), 209 kg chromium (Cr) and 5.1 kg mercury (Hg) in addition to 10.9 tons of nitrogen and 30.8 tons of solid wastes (www.bursa.bel.tr/marmara-ya-gunde-2-milyon-metrekup-evsel-atik-su-desarj-ediliyor/haber/10700).
- The total domestic discharge to the Sea of Marmara from the capital cities of eight provinces, including Istanbul, Bursa and Izmit, is 2.1*10^6 m$^3$. 


The chlorophyll maxima has been observed at 15 m, where the photic layer corresponds to the halocline. In general, the observed chlorophyll maxima in the upper layer, e.g. up to 10 μgL⁻¹ were recorded in February and March at depths where the light intensity ranges from 1 - 10 % of the surface equivalent (Polat et al., 1998).

The Sea of Marmara is characterized by eutrophication induced strong and extended phytoplankton blooms and complex ecosystem structure compared to the mesotrophic Aegean Sea and the oligotrophic Mediterranean Sea. Apparent decreasing trends in phytoplankton biomass, abundance and production from the Sea of Marmara to the NE Aegean Sea are remarkable (Zervoudaki et al., 2011). For centuries human activities in the Sea of Marmara have gradually intensified in the neritic waters (like in the whole Mediterranean Sea) and there has been a sharp increase in the frequency of blooms due to eutrophication. Toxic and harmful blooms were more widespread in the eastern Mediterranean, Aegean, and Black seas during and after the World War II (Nümann, 1955). At the end of 1950’s, only a few species of dinoflagellates were thought to produce red tides and harmful effects (Acara and Nalbantoglu, 1960). A review on plankton studies in the Sea of Marmara since 1990s (Balkis and Aktan, 2004; Uysal, 1995; Uysal and Unsal, 1996; Balkis, 2000; Balkis, 2003) and 11 toxic/nuisance phytoplanktonic species have been identified.

Harmful but non-toxic blooms are also very frequent in the eutrophic Black Sea, Sea of Marmara, and the eastern Aegean coasts. Mucilage formation was first observed in the Sea of Marmara in October 2007, where dozens of square kilometers of the sea surface was covered by mucilage (GFCM:SAC 13/2011/Inf.17).

Results have shown a decreasing pattern in phytoplankton abundance from August to October 2007, indicating the presence of high numbers of planktivorous species. In 2005, dense distributions of the non-indigenous jellyfish *Liriope tetraphylla* was detected at bloom levels, particularly in the northern parts of the sea. The dominance of this species over other macro-gelatinous species was 63%. The species outnumbered the most common and dominant species *Aurelia aurita* and *Mnemiopsis leidyi*, the latter of which caused a drastic collapse of Turkish fisheries in 1990’s. In October, following the mucilage matter production another new species for the region *Gonyaulax fragilis* was observed through the basin. Overfishing in the Sea of Marmara has provided a ground for invasive and/or opportunistic species and an increase in abundance of planktivorous species. As a result, *Liriope tetraphylla* became more dominant in the disturbed environment of the Sea of Marmara (Kideys et al., 2013).

The Sea of Marmara is populated by species from the North Atlantic (34%), East Atlantic (11.3%), West Pacific (33%), and Indo-Pacific (11.4%) regions. It is likely that most of these species were transported through ship ballast water, however some species, e.g. *Rhizosolenia calcar avis*, *Mnemiopsis leidyi*,...
Rapana thomassiana, Scapharca inaequalvis, may have been introduced with the water current from the Black Sea (Zaitsev and Öztürk, 2001).

There are five seagrass (Phanerogamae) species around Turkish coasts; Posidonia oceanica, Zostera noltii, Z. marina, Cymodocea nodosa, Halophila stipulacea. H. stipulacea is a non-indigenous lessepsian immigrant species, which entered in the region through the Suez Canal. This species has already extended in geographical range down to the Dardanelles Strait, but yet there is no record in the Sea of Marmara. There are also two indigenous Black Sea sea grasses: Ruppia spiralis and Potamogeton pectinatus. P. oceanica is very scarcely distributed in the Sea of Marmara. The first isolated bed of P. oceanica was recorded in the central southern part of the Sea of Marmara by Yüksel and Okus (2004). After that Meinesz et al. (2009) made the distribution map of P. oceanica at Dardanelle strait and the Sea of Marmara.

According to Dural and Aysel (2007), there are 815 macroalgae species including subspecies levels such as varieties around Turkish marine waters distributed in four major taxa, however there is no comprehensive study on their inventory and distribution in the Sea of Marmara. There are only some studies on the species which are of economic importance (Aysel and Gürer, 1979, 1980, 1982).

There is no research addressing the structure of macrozoobenthic communities in relation to environmental conditions in the Sea of Marmara. There are however a few studies on the taxonomy of certain benthic fauna. Bakır (2012) indentified 77 species of Crustacean and Palaz et al. (2010) identified 22 species (from 7 orders of 5 classes) of Crustacean in the southern part of the Sea of Marmara. Seven non-indigenous species of macroinvertebrates have been reported in the Sea of Marmara (Zaitsev and Ozturk, 2001). Since 2012, there has been an ongoing project monitoring the biodiversity and structure of benthic communities in the Sea of Marmara and straits, which is supported by Turkish Science and Technology Research Council (TUBITAK-111Y268).

According to the Turkish Environment Ministry, 30 years ago, only along the Bosphorus, there were approximately 60 fish species. Out of those 26 were economically valuable, such as bluefin tuna, blue fish, swordfish, sea bass, sea bream, picarel, and mackerel. Today, their number is estimated as 20 species and only 11 of those are economically important (http://www1.american.edu/ted/tunny.htm). More recent studies reveal that fish species in the Sea of Marmara declined from over 100 species in the 1960s to tens of species in the present day (Uras, 2006). Among the commercially important species, red porgy (Pagrus pagrus), leerfish (Lichia amia), forkbeard (Phycis phycis) are the most in demand. Nevertheless, the cause of the decline of these fish populations is not only related to overfishing, illegal fishing methods and ship originated pollution, but also to organic pollution, changing hydrological regime and other ecological factors. Regarding fisheries ecology, together with the straits the Sea of Marmara functions as a main
passage and nursery ground for migratory species such as mackerel (*Scomber scrombrus*), bonito (*Sarda sarda*), bluefin tuna (*Thunnus thynnus*), bluefish (*Pomatomus saltatrix*) and swordfish (*Xiphias gladius*).

**Hotspots:**

**Izmit Bay** is one of the most polluted and populated enclosed seas in Turkey. It has been the centre of industrial activities (more than 300 industries’ effluents) for the last 30 years. Pollution problems have occurred since 1960. Since then, because of eutrophication, red tides (mainly caused by *Prorocentrum* spp) and fish mortalities have been observed in some periods (Aktan, 2005). In 1999-2000, 14 toxic/nuisance phytoplankton species were observed: *Ceratium furca*, *Dinophysis acuminata*, *D. acuta*, *D. caudata*, *D. sacculus*, *Gymnodinium sanguineum*, *Lingulodinium polyedrum*, *Noctiluca scintillans*, *Phalacroma rotundatum*, *Prorocentrum micans*, *P. minimum*; and the diatoms *Pseudo-nitzschia delicatissima*. In addition to these species, *Prorocentrum lima* was also recorded as epipelic and epiphytic (on *Bryopsis hypnoides*, *Codium fragile*, *Cystoseira barbata* C. Agardh var. *barbata*, *Cymadocea nodosa* and *Zostera noltii*) in the littoral zone. *P. lima* is a benthic dinoflagellate usually found attached to or associated with macrophytes, floating detritus, debris or other substrates and less commonly in plankton (Aktan, 2005). Three major groups Dinoflagellata (about 60%), Diatom (about 25%) and others (about 15%) were determined during 2009-2010 period (Kucuk and Aytekin, 2011).

Four major mucilage events were recorded in Izmit Bay in the Sea of Marmara: October 2007, January 2008, September-October 2008 and December 2009. In almost all the recorded events, dinoflagellates were either more abundant or at comparable numbers with diatoms. Among them *Gonyaulax fragilis* or *Gonyaulax* sp. was dominant. In the Sea of Marmara, *Gonyaulax fragilis* produces mucus (Tüfekçi et al., 2010).

In spite of the severity of the impacts on the ecosystem state of the Sea of Marmara, there are also promising developments in some major hotspots such as Golden horn and Izmit Bay. Today, several recreational activities like swimming, sports fishing are possible in these spots after some large scale environmental management initiatives was started (Tolun et al., 2012). Signs of recovery like local increases in the number of fish species and decrease innt anoxic seabeds have been observed.
2.4. Mediterranean Sea

Introduction

This ecosystem overview aims to outline the main features of the Mediterranean Sea ecosystem from the point of view of biodiversity, habitats and impacts. The overview relies heavily on previous published work and reviews. This includes major regional resources (e.g. UNEP/MAP, 2009; UNEP/MAP-RAC/SPA, 2010a; UNEP/MAP-RAC-SPA, 2010b; UNEP/MAP, 2012a, 2012b), recent published biodiversity and impacts reviews (e.g. Coll et al., 2010, Danovaro et al., 2010, Coll et al., 2011, Micheli et al., 2013) as well as EU projects outputs (e.g. the DEVOTES Deliverable D.4.1, Piroddi et al., 2013; the ODEMM deliverable Knights et al., 2011 and the PERSEUS deliverable Laroche et al., 2013).

Key characteristics and habitats

The Mediterranean Sea extends from 30°N to 45°N and from 6°W to 36°E and constitutes the world’s largest (2,969,000 km²) and deepest (average 1,460 m, maximum 5,267 m) enclosed sea connected to the Atlantic Ocean by the Strait of Gibraltar in the west, to the Black Sea by the Bosphorus, and the Dardanelles in the north-east and to the Red Sea via the Suez Canal in the south-east (Figure 7), taken from Coll et al. 2010). Overall the basin is considered oligotrophic with some exceptions along coastal areas due mainly to river discharges (Barale and Gade, 2008). Phosphorus, rather than nitrogen, is the limiting nutrient. Biological productivity decreases from north to south and west to east whilst an opposite trend is observed for temperature and salinity. In particular, the mean sea surface temperature varies between 14–16°C (west to east) in winter, and maximum of about 20–26°C (again, west to east) in summer (with the exception of the shallow Adriatic Sea where the range is between the 8–10°C of winter and the 26–28°C of summer; Barale and Gade, 2008). Evaporation greatly exceeds precipitation and river runoff, and it increases from west to east, causing the water level to decrease and salinity to increase eastward (Coll et al., 2010). The Mediterranean Sea has a diverse continental shelf that varies from south (mainly narrow and steep) to north (wider areas); a few exceptions to this north-south rule are found, in the northern part concerning parts of the the Turkish coast, the Aegean, Ligurian and northern Alboran Seas and, in the southern part, in Tunisia and near the Nile Delta (Pinardi et al., 2006). Shelf waters represent 20% of the total Mediterranean, the rest is open sea (Coll et al., 2010).
The region comprised a wide array of habitats, including brackish water lagoons, estuaries, transitional areas, coastal plains, wetlands, rocky shores, sea grass meadows, coralligenous communities, upwellings, seamounts and pelagic systems (UNEP/MAP, 2012a). Most of the Mediterranean habitat research has been focused on priority, endangered, threatened and in need of conservation marine habitats. The most typical example is the *Posidonia* meadows, which is included in Annex I of the Habitat Directive, and in Annex II of the List of Endangered or Threatened Species of the SPA/BIO Protocol concerning specially protected areas and biological diversity in the Mediterranean under the Barcelona Convention. *Posidonia* is a EUNIS level-5 habitat (A5.535 *Posidonia* beds). Most of the recent habitat reviews/assessments recognize the lack of habitat data at grosser scales (e.g. EUNIS level 3) and at sea basin scales (Mangos et al., 2010). Mapping at EUNIS level 2 or 3 habitats, as appearing in many MSFD related documents is mostly lacking for the Mediterranean and especially so for the Eastern and Southern parts (but see EUSEaMap, 2010 for significant progress made for the Western Mediterranean). Although UNEP (2002) and MESMA (2010), have very detailed descriptions for some of these biotopes at EUNIS level 3 or 4 or 5 the spatial aspects are often missing.

The Mediterranean is considered as a hotspot of both terrestrial and marine biodiversity (Bianchi and Morri, 2000; Myers et al., 2000; Coll et al., 2010), hosting species of conservation priority, such as the bluefin tuna, *Thunnus thynnus*, and the Mediterranean monk seal, *Monachus monachus*, along with a high habitat diversity, such as meadows of the endemic *Posidonia oceanica*. *Posidonia* is one of the leading Mediterranean ecosystems in terms of both biodiversity and as an ecosystem goods and services provider.
including supporting a very high number of marine species of the region as well as spawning and refuge habitat functions for commercial species, and water oxygenation and beach erosion protection services (UNEP/MAP, 2009; Mangos et al., 2010). *Posidonia* occurs in shallow waters (mostly up to 50 m depths but occasionally deeper) in both soft and hard substrata and is found in most of the region although not everywhere (Giakoumi et al., 2013). *Posidonia* is considered a priority habitat under the EU Habitats Directive and the Barcelona Convention. The species and habitat is maybe the best studied and cited habitat in the region (UNEP/MAP, 2009) while its distribution and extent is still not fully documented or known despite most recent mapping and modelling efforts (e.g. MESMA Project: MESMA, 2010; Salomidi et al., 2012, MEDISEH Project: MEDISEH, 2013 and the NETMED Project: Giakoumi et al., 2013).

Coralline habitats harbour the most biologically rich communities in Europe (OCEANA, 2006). In the Mediterranean coral

Coralligenic formations or reefs or concretions are built up through the accumulation of calcareous algae (mainly corallinales of the *Mesophyllum* and *Pseudolithophyllum* type), which are common throughout the basin with the exception of the Israeli and Lebanese coasts, at a depth of between 40 and 120 m, but also closer to the surface in caves, on vertical walls and in poorly lit spots (Mangos et al., 2010). They provide a home for a vast range of sessile invertebrates (bryozoans, gorgonians, sponges) and comprise the second most important Mediterranean ecosystem in terms of biodiversity, with over 1,700 species, a high percentage of which are endemic. The species associated with the coralligenic reefs comprise 75% invertebrates, 19% macrophyte algae and numerous fish and small shark species. A large number of the species present are of commercial interest and their exploitation dates way back in history (e.g. sponges, red coral) (Mangos et al., 2010). Maërl beds, a type of coralline biogenic habitat, are comprised of unattached rhodolithes of coralline algae and the most important regional maërl-forming species are *Lithothamnion corallioides* and *Phymatolithon calcareum* (OCEANA, 2006).

Recognizing their importance and the need for habitat restoration the COUNCIL REGULATION (21 1967/2006 EC) concerning management measures of the sustainable exploitation of fishery resources in the Mediterranean Sea, prohibits fishing with trawls and other towed gears above beds of *Posidonia oceanica* or other marine phanerogams, or above coralligenous habitats and maërl beds. The regulation calls Member States to take appropriate steps to ensure the collection of scientific information with a view to the identification of habitats to be protected. However, knowledge and mapping gaps along with the drive for growth, prevent full implementation of this regulation.

While the Mediterranean Sea is one of the most intensively investigated areas of the world in terms of both terrestrial and coastal marine biodiversity, it lags behind other regions of the world in studies of its
deep-sea habitats and fauna (Danovaro et al., 2010). Beyond the 100 m isobath, open seas in the Mediterranean cover over 200000 sqkm (Mangos et al., 2010) and a very significant part of its waters are characterised as deep sea (depths from over 200 m and stretching to over 5000 m) supporting a variety of habitats including open slopes, deep basins, canyons, cold seeps, seamounts, deep-water corals and deep-hypersaline anoxic basins. The Mediterranean deep sea hosts numerous sites of conservation interest as seen in recent proposals (UNEP/MAP-RAC-SPA, 2010b; OCEANA, 2011). A number of recent EU Projects such as CoralFISH, HERMES & HERMIONE have contributed to the identification and mapping of vulnerable habitats such as deep sea cold water reefs and other deep sea biotopes in the Mediterranean.

**Key biodiversity components**

Currently approximately 17,000 species have been recorded in the Mediterranean Sea with a gradient of species richness that decreases from northwest to southeast (Bianchi and Morri, 2000; Coll et al., 2010). Of these 17000 species, at least 26% are prokaryotic (Bacteria and Archaea) and eukaryotic (Protists) marine microbes. All biodiversity components, except Bacteria and Archaea, display a decreasing pattern with increasing water depth, but to a different extent for each component (Danovaro et al., 2010).

Phytoplankton is composed predominantly of Coccolithophores, Dinoflagellata and Bacillariophyceae and includes more than 1500 species [the majority of which come from Dinoflagellata (45%) and Bacillariophyceae (49%)]; macrophytes on the other hand are approximately 850 species with Rhodophyta constituting the most important taxonomic group (77%) followed by Chlorophyta (22%) and Magnoliophyta (1%). Among microzooplankton, foraminifera is the main group with more than 600 species.

Generally, small phytoplankton taxa are the main contributors to biomass and production in the eastern Mediterranean and in the north and south Aegean Sea (Polat, 2006; Ignatiades et al., 2002; Siokou-Frangou et al., 2002). Usually, these ultra (or pico) phytoplankton are relatively numerous towards the bottom of the euphotic zone or in deep chlorophyll maxima (DCM). There is some evidence that they are adapted to low light in the green region of the spectrum (Glover et al., 1984). Heterotrophic microciliates may be important consumers of bacteria and ultra-phytoplankton.

Epipelagic mesozooplankton communities in the open Mediterranean Sea are highly diversified in terms of taxonomic composition, but copepods represent the major group both in terms of abundance and biomass. The dominance of small copepods (≤1mm) in terms of both numbers and biomass represents the major feature of the structure of mesozooplankton communities at the basin level. A few small-sized and species-rich genera of calanoids (Clausocalanus and Calocalanus, together with Ctenocalanus vanus) and cyclooids (Oithona, oncaeid, corycaeids) account for the bulk of copepod abundance and biomass
in epipelagic layers of the Mediterranean Sea (Seguin et al., 1994; Siokou-Frangou et al., 1997; Saiz et al., 1999; Andersen et al., 2001; Youssara and Gaudy, 2001; Gaudy et al., 2003; Fernandez de Puelles et al., 2003; Mazzocchi et al., 2003; Riandey et al., 2005; Licandro and Icardi, 2009). West-to-east differences in the percentage contribution of some important species to the whole copepod assemblage might reflect differences in species biogeography, but might also be indicative of different structural and functional features of these systems.

The majority of species (~11500) are within the Animalia with the greatest contributions coming from the Crustacea (13.2%) and Mollusca (12.4%) followed by Annelida (6.6%), Plathelminthes (5.9%) and Cnidaria (4.5%) (Coll et al., 2010). Annelida, Mollusca and Crustacea contribute to the Mediterranean fauna with approximately 5500 species (Coll et al., 2010) while a total of 337 zoobenthic species within three main groups Polychaeta, Mollusca and Crustacea are reported along the Levantine coast of Turkey (Cinar et al., 2012). There are 650 marine species of fishes of which approximately 80 are elasmobranchs and the rest are mainly from the class Actinopterygii (86%) (Coll et al., 2010). In the Eastern Mediterranean, due to the east-west gradient of both salinity and temperature, fish diversity decreases (Abdul Malak et al., 2011). There are 43 other vertebrate species comprising mammals, reptiles and birds. Nine species of marine mammals (five belong to the Delphinidae, and one each to the Ziphiidae, Physeteridae, Balaenopteridae, and Phocidae) and three species of sea turtles (the green Chelonia mydas, the loggerhead Caretta caretta and leatherback Dermochelys coriacea turtle), are encountered regularly in the Mediterranean Sea. Of these sea turtles, the green and loggerhead also nest in the eastern part of the basin. Regarding seabirds only 15 species occur in the Mediterranean Sea, ten are gulls and terns (Charadriiformes), four are shearwaters and storm petrels (Procellariiformes), and one is a shag (Pelecaniformes) (Coll et al., 2010).

Out of five biodiversity components (Plankton, Fish, Marine Mammals, Reptiles, Seabirds), and Species listed under the Habitats Directive, Marine Mammals, Reptiles and Species listed under the Habitats Directive were scored as being at high risk of failing to achieve GEnS in the Mediterranean Sea (Table 3), Knights et al., 2011; Breen et al., 2012). A large number of species are characterised as being under threat, including the world’s most endangered pinniped, the critically endangered Mediterranean monk seal along with a number of threatened species of sea turtles, whales, dolphins, skates, sharks and rays; several of which are at critical risk of extinction (Cuttelod et al., 2009; UNEP/MAP, 2009; Abdul Malak et al., 2011).
Table 3. A summary of Areas of Concern, Risks to GEnS, and Confidence in Risk Assessment of GEnS Descriptors in the Mediterranean Sea, from ODEMM Project (Knights et al. 2011). In RED as high risk: Mammals, NIS, D3, D4, D6, Marine litter, Underwater noise and Habitats Directive species and habitats. *Indicates a pressure assessment approach was used, either in part of in its entirety, to evaluate the descriptor.

<table>
<thead>
<tr>
<th>GES Descriptor</th>
<th>Problems</th>
<th>Areas of Concern</th>
<th>Risks to GES</th>
<th>Risk Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a. Plankton</td>
<td>Yes</td>
<td>Alterations in the dominance of plankton species are ongoing, but no notable or maintained changes are occurring.</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>1b. Fish</td>
<td>Yes</td>
<td>30 species of carnivorous fish in the Mediterranean Sea are current threatened with as many as 75% of bony fish outside safe biological limits. Trends indicate a decline in the abundance of many species.</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>1c. Marine Mammals &amp; reptiles</td>
<td>Yes</td>
<td>Several species of marine mammal and reptiles are currently threatened (IUCN criteria) with rates of decline in abundance and distributional range suggesting those species may be lost within the next 20 years.</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>1d. Seabirds</td>
<td>Yes</td>
<td>60% of Annex II SPA-BID species (Barcelona Convention) are listed as threatened or endangered shown by reducing population (breeding) sizes, however, these species are not currently expected to be lost</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>1e. Predominant Habitats</td>
<td>Yes</td>
<td>Nearly all predominant habitat types in the Mediterranean are declining or exhibiting some degree of degradation with many in poor, endangered or unfavourable status.</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>2. Non-indigenous species (NIS)*</td>
<td>Yes</td>
<td>There are a considerable number of invasive species in the Mediterranean that have resulted in widespread negative impacts on native species. Introductions continue to occur as a result of shipping, mariculture and entry via the Suez canal.</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>3. Commercial fish and shellfish</td>
<td>Yes</td>
<td>More than 25% are explored beyond sustainable levels, with most key pelagic and demersal species over-exploited and at high risk of stock collapse. Contributing factors include unregulated fishing practices, lack of enforcement, illegal gears and fishing and absence of management or protection measures.</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>4. Food webs</td>
<td>Yes</td>
<td>The prevalence of invasive jellyfish species and structure of top predators suggests that the Mediterranean food web is in an advanced state of degradation.</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>5. Eutrophication*</td>
<td>Yes</td>
<td>Algal blooms, hypoxia, eutrophication hot spots coupled with local oxygen deficiencies are of some concern, but due to low nutrient inputs and given the large area of the basin, eutrophication is a problem limited to sheltered marine waters such as harbours or bays and not expected to be of concern in the next two decades.</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>6. Seafood integrity*</td>
<td>Yes</td>
<td>Human activities such as agriculture, coastal infrastructure, fishing, navigational dredging, non-renewable energy (oil &amp; gas), shipping, and tourism and recreation contribute widespread and persistent pressures that have detrimental effects on several aspects of the Mediterranean Sea ecosystem.</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>7. Hydrographic conditions*</td>
<td>Yes</td>
<td>Increases in sea surface and bottom temperatures indicate warming sea in conjunction with continued ocean acidification and increases in pCO₂</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>8. Contaminants</td>
<td>Yes</td>
<td>Heavy concentrations of some heavy metals are present in the region and concentrations continue to rise from transport introductions, however, other contaminants are declining e.g. Pb and PAHs.</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>9. Fish and Shellfish Contamination</td>
<td>Yes</td>
<td>Concentrations of Mercury currently exceed benchmark dose limits (BMDL) and some heavy metals are high in concentration, but they occur from natural sources.</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>10. Marine Litter*</td>
<td>Yes</td>
<td>More than 111 species of seabird and several species of marine mammals and reptiles have been reported to ingest marine debris. Although the amount of litter (number of items and mass) has reduced, shoreline and recreational activities continue to discard large volumes of litter into the marine environment.</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>11. Energy (Underwater noise)*</td>
<td>Yes</td>
<td>Trends indicate an increase in shipping activity leading to an increase in underwater noise throughout the region.</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>12. Habitats Directive Habitats</td>
<td>Yes</td>
<td>35% of habitats are in unfavourable status under at least one assessment criterion and over 40% declining in some aspect (e.g. range, area, structure and function, or future prospects). There is considerable uncertainty of the status of many habitats.</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>12. Habitats Directive Species</td>
<td>Yes</td>
<td>&gt;50% of species are in unfavourable condition, with many species exhibiting declines across all assessment criteria (range, population size, habitat, and future prospects).</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>
Human uses, pressures and impacts

Historical and current pressures have caused major shifts in Mediterranean marine ecosystems and the region has been characterised as a sea «under siege» (Galil, 2000; Lotze et al., 2006; Coll et al., 2011; Micheli et al., 2013). With its densely populated and well visited coasts, over the centuries, this basin has been always subjected to human activities affecting/threatening its marine diversity. The most important threats in the region are habitat loss and degradation (through urbanization, industrialization, coastal infrastructure, shipping and tourism), pollution (including litter), harmful algal blooms, invasive species, overexploitation of marine resources, fisheries related impacts (unsustainable fishing practices, bycatches and discards, illegal fishing) as well as climate change (UNEP/MAP, 2009; Coll et al., 2010; Costello et al., 2010).

Currently, habitat degradation and loss is considered to be the most widespread threat due mainly to coastal development and pollution which are responsible for reducing the extent of marine habitats (e.g., seagrass meadows, oyster reefs and macroalgal beds) and a variety of dependent benthic organisms (such as, bryozoans, sponges, echinoderms, benthic decapods) (Coll et al., 2010). At least one third of the Habitats listed under the Habitats Directive are in unfavourable conservation status and predominant habitats exposed to a multitude of pressures are assessed as being at high and moderate risk of failure to achieving GEnS under the MSFD (Knights et al., 2011; Breen et al., 2012). The Mediterranean Sea is subject to pollution by sources either from land or from the sea; those related to land are relevant to agricultural, urban and industrial activities, while those related to the sea mostly concern maritime traffic activities. Chemical contamination of sediments and biota, along with the impact of marine litter (concentrated especially in shallow areas) and eutrophication, localized in semi-enclosed basins are regarded as issues of great concern across the Mediterranean due to their harmful impacts on the environment (UNEP/MAP, 2012a). Pollution affects are of great concern not only for benthic organisms and their habitats but also for species at the top of the food web (Borrell et al., 1997; Giangrande et al., 2005; Sanpera et al., 2007). In terms of eutrophication, although the Mediterranean is regarded as an oligotrophic basin, in coastal areas of large cities the impacts of nutrients and organic enrichment are more significant, especially in cases where waste waters are poorly treated. The North-western Mediterranean and the Adriatic Sea are considered as areas of high concern due to the impacts that organic contaminants in sediments have on benthic communities. Marine litter pollution is an emerging issue in the Mediterranean region, and most studies show that it is mostly accumulated in bays and coastal areas rather than in the open sea (Galgani et al., 2010; Koutsodendris et al., 2008).

Exploitation of marine species is another important threat to marine biodiversity. In the Mediterranean Sea, several fish, macrophytes and a variety of invertebrates are highly exploited or overexploited (Papaconstantinou and Farrugio, 2000; Lleonart and Maynou, 2003). Additionally, unsustainable
exploitation affects many of the commercially exploited fish stocks of the Mediterranean, causing shifts in species diversity, community structure and, thus affecting ecological processes. During the last half-century the mean trophic level of Mediterranean catches declined by about one trophic level, placing a great impact upon marine food webs by reducing the abundance of large predator species (Pauly et al., 1998).

Bottom fishing and dredging have important impacts on the structure of benthic communities and seafloor integrity, contributing to the degradation of the Mediterranean ecosystems (UNEP/MAP, 2012b). Deep water corals such as *Leptometa phalangium*, *Funiculina quadrangularis* and *Isidella elongata* are among the most vulnerable species to this kind of impact in open seas (UNEP/MAP, 2012b). Fisheries also affect marine mammals, sea turtles and seabirds directly and indirectly through by-catch, direct killing and prey depletion (Tudela, 2004). Under IUCN criteria, several species of marine mammals and reptiles are currently threatened and suffering considerable declines (Reeves and Notarbartolo di Sciara, 2006; Cuttelod et al., 2009). Chondrichthians (sharks, rays and chimeras) are at particular risk with at least 40% of these classified as threatened under IUCN criteria (Cavanagh and Gibson, 2007).

Sea based activities result in higher scores in the western and southern regions, while land-based activities broadly affect coastal areas and large portions of the Adriatic (Micheli et al., 2013). Areas of potential high cumulative threats are widespread in both the western and eastern basins, with fewer areas located in the south-eastern region. A number of spatially variable, high threat sector-pressure combinations have been identified in the region depending on their extent, frequency and severity of impacts along with resilience and persistence parameters (Knights et al., 2011, Table 4). Spatial overlap of areas of both high biodiversity and high threats to various biodiversity components is seen in both the western and eastern basins (Figure 8), while climatic drivers have the greatest impact scores in the Eastern Mediterranean (Coll et al., 2011; Micheli et al., 2013).

As most of these anthropogenic pressures are expected to increase (Coll et al., 2010), it is expected that future monitoring will shed more light on their impacts and allow for robust conclusions.
### Table 4. High threat sector-pressure combinations in all predominant habitat types in the Mediterranean Sea. (Source ODEMM Project, from Knights et al., 2011).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Extent</th>
<th>Frequency</th>
<th>Degree of Impact*</th>
<th>Resilience</th>
<th>Persistence</th>
</tr>
</thead>
<tbody>
<tr>
<td>106 High Threat Pressure Combination identified</td>
<td>1. Widespread</td>
<td>1. N/A</td>
<td>1. Acute/Chronic</td>
<td>N/A</td>
<td>1. Continuous/High</td>
</tr>
<tr>
<td></td>
<td>2. Widespread</td>
<td>2. Persistence/Common/Occasional</td>
<td>2. Acute</td>
<td>N/A</td>
<td>2. N/A</td>
</tr>
<tr>
<td></td>
<td>3. Widespread</td>
<td>3. Persistent/Common</td>
<td>3. Chronic</td>
<td>N/A</td>
<td>3. N/A</td>
</tr>
</tbody>
</table>

#### Summary of High Threat Sectors:

- **Combination 1**: Sectors include Aquaculture, Coastal Infrastructure, Fishing, Shipping, Non-renewable energy (oil and gas) and Tourism/Recreation.

- **Combination 2**: Sectors include Agriculture, Aquaculture, Coastal Infrastructure, Fishing, Navigational dredging, Non-renewable energy (oil and gas), and Tourism/Recreation.
  - **Pressures**: Abrasion, Introduction of synthetic compounds, Marine litter, Selective extraction of non-living resources, Selective extraction of species, Smothering and Substrate loss.

- **Combination 3**: Sectors include Aggregates, Agriculture, Aquaculture, Coastal Infrastructures, Fishing, Non-renewable energy (oil and gas), Shipping and Tourism/Recreation.

* Acute and chronic degree of impact is defined as having a detrimental effect on the habitat or its characteristic species (i.e. loss, removal or mortality)

### Figure 8. Areas of conservation concern where high biodiversity and high threats to biodiversity components overlap (overlap ranging from a) around 25%, b) equal/over 50% and c) equal/over 75%), from Coll et al., 2011.
Non-indigenous species

Bioinvasions and the increasing establishment of alien species is the recent of the most important regional pressures (Coll et al., 2010; UNEP/MAP, 2012a). To date, nearly 1,000 alien marine species have been introduced in the Mediterranean, of which more than half are considered to be established and spreading (Zenetos et al., 2010, 2012). Marine alien species may become invasive and displace native species, cause the loss of native genotypes, modify habitats, change community structure, affect food-web properties and ecosystem processes, impede the provision of ecosystem services, impact human health, and cause substantial economic losses (Wallentinus and Nyberg, 2007; Vilà et al., 2009). The five dominant groups among alien species are Mollusca (with 215 species), followed by Crustacea (159), Polychaeta (132), Macrophyta (128) and Fish (126). The majority of aliens occur in the eastern Mediterranean (775), whereas a lower number of species is present in the western and central parts of the basin (308 and 249 respectively), and even lower in the Adriatic Sea (190) (Zenetos et al., 2012). In terms of alien species richness there is a marked gradient from southeast to northwest. Very few alien species have been reported in offshore areas so far. More than half (54%) of the marine alien species in the Mediterranean Sea were probably introduced by corridors (mainly Suez Canal). Shipping is the second most common pathway of introduction (49%), followed by aquaculture (12%) and the aquarium trade (2%). The impact of invasive alien species in the Mediterranean has been severe and in some cases has greatly affected keystone species or entire ecosystem processes, while many alien species are considered habitat engineers and creators of novel habitats. For example several biotopes are affected by the coarse sea grape Caulerpa racemosa var. cylindracea, (Klein and Verlaque, 2008; Katsanevakis et al., 2010).

The analysis of the spatial distribution and severity of these anthropogenic pressures shows the most severely impacted subregions or eco-regions by single stressors or cumulatively. The Levantine Sea is severely impacted by bioinvasions, and the Alboran and the Levantine regions have the highest average cumulative impacts (Coll et al., 2010, 2011; Micheli et al., 2013). Data on recent introductions of alien species (e.g. last decade) and trends since the 1950’s in the temporal and spatial distribution of alien invasion in the Mediterranean clearly show the increased pressure for the Eastern Mediterranean MSFD subregion (Zenetos et al., 2012, Figure 9).
Figure 9. Non indigenous species trends in the Mediterranean (from Zenetos et al., 2012.)
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Website links:

DEVOTES project: http://www.devotes-project.eu/
EUSeaMap (Mapping European seabed habitats): http://jncc.defra.gov.uk/page-6266
MeshAtlantic Project: www.meshatlantic.eu
BSC Black Sea Phytoplankton checklist: http://phyto.bss.ibss.org.ua