THE EUROPEAN ENVIRONMENT

STATE AND OUTLOOK 2010

MARINE AND COASTAL ENVIRONMENT

European Environment Agency

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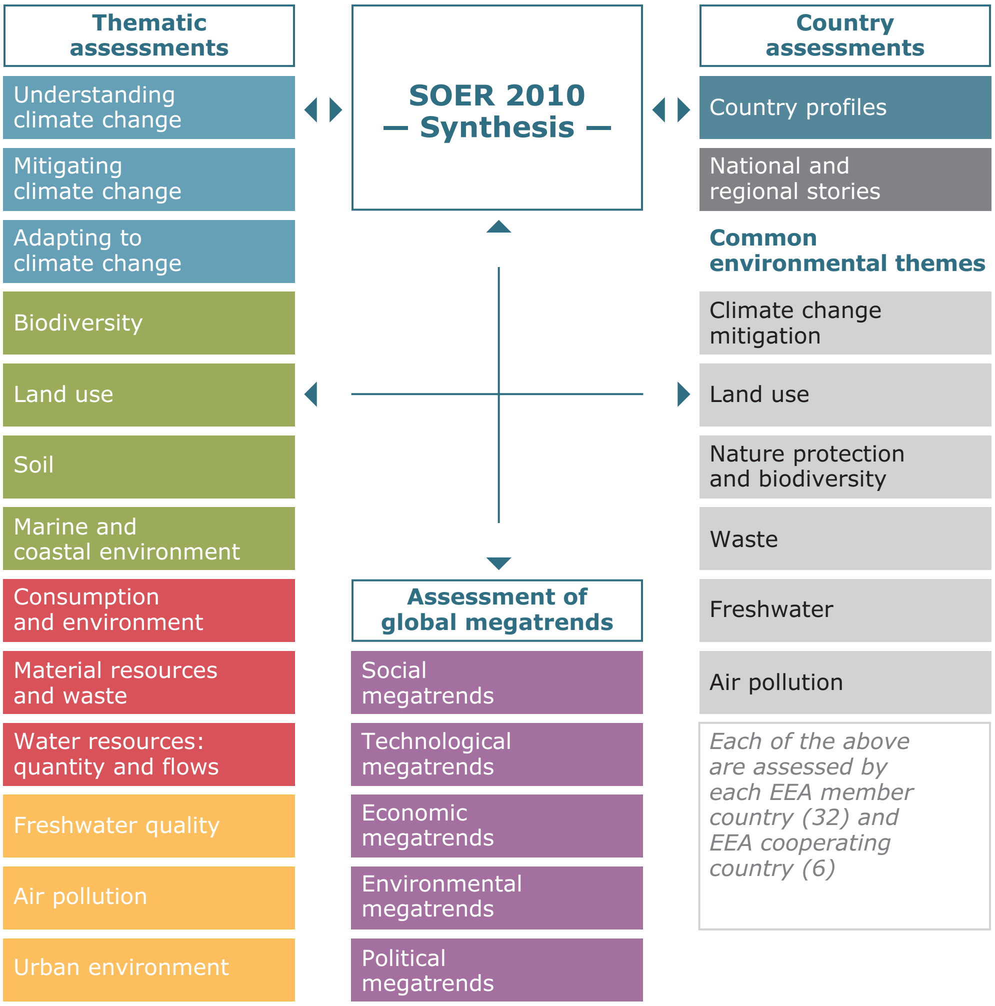

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Marine and coastal environment

Summary

European marine regions include the north-east Atlantic and Arctic oceans, and the Mediterranean, Black and Baltic seas. Human activities — such as fishing, aquaculture and agriculture — and climate change cause large and severe impacts on Europe's coastal and marine ecosystems. The EU objective of halting biodiversity loss by 2010 has not been met in either the coastal or the marine environment. Recognising the need for an integrated ecosystem-based approach to reduce pressures, the EU Integrated Maritime Policy allows for the development of sea-related activities in a sustainable manner. Its environmental pillar, the Marine Strategy Framework Directive, aims to deliver 'good environmental status' of the marine environment by 2020, and the Common Fisheries Policy will be reformed in 2012 with the aim of achieving sustainable fisheries. Complementary policy efforts include the EU Water Framework Directive and other freshwater legislation, and the Habitats and Birds Directives.

Drivers and impacts

The impacts on Europe's seas and coasts are driven by human activities such as fishing and aquaculture, land-based activities such as fertiliser and pesticide use in agriculture, chemical pollution from industries and shipping, and the exploitation of oil, gas and other resources. Further negative factors include the introduction of alien species, marine litter, noise, urbanisation and tourism, and the destruction of habitats for ports and off-shore structures. Many of these impacts are exacerbated by climate change.

As a result, the ecosystem services provided by Europe's seas and coasts are deteriorating, including a decline in goods such as fish and recreational quality. Examples of impacts include the risk of ecosystem collapse (which has occurred in the Black and Baltic seas), toxic algae blooms, anoxic water (i.e. oxygen depleted), destruction of habitats, invasions of new species and chemical pollution of seafood.

Fishing pressures in most of Europe's seas exceed sustainable levels and safe biological limits (SBL), and since 1985, there has been a general decline in fish catches. The capacity of European fishing fleets has also not been sufficiently reduced to be in balance with available fish resources. As a result, 30 % of Europe's commercial fish stocks are now fished beyond SBL, and in 2010, 70 % of commercial stocks were fished above maximum sustainable yield. Other pressures include: by-catch; the destruction of sea-floor habitats; and illegal, unreported and unregulated fishing.

European aquaculture production has increased over the past 15 years, driven by the combined effects of decreased wild catches and increased demand for fish. Impacts include discharges of nutrients, antibiotics and fungicides, the potential for the 'genetic pollution' of wild species, and an increase in the fishing mortality of wild stocks used for feed.

Human activities on land can result in marine pollution from fertilisers and pesticides used in agriculture, sewage and industrial waste. Excess nutrients can create 'eutrophication' which can lead to the depletion of oxygen and loss of life in bottom waters. In spite of measures to reduce nutrient concentrations in European seas, 85 % of measurement stations show no change in nitrogen concentrations and 80 % show no change in phosphorous concentrations. Oxygen depletion is particularly serious in the Baltic and Black seas.

Toxic chemicals, while on a downward trend, are found in high concentrations in fish and shellfish in most of Europe. Pollution also includes illegal oil discharges and accidental oil spills from ships, although the phase-out of single-hull oil tankers has facilitated a significant decrease in accidental oil spills. Invasive species are introduced, for example, through ship ballast water discharge or aquaculture, sometimes causing serious ecosystem damage. Marine litter — commonly plastics — and noise are also growing concerns.

Climate change has increased ecosystem vulnerability. Sea surface temperature changes in Europe's regional seas have been up to six times greater than in the global oceans in the past 25 years. Consequences include reduced Arctic sea ice coverage, sea-level rise, and increasing ocean acidification due to rising atmospheric CO_2 levels. Temperature increases are changing the composition of plankton and some fish species, thus changing fishing opportunities in European seas. In the future, less sea ice will ease access to the Arctic's resources and could result in both new economic opportunities and additional environmental pressures.

Response

European policies governing the coastal and marine environment now widely include the ecosystem-based approach — a strategy for the integrated management of activities on land, at sea and of living resources that promotes conservation and sustainable use, and which addresses the combined effects of multiple pressures.

The European Union's (EU) Marine Strategy Framework Directive (MSFD) aims at 'good environmental status' of EU marine waters by 2020, while allowing for the sustainable use of marine goods and services. The MSFD is seen as the environmental pillar of the EU Integrated Maritime Policy which aims to provide a policy framework aligning the sustainable development of activities in seas with conservation objectives — including the implementation of conservation objectives in the Common Fisheries Policy (CFP) as called for in a recent European Commission Green Paper for CFP reform.

EU water legislation, including the Water Framework Directive (WFD), Urban Waste Water Treatment Directive and Nitrates Directive, will help to improve the quality of freshwater (e.g. by reducing nutrient and chemical pollution) before it enters coastal waters.

Through the Natura 2000 network of protected sites (under the EU Habitats and Birds Directives), designated marine sites are primarily found close to the coasts. Only 8 % and 11 % of coastal habitats and species, respectively, and 10 % and 2 % of marine habitats and species, respectively, are in favourable conservation status. The remaining majority of habitats and species either have unfavorable conservation status or are un-assessed. Species here include some of the most threatened plants, reptiles, mammals and fish in Europe's seas.

1 Introduction

Although not always immediately apparent, our wellbeing as humans is affected by the environmental state of our seas, because many aspects of our lives benefit from the goods and services provided by well-functioning marine and coastal ecosystems. These ecosystem services offer a multitude of opportunities to provide an income for people for instance through production of fish and shellfish for human consumption or an environment suitable for tourism and recreation.

Environmental impacts in European seas, which affect the marine ecosystem in many different ways, are driven by a large number of human activities including agriculture; fisheries and aquaculture; industry; shipping; urbanisation; tourism; space demand for ports and off-shore structures; and oil, gas and other mineral extraction. As a result, the ecosystem services provided by the marine environment deteriorate, that is the ecological functions that are a result of the interactions between organisms in the sea and their physical, and chemical environment deteriorate. This can lead to the disruption of habitat or marine food web functioning that can have amplified and cascading effects within the ecosystem, and may ultimately cause an ecosystem to collapse. Other manifestations of impacts vary from nuisance to toxic algae blooms, anoxic water, destruction of habitats, chemical pollution of sea food, changed geographical distributions of commercially relevant species and destructive species invasions — which when combined increase ecosystem vulnerability to changes. Many impacts are expected to be exacerbated by increased sea temperatures, rising sea levels, and ocean acidification that are the consequences of global warming and increased CO_2 concentration of the atmosphere. The impacts lead to a decline of the goods — such as fish — and services including recreational quality provided by the coast and seas. While many of the activities that harm the environment are a consequence of immediate human needs, they impact species and habitats that have evolved over thousands if not millions of years, sometimes irreversibly.

The aftermath of the financial crisis calls for future transformations towards more eco-efficient economies. This will increase the use of resources at sea for new industries linked for example to renewable energy or sustainable tourism, thus promoting the development of more environmentally friendly technologies, products and services. This is expected to reduce some of the environmental pressures known today, provided that an ecosystem-based approach is in place.

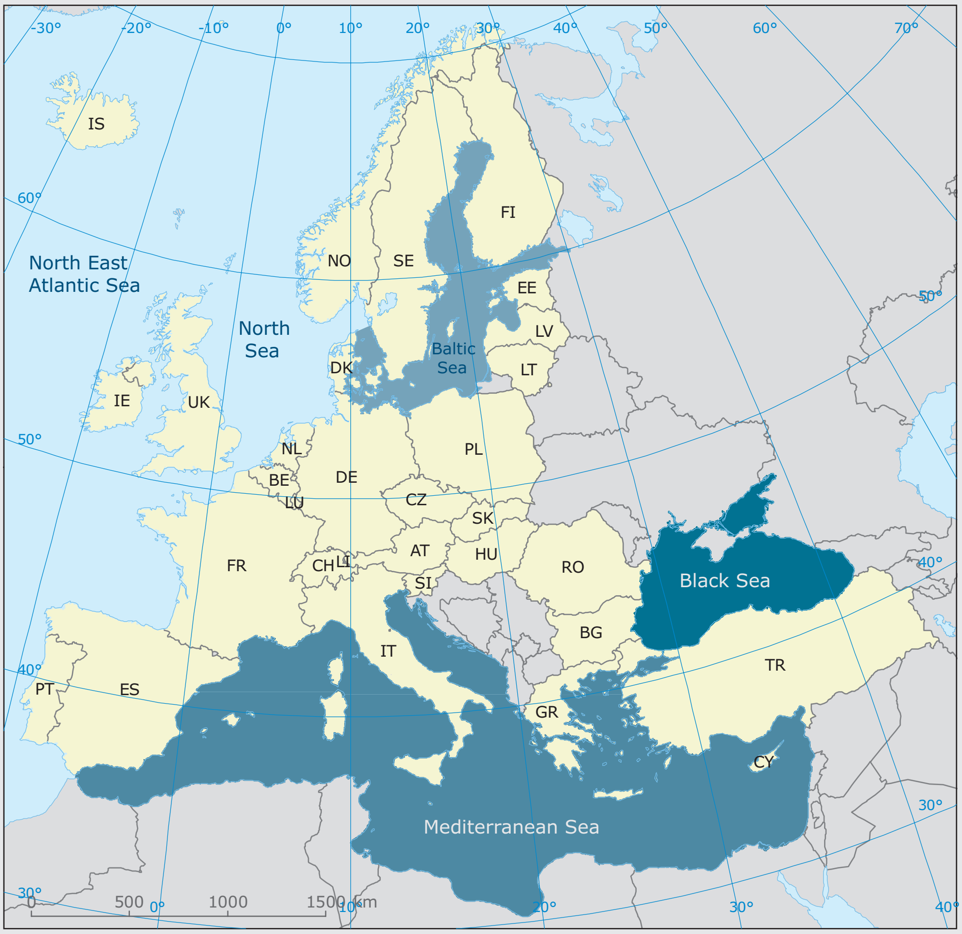
As a consequence of these concerns, it has long been recognised by the global community that a strategy for integrated management of activities on land, at sea and of living resources to promote conservation and sustainable

Box 1.1 Some interesting facts about Europe's seas and coasts

- The maritime areas under the jurisdiction of EU Member States are larger than the total land area of the EU;
- The EU has a coastline of 68 000 km — that is more than three times longer than that of the United States and almost twice that of Russia. When EEA member countries Turkey, Iceland and Norway are also included, the coastline length is 185 000 km;
- Almost half of the EU's population lives less than 50 km from the sea, the majority concentrated in urban areas along the coast. In 2001, 70 million people or 14 % of the entire EU population lived within 500 meters of the coast.
- The sea is Europe's most popular holiday destination: 63 % European holiday makers choose the seaside as their holiday destination. For example, Europe has an estimated 8–10 million anglers fishing for sport or pleasure at sea supporting an industry of EUR 8–10 billion per year;
- Economic assets within 500 meters of the sea have an estimated value between EUR 500–1 000 billion;
- EU public expenditure on coastline protection from the risk of erosion and flooding is expected to reach EUR 5.4 billion a year for the period 1990–2020.

Source: EC, 2006.

Box 1.2 Regional sea characteristics



Europe's seas include the Baltic, North East Atlantic, Black, and Mediterranean Seas. The North East Atlantic includes the North Sea, but also the Arctic and Barents Seas, the Irish Sea, and the Celtic Sea, Bay of Biscay and Iberian Coast.

The Baltic Sea is semi enclosed with low salinity due to restricted water exchange with the North East Atlantic and large river run-off. These conditions make the sea particularly vulnerable to nutrient pollution.

The Black Sea is also semi enclosed; it is the world's largest inland basin with restricted water exchange with the Mediterranean. Its waters are anoxic at depths below 150–200 meters. Surface water salinities of the Black Sea are within an intermediate range. Most of the Black Sea is believed to host oil and gas reserves, and oil and gas exploration is beginning in the area.

The Mediterranean Sea is also a semi enclosed sea with high salinity due to high evaporation rates and low river run-off. It has restricted water exchange with the Atlantic and Black Sea. It is the most biologically diverse sea in Europe.

The North East Atlantic covers a range of seas and a large climatic gradient. It is a highly productive area that hosts the most valuable fishing areas of Europe and many unique habitats and ecosystems. It is also home to Europe's largest oil and gas reserves.

The coast is the area defined by the coming together of the land and the sea. Based on Corine Land Cover data from 2000, in the 24 EEA coastal countries there is 560 000 km^2 of coastal zones corresponding to 13 % of the total land mass of these countries (EEA, 2006).

The deep sea and sea floor forms an extensive and complex system which is linked to the rest of the planet in exchanges of matter, energy and biodiversity. The functioning of deep sea ecosystems is crucial to global biogeochemical cycles upon which much terrestrial life, and human civilization, depends. It is found both in European and international waters of the Atlantic and in the Arctic Ocean. Usually the deep sea refers to depths greater than 400 meters (Weaver et al, 2009).

use was needed (Earth Summit, 1992). This management strategy is also often referred to as the ecosystem-based approach to management and is now widely implemented in European policies governing the coastal and marine environment — in line with commitments under the 6th Environment Action Programme (6EAP): the Integrated Maritime Policy, and its environmental pillar the Marine Strategy Framework Directive (MSFD) (EC, 2008c), the Water Framework Directive (WFD) (EC, 2000), the Habitats and Birds Directives (EC, 1979; 1992), and possibly in the upcoming 2012 reform of the Common Fisheries Policy (CFP).

Two of these policies, however, have future targets for their environmental improvements. The MSFD has a target to deliver good environmental status of Europe's seas in 2020, and the WFD aims to deliver good ecological status of coastal and transitional waters in 2015. Environmentally responsible strategies for the use of space at sea and on the coast are being developed for specific locations under the Habitats Directive and more generally under Maritime Spatial Planning and Integrated Coastal Zone Management, currently on a voluntary basis. The obligation to promote conservation and sustainable use of living resources embedded in the ecosystem approach implies that conservation objectives should increasingly set the boundaries for sustainable use of the natural environment. The concrete manifestation of the ecosystem-based approach for Europe's seas is, however, yet to be developed among EU Member States.

This assessment covers aspects of the marine and coastal environment in all four European marine regions: the North East Atlantic Ocean — which includes the Arctic — the Mediterranean, Black and Baltic Seas (Box 1.2). It lends support to the need of an ecosystem-based approach for managing the marine and coastal environment by reporting data and information extracted from a growing body of evidence, which shows that human activities are having large and severe impacts on marine and coastal ecosystems in Europe. Finally, it briefly reviews the means available within European legislation to achieve this approach.

2 State of marine and coastal ecosystems

2.1 State of ecosystems

Marine ecosystems are a complex of habitats defined by the wide range of physical, chemical, and geological variations that are found in the sea. Habitats range from highly productive near shore regions to the deep sea floor, only inhabited by highly specialised organisms. Habitats are found on the sea floor as well as in the water column where plants and animals follow the ocean currents. Protection of habitats from physical destruction is vital to the survival of some of the most threatened coastal and marine species, but also to the general health of marine ecosystems.

Within marine ecosystems, plants and animals have adapted in a multitude of ways to satisfy their basic life cycle needs: food, shelter, and reproduction. Interactions, particularly those linked to feeding habits, are described as the marine food-web. Broadly, primary produces — zooplankton — small predators and large predators form the different levels of the marine food chain, while feeding preferences are described in a marine food web (Figure 2.1).

In European seas there are infinite unique ways in which the marine food web functions, often developed over thousands of years in adaptation to a very specific set of local conditions. Although the basic components are the same in all seas the pathways of interaction between different species are diverse and sometimes non-linear — a seemingly small change can have a large impact. Most of these pathways are also not well understood and thus there are many examples of human actions that have inadvertently had catastrophic consequences for marine ecosystems. Most environmental problems in Europe's seas are a consequence of disturbance to the functioning of one or several elements of the food-web. This is the case for problems related to pollution, fisheries, and climate change.

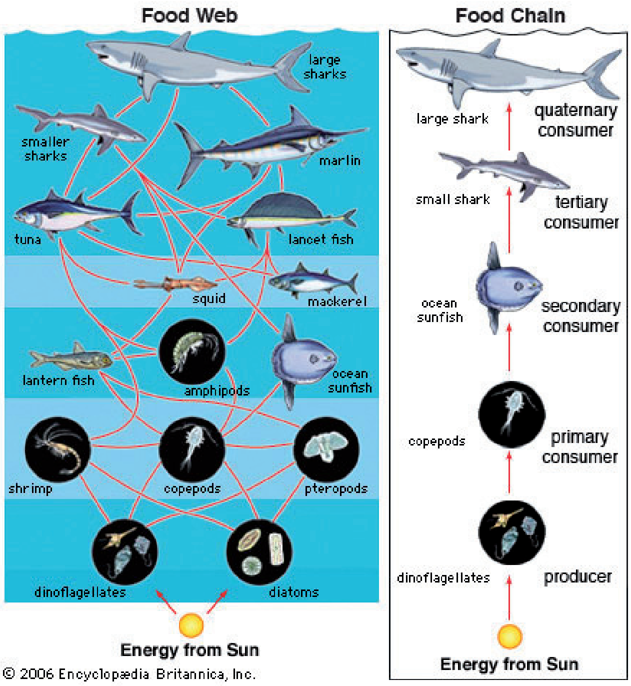
Ecosystem shifts — a consequence of multiple impacts

Multiple impacts that shift the balance of an entire ecosystem have been observed in Black Sea and in the Baltic Sea and are at risk of occurring in the North Sea and in the Arctic. These shifts were all due to several pressures acting on the marine ecosystem simultaneously, fundamentally changing its functioning in those seas. Such changes are difficult to predict, but when they occur they disrupt important ecosystem services and have significant economic consequences. In the Mediterranean Sea and in the deep sea, the risk of an ecosystem shift has not been assessed, but those ecosystems are also subject to multiple large pressures, implying a potential risk.

Black Sea

The collapse of the anchovy stocks in the Black Sea in the late 1980s was originally explained by the invasion of the alien ctenophore *Mnemiopsis leidyi* (Oguz, 2007; Oguz and Gilbert, 2007; Oguz et al., 2008). However, a recent model-based study has indicated that the story is more complicated and that over-fishing played a major role in this ecosystem shift. By the mid-1980s the system was characterised by high anchovy biomass and moderate gelatinous biomass — mainly *Mnemiopsis leidyi* — due to the high competitive advantage of anchovy on the zooplankton resource consumption. At the same time high nutrient inputs from the River Danube resulted in hypoxia and the subsequent collapse of benthic habitats on the North Western Shelf (Langmead et al., 2009). The combined effects of a climate change-induced

Figure 2.1 The marine food web



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temperature increase and the nutrient enrichment together and over-fishing of the anchovy reversed the system to high gelatinous biomass and low anchovy biomass in the late 1980s (Oguz et al., 2008). Following the economic collapse of the socialist republics in the early 1990s, nutrient loading was reduced in the Danube, and the ecosystem started to recover (Langmead et al., 2009). This, among other causes, has created less favourable environmental conditions for *Mnemiopsis leidyi* which is further supported by the presence of another accidentally introduced species, *Beroe ovata,* that feeds on the zooplankton (Mutlu, 2009), and the anchovy fisheries have since recovered. However, *Mnemiopsis leidyi* has since spread to the Mediterranean, the North Sea and the Baltic Sea. This has been of particular concern in the Baltic Sea, but it has recently been shown that *Mnemiopsis leidyi* is not able to reproduce in the low temperature and salinity conditions and proliferation is only likely in the southern Baltic Sea (Lehtiniemi et al., 2007, 2010).

Baltic Sea

An ecosystem shift has also been documented in the Baltic Sea which is subject to excessive nutrient pollution while being a relatively low-complexity ecosystem characterised by low species diversity and a simple food web. Möllmann et al. (2009) show how a sequence of impacts has led to fundamental changes in the Baltic Sea ecosystem. In the mid 1980s cod fisheries in the sea collapsed. It is thought this occurred as a consequence of a climate change-induced shift in the salinity and temperature. In parallel, nutrient levels increased as a consequence of historic land-based inputs and their long residence time in the Baltic Sea system leading to low oxygen conditions of the sea. Combined, these effects led to less favourable conditions for cod reproduction. As fishing continued at high levels the cod stock became depleted, and the community changed from cod-dominated to reliance on herring and sprat (MacKenzie and Köster, 2004). Because sprat has a higher reproductive capacity than cod and fishing pressure on cod has remained high relative to its reproductive capacity the ecosystem has not recovered although environmental conditions would favour a recovery (Möllmann et al., 2009).

North Sea

In the North Sea, concern is particularly aimed at the combined consequences of increased sea temperatures and fishing. The decline in cod stocks in recent years is mainly due to high fishing pressure, but there is also concern that this species is particularly vulnerable to climate change because it has a very well defined thermal niche (Pörtner and Farrell, 2008). It has been documented that the quality of food — zooplankton — available for larval cod has a large impact of its reproductive success (Beaugrand and Kirby, 2010). Cod in the North Sea are at the southern edge of their distribution and the abundance of a specific zooplankton — *Calanus finmarchicus* — is associated with high probability of cod occurrence. Increasing temperatures in the North East Atlantic are acting to shift the distribution of temperate plankton species further northward (Beaugrand et al., 2002). Consequently, a decrease or even collapse of cod at the southern margin of their distribution such as in the North Sea could be triggered by climate change effects alone (Beaugrand and Kirby, 2010) while the high fishing pressure on it, is increasing its vulnerability.

Mediterranean

The Mediterranean is a biodiversity hot-spot. Over 50 % of marine species there originate from the Atlantic Ocean, 17 % from the Red Sea, including ancient species and more recently introduced species following the installation of the Suez Canal, and 4 % are relic species (UNEP, 2009). Diversity is essentially concentrated in the west of the basin and at shallow depths — up to 50 m. Two remarkable ecosystems, *Posidonia* and coral beds, can be found in coastal zones. There is no extensive knowledge on off-shore ecosystems as study programmes only cover coastal ecosystems (UNEP, 2009). As mentioned previously, the risk of an ecosystem shift has not been assessed, but its ecosystems are also subject to multiple large pressures.

Arctic

Arctic summer sea ice is likely to continue to shrink in extent and thickness, leaving larger areas of open water for an extended period whereas winter sea ice will still cover large areas (EEA, 2008b). The speed of change, however, is uncertain. Several recent international assessments concluded that mostly ice-free late summers might occur by the end of the 21st century (IPCC, 2007a). Sea ice is an ecosystem filled with life uniquely adapted to the prevailing conditions, from micro-organisms in channels and pores within the ice, and rich algal communities underneath it, to fish, seals, whales and polar bears. The diversity of life in the ice usually increases with the age of the ice floes. As the ice gets younger and smaller, the abundance of ice-associated species is reduced, with a risk of extinction for some of them, and with the possibility of large ecosystem changes as a consequence. Some of these species are a food source for other species that indigenous Arctic people target for fishing and hunting, and these people are likely to face large economic, social and cultural changes.

The deep sea

The deep sea waters and sea floor hosts abundant and highly diverse life forms and ecosystems which form an extensive and complex system linked to the rest of the planet in exchanges of matter, energy and biodiversity. The functioning of deep-sea ecosystems is crucial to global biogeochemical cycles upon which much terrestrial life, and human civilization, depends (Danovaro et al., 2008). In addition to cold water coral reefs, there are a wide variety of habitats in the deep, notably seamounts, canyons, sponge fields, hydrothermal vents, and cold seeps.

Notwithstanding its remoteness and relative inaccessibility, the deep sea is far from pristine and untouched. We are now witnessing increasing direct and indirect anthropogenic pressures and impacts on these environments (van den Hove and Moreau, 2007; Davies et al., 2007). Direct anthropogenic pressures come from past and current human activities such as deep water fishing, in particular bottom trawling; oil and gas exploration and production; submarine cable laying; military activities; shipping; scientific research; bioprospecting; dumping of waste; off shore structures; wrecks and World War 2 ammunition. Pressure and impacts may also emerge from future activities such as carbon sequestration below the seabed, mining or gas hydrates extraction. In addition, indirect pressure comes from pollution from land-based activities, atmospheric deposition of elements and contaminants, climate change and ocean acidification. The resulting impacts have consequences in terms of loss of biodiversity and of the flow of deep-sea ecosystem goods and services provided by these environments (Armstrong et al., 2010).

2.2 State of protected habitats and species

Protection of some species and habitats within coastal and marine ecosystems is accomplished by identifying sites where human activities should be restricted and by assessing the conservation status in agreement with provisions in the Habitats and Birds Directives. Together the Habitats and Birds Directives form the cornerstone of Europe's nature conservation policy. The aim of the Birds Directive (EEC, 1979) is to provide for the protection, management and control of naturally occurring wild birds and their nests, eggs and habitats within the EU. In particular it seeks to protect all wild birds and the habitats of listed species through the designation of specially protected areas (SPAs), which are incorporated in the Natura 2000 network established by the Habitats Directive (EEC, 1992). The Habitats Directive has the objective of achieving and maintaining favourable conservation status for the listed habitat types and species according to their distribution over the whole territory of a Member State. It requires Member States to designate sites and to develop a strict system of protection for habitat types and species listed in its Annexes. These directives thereby establish the Natura 2000 network of protected sites, which includes Sites of Community Interest (SCIs) and SPAs. The implementation of the Habitats and Birds Directives specifically requires designation of marine SCIs and SPAs in the Natura 2000 network. The designation and management of new marine Natura 2000 sites is also included as one of the measures to be taken to maintain or achieve Good Environmental Status under the MSFD.

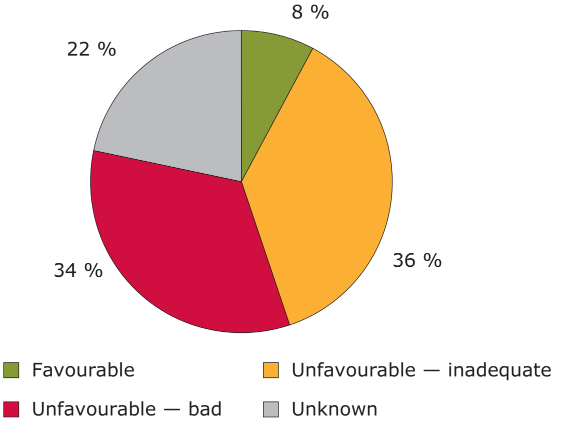
Designation of marine Natura 2000 sites

Although the Habitats and Birds Directives aim at protecting some of the most vulnerable species and habitats in the marine environment, the designation of marine Natura 2000 sites has been considerably slower than the designation of terrestrial sites. Recently, however, there has been an increase and in May 2010, about 165 000 km^2 marine Natura 2000 sites had been designated (EC, 2010c). Most of the designated marine Natura 2000 sites — approximately 75 % of the designated area — are located within 12 nautical miles of the coast and a coherent network of offshore areas is particularly absent (Map 2.1). In addition the marine network is much less comprehensive than the terrestrial one: in 2010, marine sites account for only 20 % of the total designated area in Europe.

State of coastal habitats and species

Habitat types and species in need of protection are identified in Annexes I, II, IV and V of the Habitats Directive. Of those habitat types and species, 50 habitat types (EC, 2010f) and 130 species are considered coastal — both aquatic and terrestrial habitats and species. Assessments of their conservations status have been made based on data reported by Member States as part of the HD Article 17 requirements. For coastal habitats, only 8 % have a favourable conservation status, and most of these are found on the inland side of the coast. Seventy per cent of habitats are in an unfavourable condition, and for 22 % their status is unknown, implying that no assessment has been made (Figure 2.2). For example, no favourable assessments have been made of coastal habitats in the Atlantic region or in the marine Atlantic, Baltic or Mediterranean regions (EC, 2010f).

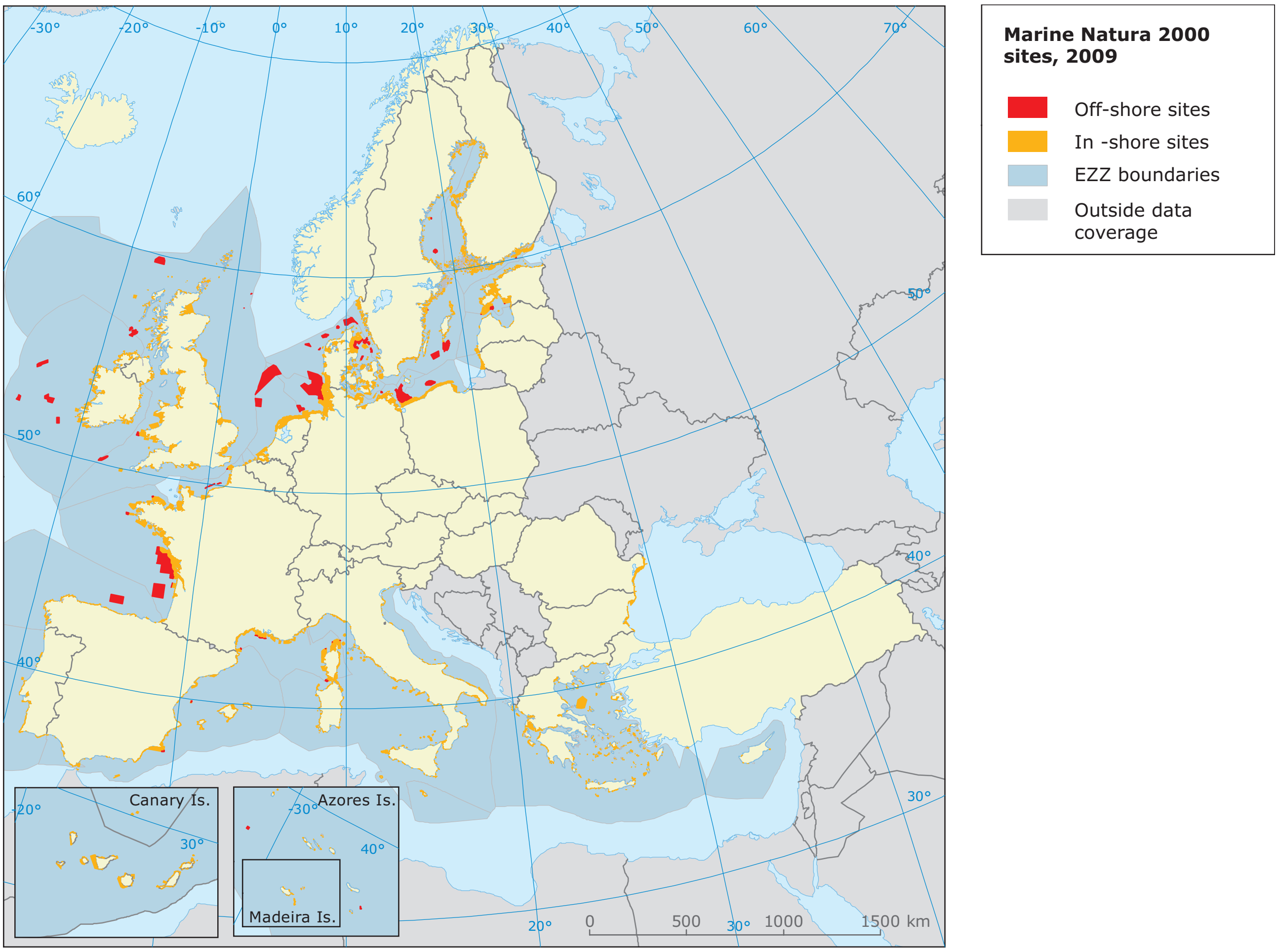
Figure 2.2 **Conservation status of 50 coastal habitats**



Note: Statistics are based on 139 assessments. Geographical coverage: EU except Romania and Bulgaria.

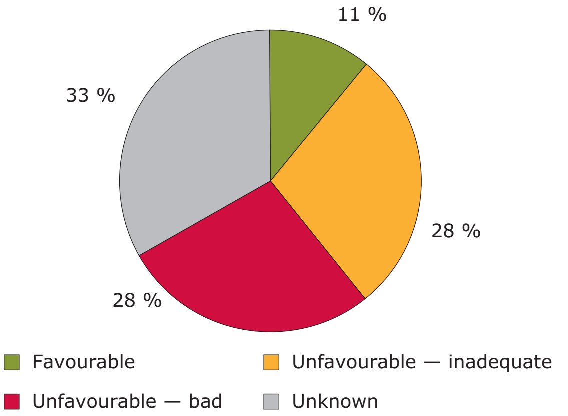
Source: EEA/ETC-BD database 2008.

Map 2.1 In-shore (within 12 nautical miles) and off-shore Natura 2000 sites



Source: EEA.

Figure 2.3 Distribution of outcomes of assessments of species of European interest in coastal ecosystems



Note: Statistics are based on 189 assessments. Geographical coverage: EU except Romania and Bulgaria.

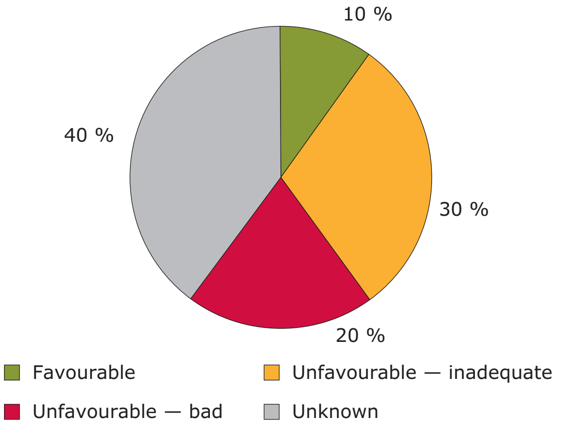
Source: EEA/ETC-BD database 2008.

For coastal species, only 11 % are in favourable condition, 56 % of the assessments indicate unfavourable conservations status, and 33 % of the assessments indicate unknown conservation status (Figure 2.3). There are no favourable assessments of the Atlantic, marine Baltic, marine Macaronesian or the marine Mediterranean biogeographical regions (EC, 2010f). The species with an unfavourable conservation status include the most threatened fish, invertebrates, mammals, plants and reptiles in Europe.

State of marine habitats and species

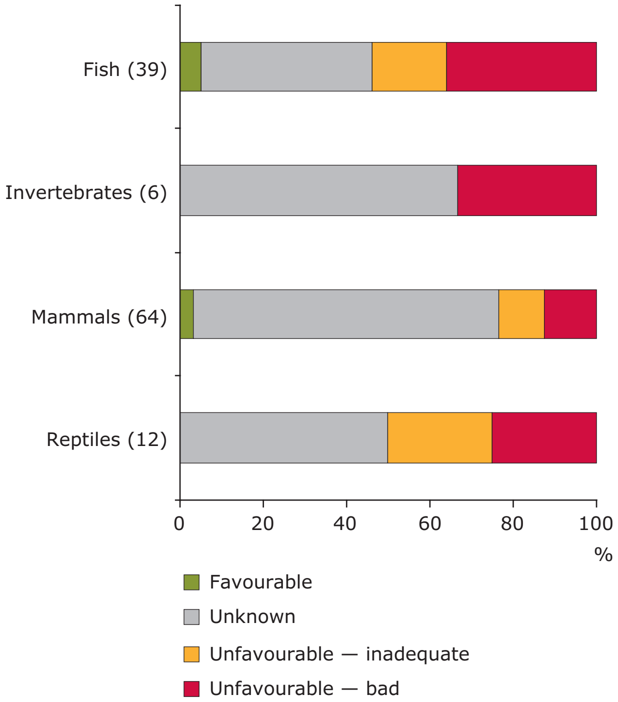
A much smaller selection of the HD Annex I habitat types are considered marine; only 6 types are grouped into this category including: sandbanks, *Posidonia* beds, large shallow inlets and bays, reefs, submarine structures made by leaking gases, and sea caves. Where marine species and habitat types have been assessed, the majority were found to be in an unfavourable or unknown condition; only 10 % of habitats and 2 % of species had a favourable status (Figures 2.4 and 2.5). The species known to have

Figure 2.4 **Conservation status of marine habitats**



Source: EEA/ETC-BD database 2008.

Figure 2.5 **Conservation status of species of European interest in marine habitats**



Source: EEA/ETC-BD database 2008.

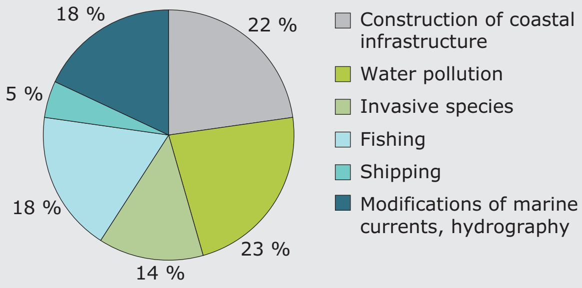
Box 2.1 Seagrass meadows as an indicator of a well-functioning marine ecosystem

Seagrass meadows represent some of the most productive ecosystems on Earth. They are sources of primary and secondary production, carbon sequestration, and oxygen production (Boudouresque et al., 2009). For example, it is estimated that 1 m^2 of seagrass meadow contributes to the production of 14 litres of oxygen per day. Seagrass meadows also reduce the hydrodynamic force of waves and thus protect the coast (Boudouresque et al., 2009).

Posidonia oceanica is distributed along almost the entire Mediterranean coastline with more than 400 plant species and thousands of animal species hosted within their beds. Indeed, these meadows are spawning and nursery areas for many species of economic interest such as crustaceans, molluscs, and fish. They also provide protection from predators, thereby promoting the survival of juveniles and benefiting a range of commercial species (Boudouresque et al., 2009).

Posidonia beds are specifically mentioned as a natural habitat type the conservation of which requires the designation of special areas of conservation (EEC, 1992). In spite of this, recent data suggests that *Posidonia* beds are under threat. The reporting process carried out by the Mediterranean Member States under the Habitats Directive indicates that the general conservation status of this habitat type in the Mediterranean is unfavourable/ inadequate (EC, 2009c). The clustered main threats that are affecting the long-term viability of *Posidonia oceanica* meadows in an overlapping manner include water pollution, construction of coastal infrastructure, fishing, shipping, invasive species, and changes to water currents.

Figure 2.6 **Foreseen threats to *Posidonia* oceanica beds grouped by activity as reported by Mediterranean EU Member States under the EU Habitats Directive**



Source: ETC/BD source, 2009.

Box 2.2 Example of protection needs of deep sea habitats

The North East Atlantic is home to the cold water coral *Lophelia pertusa*, a key species in vulnerable marine habitats and often found in deeper parts of the sea. Coral grounds appear to act as a habitat for many species; including fish of commercial value. The branches of corals also act as a refuge for many deep-water species and are populated by distinct microbial communities. Invertebrates such as brittle stars, sea stars and feathery crinoids live directly on the coral colonies, and smaller animals burrow into the skeletons. Corals have gradually been destroyed by trawlers that drag their nets or long lines over the sea floor (Fosså et al., 2002). Since the late 1990s, an increasing number of fisheries have been closed to protect these habitats. Prominent examples of such closures include the Darwin Mounds that were specifically protected in 2003, and parts of the Rockall Bank in EU waters have been protected since 2007 (ICES, 2009).

Natura 2000 sites have to include protection of habitat-type reef and require identification of more specific conservation objectives such as the conservation of *Lophelia pertusa*. When fishery closures are needed of sites located in EU waters — including Natura 2000 sites — they are managed under the CFP because the measure of protection needed involves regulation of fisheries for example in the form of establishing no-take zones. Unfortunately, this is a rather long and cumbersome process (EC, 2010d; De Santo and Jones, 2007), sometimes delaying pressing conservation needs.

For the closed sites, vessel activity is monitored using satellites, which allows adjustment of the no-take area to more accurately cover the habitat area. These kinds of adjustment have turned out to be the key to achieving good compliance, even by international fleets in remote areas (Hall-Spencer et al., 2009). Yet many issues remain in relation to enforcement and compliance, in particular with regards to availability of human activity data and Vessel Monitoring System (VMS) requirements (Benn et al., 2010).

a favourable status are a small fraction of the protected fish and mammals. The status of protected reptiles and invertebrates is either unfavourable or bad (Figure 2.5). Information is also sparse — the status 40 % of the habitat types and 74 % of species being classed as unknown.

While the information presented in this section refers specifically to protected habitats and species, it is also a reflection of the generally low level of information available regarding habitats and species in the marine environment. The marine environment is diverse but it is also inaccessible and expensive to study and thus fundamental data and time series are lacking for most of the plants and animals living in the sea. However, in the sea, it is not possible to only protect selected plants and animals. In general, survival of these species will require that most elements of the marine ecosystem are healthy because life forms in the sea are very inter-connected. Hence the pressures on protected species and habitats that stem from climate change, pollution, fisheries, and expansion of human activities, are the same pressures deteriorating the entire marine ecosystem. The MSFD objective to deliver good environmental status for Europe's seas should be seen in this wide context.

3 Impacts of climate change

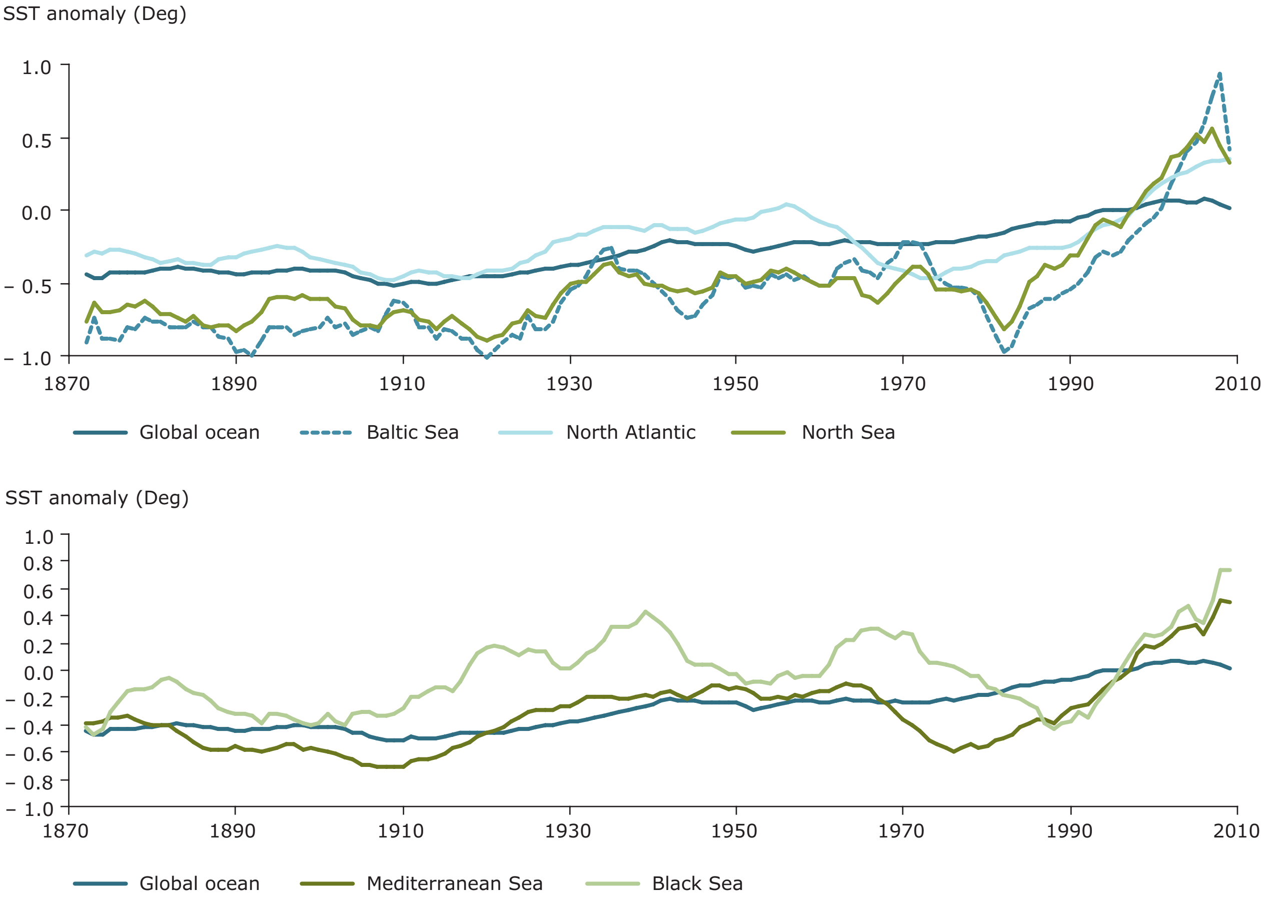
3.1 Sea surface temperatures

Most marine life is sensitive to temperature and many organisms have life cycles adapted to a certain temperature range. Sea surface temperatures (SST) are increasing in Europe's seas. The changes have been up to six times greater than in the global oceans in the past 25 years. The most rapid warming trend is in the Baltic and North Seas, while the rates are lower in the Black and Mediterranean Seas. Such changes have not been observed in any other 25-year period since systematic observations started more than a century ago (Figure 3.1).

Increasing temperatures in Europe's seas are resulting in a northward shift of the distribution of plankton at the bottom of the marine food chain, which in return affects the distribution of other species higher up the chain. In the Baltic Sea, increased precipitation is expected to change the salinity balance, also fundamental to the life forms found in that area.

Several studies in Europe confirm that marine fish and invertebrate species respond to ocean warming by shifting their latitudinal and depth ranges (Cheung et al., 2009). Higher water temperatures changed the composition of

Figure 3.1 Changes in sea surface temperature of European seas



Note: Data show the difference between annual average temperatures and the 1982–2010 mean in different seas.

Source: Global data: Hadley Centre — HADISST1; Mediterranean Sea: MOON; Baltic and North Seas: Bundesamt für Seeschifffahrt und Hydrographie (Coppini et al., 2010).

Box 3.1 Jellyfish

Jellyfish outbreaks are now seen in all European seas, and these blooms are increasingly being linked to changes in food web structures resulting from over fishing. For example an analysis of a 55-year time series from the North Sea of plankton, cod and sea surface temperature suggests that the combined effects of reduced cod numbers and increased sea surface temperature has created an ecological niche that favours lower trophic-level species over those that are economically important. At the climax of these changes a proliferation of jellyfish was observed (Kirby et al., 2009). Jellyfish are problematic because they obstruct the function of ecosystems with consequences for commercial fisheries, and cause nuisance to swimmers, tourists, and aquaculture. Some species such as Portuguese men-of-war observed in the Mediterranean in 2009 are highly toxic. In 2009 and 2010, Israel experienced incidents where power and desalination plants reduced their functioning because large numbers of jellyfish clogged pipes and filters (GFCM, 2010).

fish species in the North Sea between 1985 and 2006 and in the Baltic in the late 1980's. In general, smaller species of southern origin increased while large northern species decreased. Some of this change could, however, also be partly explained by commercial overexploitation of large predator fish species (Hiddink et al., 2008).

3.2 Sea-level rise and coastal land-cover changes

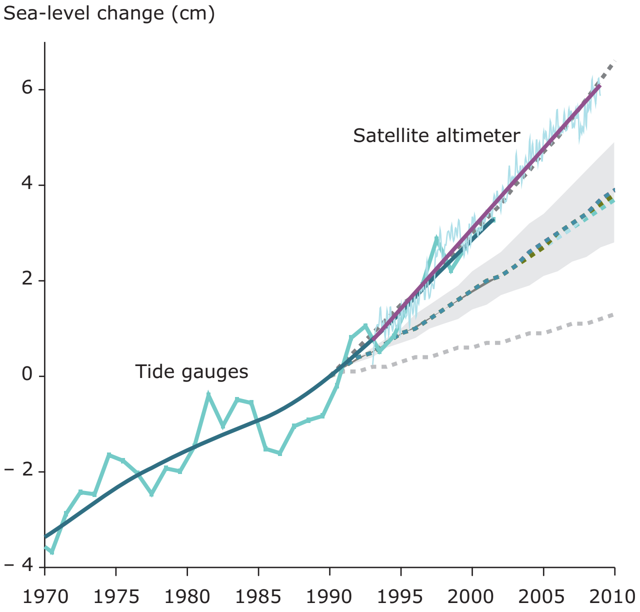
During the 20th century, tide gauge data show that the global sea level rose by an average of 1.7 mm/year (IPCC, 2007a). This was due to an increase in the volume of ocean water as a consequence of temperature rise, although inflow of water from melting glaciers and ice-sheets is playing an increasing role. For the period 1961–2003, thermal expansion contributed about 40 % of the observed sea-level rise, while shrinking mountain glaciers and ice sheets contributed about 60 % (Allison et al., 2009; IPCC, 2007a). Sea level rise has been accelerating over the past 15 years, 1993–2008, to 3.1 (± 0.6) mm/year, based on data from satellites and tide gauges, with a significantly increasing contribution from the ice-sheets of Greenland and Antarctica (Figure 3.2) (Alblain et al., 2009, EEA, 2010h).

Current land-use practices are producing wide spread pressures on inter-tidal habitats such as salt marshes and other coastal wetlands. These, and other coastal wetlands, may be lost due to urbanization and other human activities such as intensive maritime navigation, port expansions, dredging, coastal aquaculture and fisheries, aggregate extraction and recreation, such as leisure boating.

Coastal erosion occurs both as shoreline erosion and as a consequence of reduced sediment input from rivers, and can also contribute to coastal habitat destruction. These activities have resulted in a net loss of wetland of 0.7 % of its area between 2000 and 2006 (Figure 3.3). Between 1990 and 2000, artificial surfaces in coastal zones also increased in almost all European countries as a consequence of urbanisation. The highest increase in artificial surfaces has been observed in the coastal zones of Portugal, Ireland and Spain.

The high degree of urbanisation is of particular concern because it is increasingly reducing the space available for natural habitat development in the coastal zone needed to allow ecosystem adjustments to, for example, climate change. Coastal habitats will naturally adapt to rising sea level by migrating inland. In highly populated areas there is, however, no room for this process as the

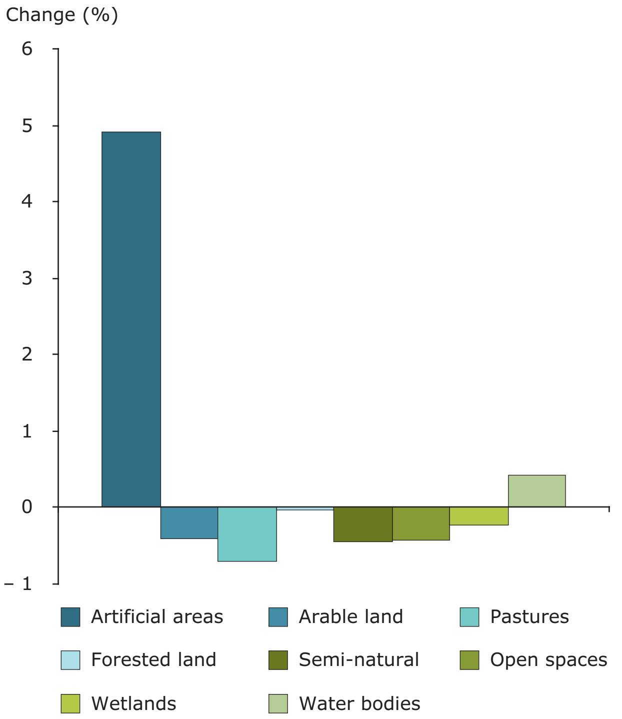
Figure 3.2 **Change in sea level 1970–2008, relative to the sea level in 1990**



Note: The solid lines are based on observations smoothed to remove the effects of inter-annual variability (light lines connect data points). Data in most recent years are obtained from satellite-based sensors. The envelope of IPCC (2001) projections is shown for comparison; this includes the broken lines as individual projections and the shading as the uncertainty around the projections.

Source: University of Copenhagen, 2009; Rahmstorf, 2007.

Figure 3.3 **Net land-cover change within the 0–10 km coastal zone between 2000 and 2006**



Note: Based on EU coastal countries and Albania, Bosnia and Herzegovina, Croatia, Iceland, Montenegro, Norway and Turkey.

Source: CLC 2006, analysis by ETC/LUSI.

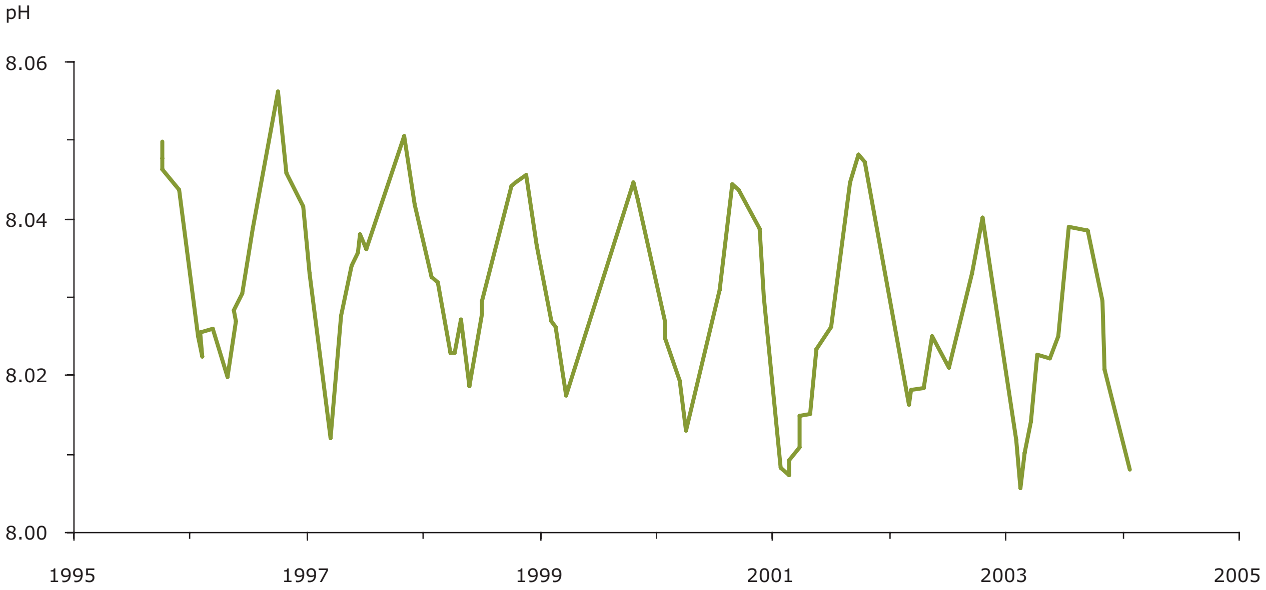
land is used for industry, housing or recreation and will be defended by structures due to its high commercial value — the natural coastal environment then becomes squeezed.

3.3 Acidification

Across the ocean, the acidity (pH) of surface waters has been relatively stable for millions of years. Over the past million years, average surface-water pH oscillated between 8.3 during cold periods, for example during the last glacial maximum 20 000 years ago, and 8.2 during warm periods such as just prior to the industrial revolution. But human activities are threatening this stability by adding large quantities of a weak acid to the ocean at an ever increasing rate. This anthropogenic problem is referred to as ocean acidification because seawater pH is declining, even though ocean surface waters are alkaline and will remain so. The cause is the gas that is the main driver of climate change, CO_2, which acts not only as a greenhouse gas but also an acidifying one.

Already, average surface-water pH has dropped to 8.1 and is projected to decline to 7.7–7.8 by 2100. These changes only seem small because pH is measured on a logarithmic scale. The current reduction of 0.1 that has occurred over the industrial era translates to a 30 % increase in ocean acidity — defined here as the hydrogen ion concentration. This change has occurred at a rate that is about a hundred times faster than any change in acidity experienced during

Figure 3.4 **Times series of observed ocean pH in the waters around the Canary Islands**



Source: Based on Santana-Casiano et al., 2007.

the past 55 million of years. A further decline of 0.3–0.4 pH units, projected for surface waters during the 21st century, represents a 100–150 % increase in acidity (Caldeira and Wickett, 2003).

The current decline in pH is already measurable at the three ocean time-series stations that are suitable for evaluating long-term trends, located offshore of Hawaii, Bermuda, and the Canary Islands (Figure 3.4). The measured reductions in surface pH at these stations are indistinguishable from what is expected from measurements of increasing atmospheric CO_2 concentrations, assuming thermodynamic equilibrium between the ocean surface and the atmosphere (Dore et al., 2009 and Santana-Casiano et al., 2007).

The acidification of Europe's seas is just starting to be studied. Basic equilibrium calculations illustrate that the average surface pH of the Black Sea is substantially higher than that of the Baltic and Mediterranean Seas. Differences in surface pH between these seas are largely explained by differences in carbonate ion concentrations. The relative change in the pH is slightly more in the Baltic Sea where the carbonate ion concentration is lowest and it is slightly less in the Black Sea, where carbonate ion concentrations are highest. Carbonate ions efficiently fulfil their role as an antacid in all European seas, but there are large differences in abundance of marine calcifying organisms even under today's conditions (Orr, 2010, *pers. com.*). For example, in the Baltic Sea, very low carbonate ion concentrations appear to prohibit growth of the calcareous phytoplankton *E. huxleyi*; conversely, in the Black Sea, large blooms of the same organism are visible from space. Well before the end of the century, surface-waters of the Baltic Sea could become corrosive to all forms of calcium carbonate whereas there is no risk of this occurring in the Black Sea and Mediterranean Seas before 2100 (Orr, 2010, *pers. com.*).

Ocean acidification is likely to have serious future adverse impacts on the marine environment, particularly as CO_2 emissions continue to increase. As atmospheric CO_2 increases, more dissolves in the ocean, increasing its acidity and preventing the process of calcification (Hoegh-Guldberg et al., 2007). Scientists believe that a critical threshold will be reached when atmospheric CO_2 concentrations reach 450 ppm (Monaco Declaration, 2008), which may happen as early as 2030. At this level of CO_2 in the atmosphere, marine species that build a calcified skeleton such as plankton — coccolithophores, foraminifera — corals, and pelagic molluscs may be hindered in their growth which in turn will impair the capacity of marine ecosystems to act as a global carbon sink (Burkill et al., 2009). The impacts of acidification will be global, but will impact Arctic, Antarctic and tropical regions the most. Many of the organisms impacted are an important contribution to the diet of millions of people around the world, and are an important source of income. The people most vulnerable to the impacts are Arctic indigenous people and people in tropical regions who depend critically on fisheries for their diet and income.

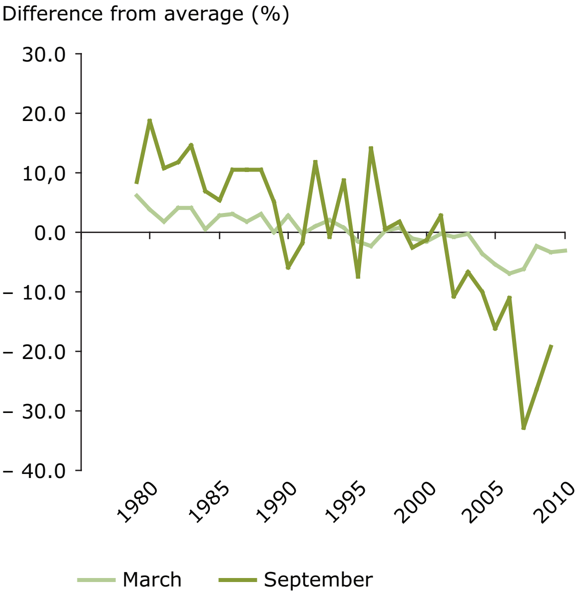
Europe has accepted its share of the obligation to reduce CO_2 emissions through its Climate and Energy Package. For the health of the marine environment it will be important that these emission reductions occur. Recovery from human-induced acidification will require thousands of years for the Earth system to re-establish roughly similar ocean chemical conditions as are known today (Tyrrell et al., 2007; Archer and Brovkin, 2008).

3.4 Sea ice and the Arctic

One of the most visible consequences of the increased temperature of the ocean is the reduced area of sea ice coverage in the Arctic polar region and there is a growing body of evidence suggesting that many marine ecosystems are responding both physically and biologically to changes in the regional climate predominantly caused by the warming of the air and ocean. The extent of sea ice in the Arctic has declined at an accelerating rate, especially in summer. The record-low ice cover in September 2007 was roughly half the size of the normal minimum extent in the 1950s.

Since more reliable satellite observations started in 1979, winter sea ice extent on average has decreased by 2.8 % per decade while summer ice has shrunk by 11.3 % per decade (Figure 3.5), and the summer decline appears to be accelerating. There is a remarkable shift in Arctic sea ice composition towards less multi-year ice and larger areas of

Figure 3.5 **Change in Arctic sea ice extent 1979–2010**



Source: Killie and Laverne, 2010.

first-year ice. The first-year ice is weaker and melts more easily in summer (see also the SOER 2010 understanding climate change assessment, EEA, 2010h).

The diminishing Arctic sea ice is already impacting indigenous people and cultures. Sea ice is an important part of the hunting grounds and travel routes of many Arctic peoples and, as ice retreats, they are forced to change subsistence strategies and address safety concerns. Indigenous Arctic peoples will thus face serious economic, social and cultural changes (EEA, 2008b).

Less summer ice will ease access to the Arctic Ocean's resources, though the remaining ice will still pose a major challenge to operations for most of the year. As marine species move northwards with warmer sea and less ice, so will fishing fleets. It is, however, hard to tell whether the fisheries will become richer or poorer; fish species react differently to changes in marine climate, and it is hard to predict whether the timing of the annual plankton blooms will continue to match the growth of larvae and young fish.

Shipping and tourism have already increased and will continue to do so. In 2009, two German ships made the first commercial passage through the north-east sea route, along the Russian coast. In 2010 more such commercial passages have taken place, increasing the risk of accidents in a very inhospitable region. EU Member States combined have the world's largest merchant fleet, so many of the vessels passing through Arctic waters will come from the EU. Drift ice, short sailing seasons and lack of infrastructure will impede the rapid development of the transcontinental shipping of goods, but traffic linked to extraction of Arctic resources on the fringes of the Arctic sea routes will develop more quickly.

Expectations of large undiscovered oil and gas resources are already driving the focus of the petroleum industry and governments northwards. These activities offer new economic opportunities, but at the same time they represent new pressures and risks to an ocean that has so far been closed to most economic activities by the ice. Better international regulations of these activities will probably be needed (EC, 2010h). The 2010 disaster in the Gulf of Mexico, has increased the focus on the risks associated with oil exploration — in the Arctic low temperatures make marine ecosystems even more fragile and vulnerable to accidental oil spills. Of course the economic interest of the potential resource is very large, and it will be a challenge for the Arctic region to ensure that this exploration occurs safely.

High interest in gaining access to the resources of the Arctic may create tensions and security problems. However most borders in the Arctic Ocean have been drawn, thereby clearly defining who has the ownership of the resources and right to manage them. In the remaining unresolved issues of delimitation of exclusive economic zones (EEZ) and extended continental shelves, all the coastal states of the Arctic Ocean follow the procedures of the UN Convention of the Law of the Seas.

Box 3.2 Global Monitoring for Environment and Security (GMES)

Global Monitoring for Environment and Security (GMES) provides support to marine data infrastructure in two ways — it contributes to the funding of satellite data on the marine environment and it supports a Marine Service which provides an ocean forecasting system using a combination of space observations, *in-situ* observations and oceanographic models.

The Marine Service delivers analyses and forecasts on the state and dynamics of the ocean and ecosystems as well as sea ice. These are used in the context of management of marine environment and resources as well as maritime safety, and will also contribute to ongoing climate variability studies and forecasts. At present a prototype is being developed by FP7 project MyOcean. Several indicators used in this assessment are based fully or partly on datasets compiled by MyOcean: sea surface temperature (Figure 2.7), arctic sea ice extent (Figure 2.11) and ocean color (Map 2.5).

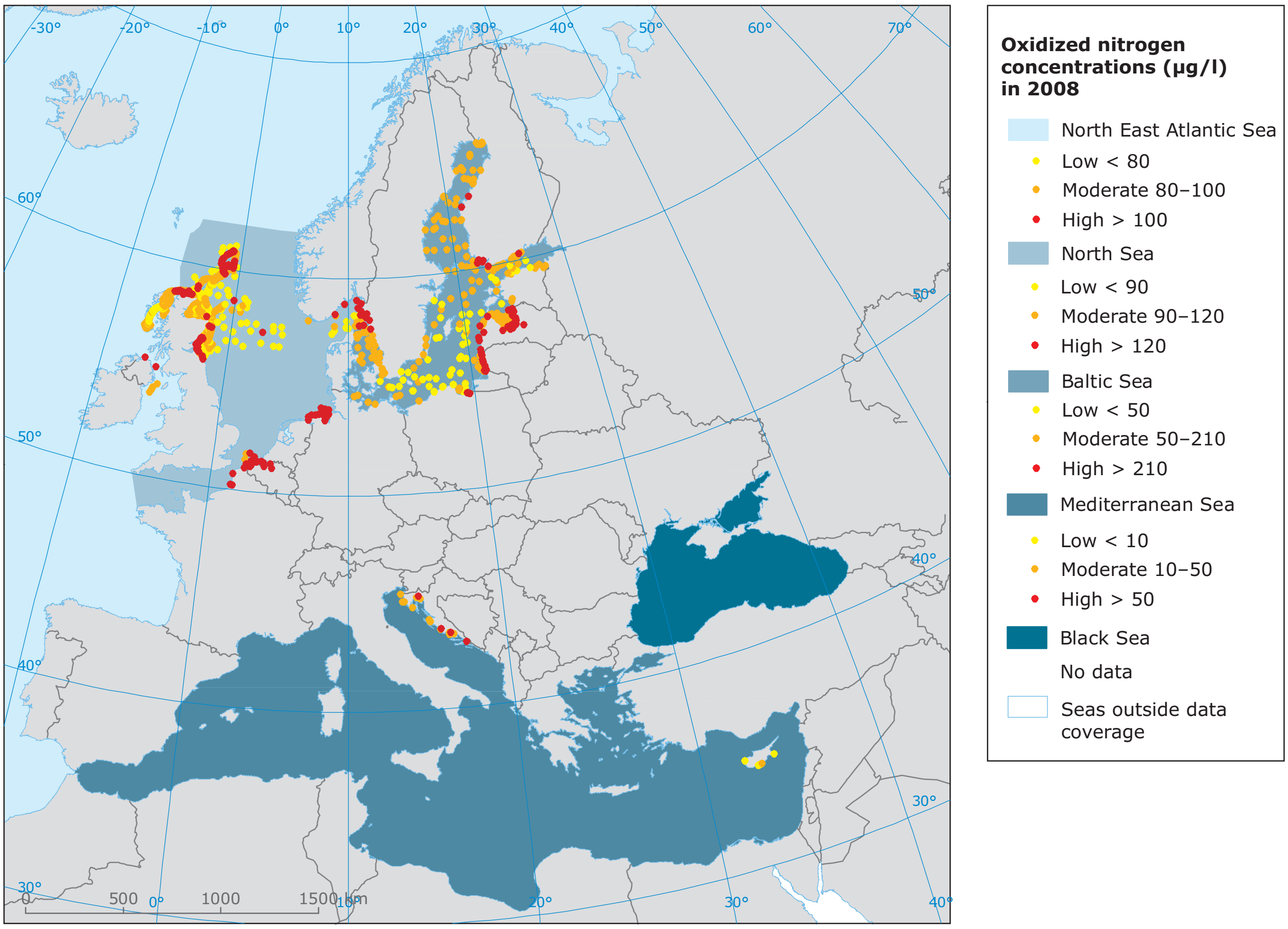
To date, satellite observations used in the Marine Service have been derived from both United States and European satellite missions, in some cases jointly. In 2013 the Jason 3 mission will be launched to ensure continuation of sea surface elevation monitoring among others in support of GMES. As GMES is moving into its operational phase a dedicated European satellite programme will be put in place. Between 2011 and 2019 the European Space Agency will launch five Sentinel missions providing an array of observations needed for the marine service including sea surface elevation, ocean colour, sea surface temperature and sea ice extent (ESA, 2010). In addition, launched in 2010, CryoSat-2 measures changes at the margins of the vast ice sheets that overlay Greenland and Antarctica and marine ice floating in the polar oceans. By accurately measuring thickness change in both types of ice, CryoSat-2 will provide information leading to a better understanding of the role of ice in the Earth's system (ESA, 2010). Under the Arctic ice sheet, these observations will be complimented by *in-situ* observations made from below the ice by submarines (Wadhams, *pers. com.*)

Satellites, however, only measure the surface of the ocean and only some parameters. To provide a quality marine service, *in-situ* observations made throughout the water column and of parameters not measureable from space are also needed. While the *in-situ* observations themselves are normally funded and measured by Member States, the EEA has been tasked with identifying which observations are key for a reliable service and proposing how to best organise a common programme for the provision and sharing of these data (EEA, 2010g).

4 State and impacts of pollution

Pollution of transitional, coastal and marine waters in many cases directly impacts the lower levels of the marine food-web: phytoplankton, zooplankton and animals living on the sea floor but impacts are moved upwards in the food chain with the many different feeding habits of marine organisms. In some cases severe pollution fundamentally alters ecosystem functioning. In particular plants, filter feeding animals like shellfish, long lived marine mammals, and seabirds are susceptible to pollution effects. There are numerous pollutants impacting the marine environment, arising from many sources. These come from land-based activities such as agriculture, industry and wastewater treatment that emit or discharge pollutants to freshwater and, therefore, ultimately to coastal waters, whilst atmospheric deposition of certain pollutants to marine waters can also be a key source. New topics like marine litter that is increasing its share of the diet particularly of seabirds, but also fish and invertebrates and noise pollution suspected of impacting communication among marine mammals are becoming of increasing concern. Human activities at sea, including oil exploration and extraction,

Map 4.1 Oxidized nitrogen ($NO_2 + NO_3$) concentrations in European seas in 2008



Note: Based on Eionet-water data reported to EEA. In 2008, data suitable for the indicator were only reported from very few stations in the Mediterranean and from no stations in the Black Sea.

Source: EEA, 2010d.

accidents and shipping that are causes of oil pollution are discussed later in Chapter 5.

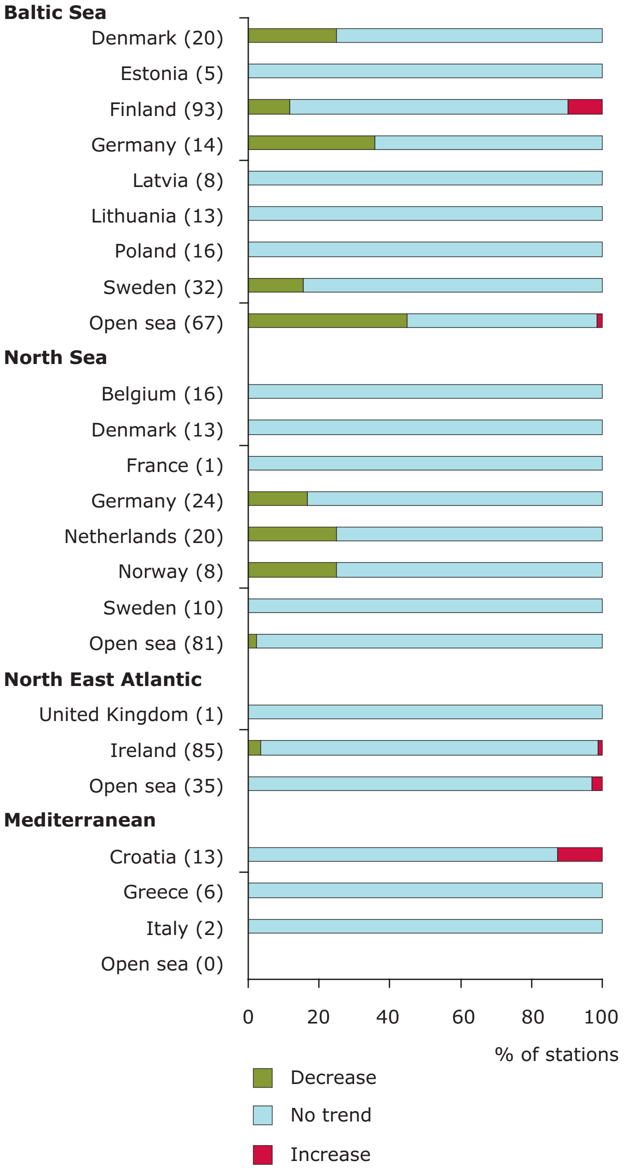
4.1 State of nutrient pollution

Excessive use of the fertilizers nitrogen and phosphorous create eutrophication of marine waters which is the accelerated, enhanced growth of phytoplankton and higher plant forms and an undesirable disturbance of the balance of organisms in the water. Land-based sources of nutrients both diffuse sources — from artificial fertilisers used in agriculture and from animal manure — and point sources from urban wastewater treatment plants, whilst reducing, are still the main sources of nutrients to waterways. Nitrogen is also released into the atmosphere and later deposited on the sea surface. Where estimates are available, they show that approximately 25 % of the nitrogen load to the sea surface is contributed as atmospheric deposition (HELCOM, 2009a). Diffuse transport pathways are slow and give rise to time-lags between the time of changes in agricultural practices and improved water quality. For example, in 1990 following the collapse of the central planned economies in eastern Europe, nitrogen and phosphorous use in agriculture were reduced by 75 % and 50 % respectively within one or two years, but nutrient loads in the Danube are still adjusting to this change (Oguz et al., 2008).

The EEA indicators on nitrogen, phosphorous and chlorophyll-a show the concentration levels of these substances and their change over time. Winter nutrient concentrations in transitional, coastal and marine waters respond to inputs from land and atmospheric sources. Algae are most abundant in the summer and their abundance is linked to the concentration of both the plant pigment chlorophyll-a in the water and nutrients. Based on the EEA indicators of nutrients (EEA, 2010d) and chlorophyll-a (EEA, 2010e) in transitional, coastal and marine waters (Maps 4.1, 4.2 and 4.3), there is clear evidence of nutrient enrichment:

- within the coastal zones, bays and estuarine areas of some parts of the North East Atlantic region, particularly those near major European river deltas;
- in the Baltic Proper and the Gulf of Finland as well as coastal areas of the Baltic Sea;
- in areas close to river deltas or large urban agglomerations in the Mediterranean Sea;
- in the Black Sea, although improvement has been significant since 1990 (Oguz et al., 2008).

Figure 4.1 Change in winter oxidized nitrogen concentrations in coastal and open waters of the North East Atlantic, Baltic, Mediterranean and North Seas



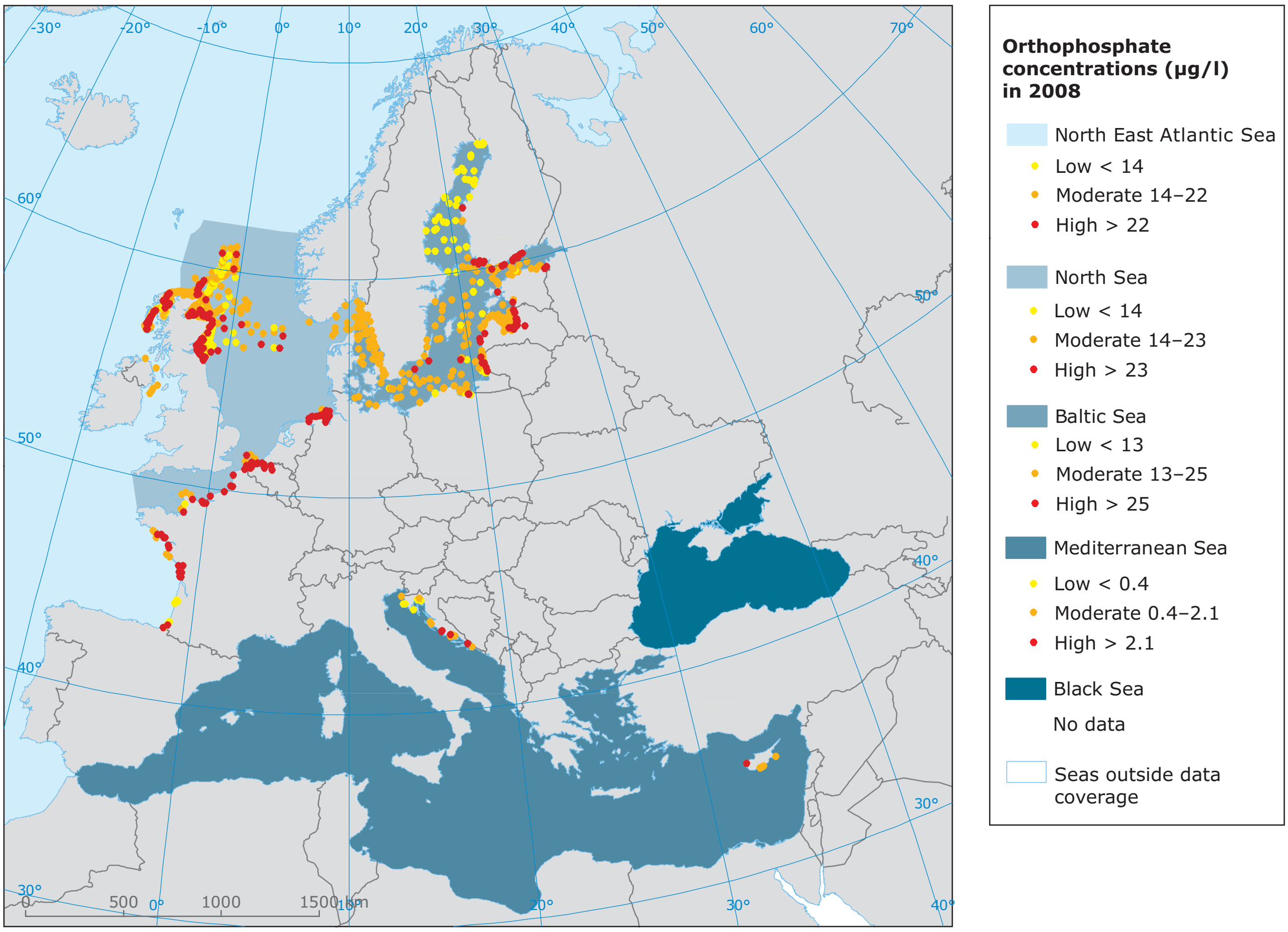
Note: Percentage of stations showing statistically significant change at the 95 % confidence level, 1985–2008. Numbers in parentheses indicate number of stations included in the analysis for each country.

Source: EEA, 2010d.

In spite of measures to reduce nutrient concentrations in European seas, 85 % of measurement stations show no change in nitrogen concentrations, 80 % show no change in phosphorous concentrations, and 89 % show no change in chlorophyll-a concentrations.

Winter oxidized nitrogen concentrations have fallen significantly at 21 % of 268 stations in the Baltic Sea and at 8 % of stations in the North Sea. The stations with

Map 4.2 **Orthophosphate concentrations in European seas, 2008**



Note: Based on Eionet-water data reported to EEA. In 2008, data suitable for the indicator were only reported from a very few stations in the Mediterranean and from no stations in the Black Sea.

Source: EEA, 2010d.

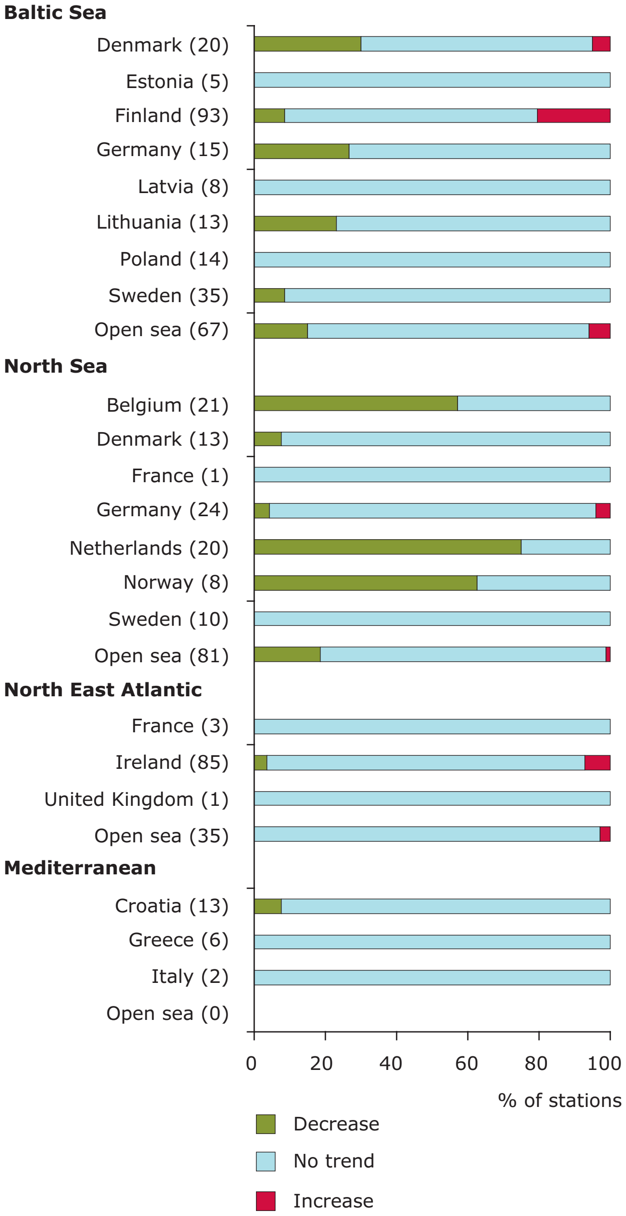
decreasing trends are in Denmark, Finland, Germany, the Netherlands, Norway and Sweden, and in the open parts of the Baltic Sea (Figure 4.1). Little improvement is seen in other seas (EEA, 2010d).

Winter phosphate concentrations show the most widespread changes. Significant decreases were observed at 13 % of stations in the Baltic, 28 % in the North Sea, and 5 % in the Mediterranean Sea (Figure 4.2). In the Netherlands, phosphate concentrations showed a statistically significant decreasing trend at 15 of 20 stations. The improvements are attributed to implementation of urban wastewater treatment which is taking place across Europe.

In some sea areas it is difficult to reduce phosphorous concentrations due to the internal recycling of phosphorous. In areas subject to anoxia on the sea floor, such as the Baltic Sea, a sequence of chemical reactions recycles phosphate stored in bottom sediments back into the water column. This process greatly increases the magnitude of phosphorous reductions needed from land-based sources to achieve a significant reduction in phosphorous concentration. In Finland, some stations show increasing concentrations of phosphate, which are linked to increased frequency of anoxia and associated recycling of phosphate (EEA, 2010d).

In 2008, the highest chlorophyll-a concentrations were observed in the Gulf of Riga, along the coast of Lithuania influenced by the Nemunas River, the Scheldt estuary in Belgium, and at the mouth of the Seine and Loire rivers in France (Map 4.3). Satellite observations of ocean colour intensity, that is related to chlorophyll-a, have a wider geographical coverage than station observations and have been used in support of the chlorophyll-a indicator. A trend analysis based on satellite observations shows that in fact no change in ocean colour intensity can be detected in 81 % of the

Figure 4.2 **Change in winter orthophosphate concentrations in coastal and open waters of the North East Atlantic, Baltic, Mediterranean and North Seas**



Note: Percentage of stations showing statistically significant change, 1985–2008. Numbers in parentheses indicate number of stations included in the analysis for each country.

Source: EEA, 2010d.

area of European seas (Map 4.4). In the Mediterranean Sea increasing concentrations are observed close to the coast. Twenty-two per cent of decreasing concentrations are observed in the Black Sea, possibly linked to decreasing agricultural fertilizer use, and hence nutrient concentrations, and nutrient loads from the Danube to the Black Sea. In the Baltic, the satellite observations show a larger proportion of increasing concentrations than indicated by the *in-situ* observations — 40 % versus 8 % — possibly because the satellite observations are influenced by large quantities of dissolved organic carbon in the water — this reduces the confidence of the observations. Satellite observations also show increases in the Bay of Biscay, but here the background concentration level is very low and thus the confidence in the calculated changes is low (EEA, 2010e).

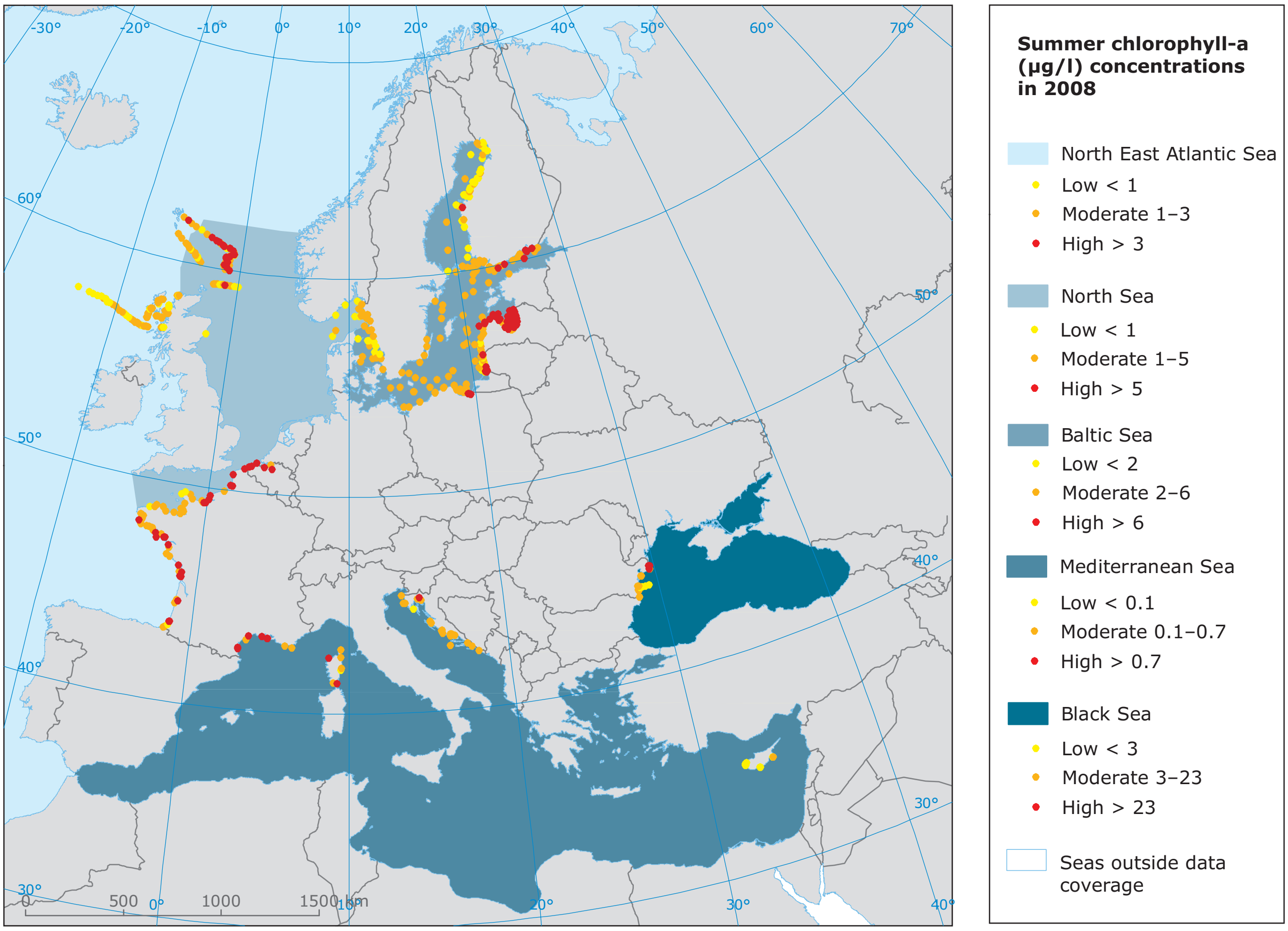
In the North East Atlantic, the EEA indicators of eutrophication are supported by the OSPAR regional assessment (OSPAR, 2010) which shows many local areas of the North East Atlantic and the entire eastern part of the North Sea from Belgium to Denmark to be problem areas. For example, according to OSPAR, 2010, a die-off of cultured mussels and benthic animals has been tentatively linked to the decay of massive algal blooms in Dutch estuaries. Further, estuaries and fjords, and parts of the Wadden Sea are particularly susceptible to oxygen deficiency as result of eutrophication, and algal foam on beaches in Belgium is a nuisance to the tourist industry. The large problem areas observed in the North East Atlantic occur in spite of more than 50 % reductions in phosphorous inputs and almost 50 % reduction of nitrogen inputs to the area (OSPAR, 2010).

In the Baltic Sea, the EEA indicators of eutrophication are also supported by a comprehensive analysis of almost 200 areas (HELCOM, 2009a). The most severely impacted were found to be in Gulf of Finland, Gulf of Riga, the eastern Baltic Proper, the southern Baltic Sea and the Danish straits. Only 13 of the assessed areas, located in the Gulf of Bothnia and in the Kattegat, can be considered non-problem areas. For example, according to HELCOM, 2009, the Baltic Sea is characterised by excessive blooms of sometimes toxic algae, low water transparency, and diminished belts of eelgrass, as well as severe oxygen depletion on the sea bottom.

4.2 Impacts of nutrient pollution

Nutrient pollution can change the composition and abundance of marine organisms and ultimately lead to oxygen depletion in bottom waters, killing bottom-dwelling organisms. This happens in a sequence of events with more nutrients leading to more algal growth and hence higher biomass — measured as higher chlorophyll-a concentration — that again leads to more organic load to the bottom ecosystem, which uses more oxygen for decomposition. Oxygen depletion occurs in several stages, the most severe being hypoxia where hydrogen sulphide is released into the water — this kills all life in the area affected. Consequently, nutrient

Map 4.3 **Chlorophyll-a concentrations in European seas, 2008**



Note: Based on Eionet-water data reported to the EEA. In 2008, data suitable for the indicator were only reported from a very few stations in the Mediterranean and the Black Seas.

Source: EEA, 2010e.

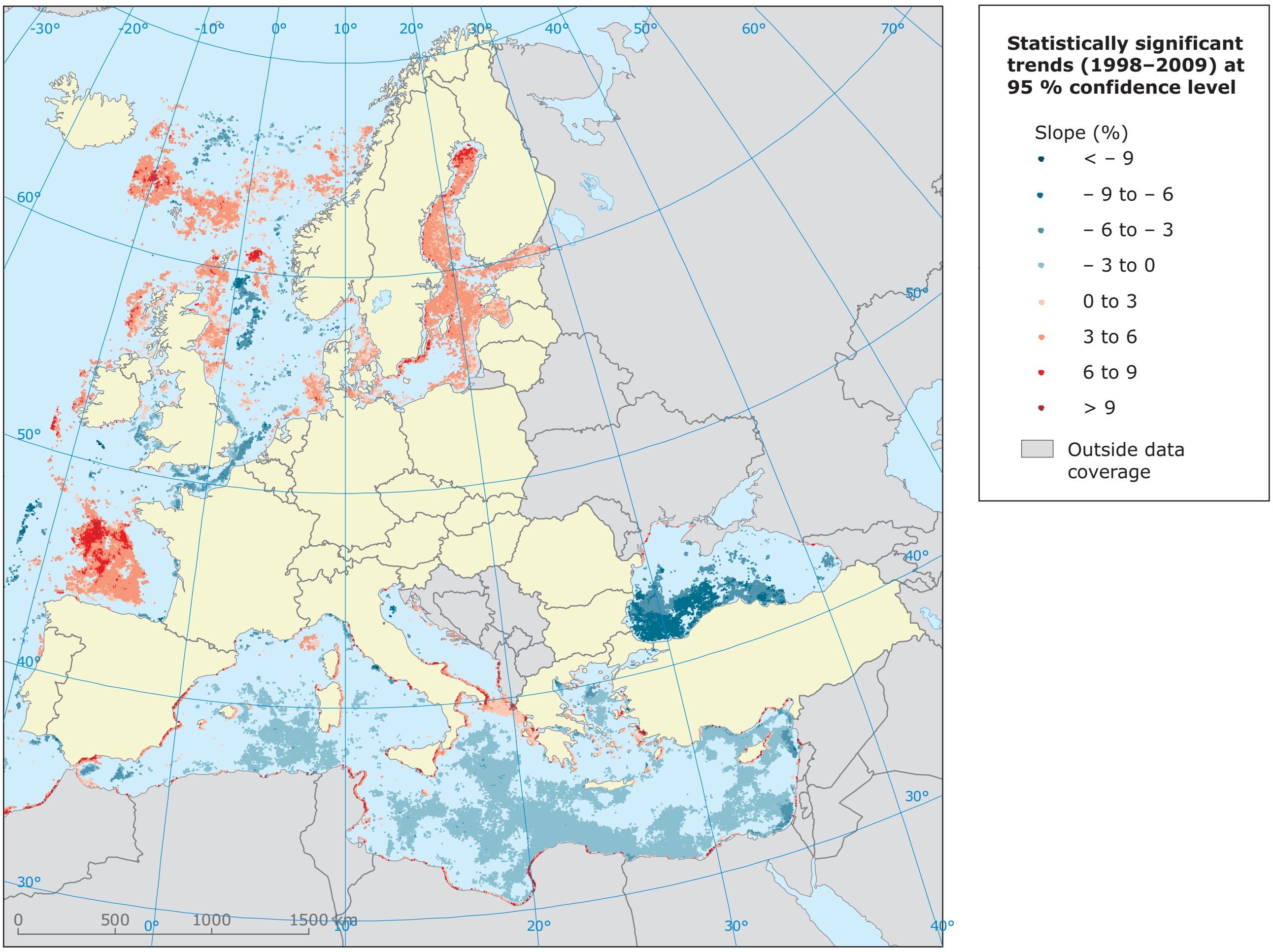
pollution affects supporting ecosystem services. The problems caused are serious and are manifested by algal blooms, anoxic water, destruction of habitats, reduced size and fecundity of marine organisms, and loss of biodiversity. All these can contribute to a decline of assets such as fish and other sea food and the recreational opportunities provided by the coast and seas.

Hypoxia is particularly serious in the Baltic and Black Seas because it affects wide areas of the sea basins. For example, in the Baltic Proper and Gulf of Finland, there is now almost permanent oxygen depletion in bottom waters (Map 4.5). Although the surface waters of the Black Sea are enriched by nutrients, the anoxic conditions in the central part of the sea are considered part of its natural state; however, the state was made worse by eutrophication in the 1980s (Oguz et al., 2008). Oxygen depletion has also been reported in the Mediterranean Sea and many other European coastal areas, where the impacts are similar but the scale smaller. In these areas, commercially important mussel beds and sites of aquaculture production may be seriously damaged.

In the Baltic Sea, blooms of toxic cyanobacteria pose a health risk to humans and domestic animals swimming in the sea. Bloom-forming cyanobacteria are a natural component of the Baltic Sea phytoplankton (Bianchi et al., 2000), but the intensity of the summer blooms has increased since the early 1990s with wide spread events in 1997, 1999, 2003, 2005, and partially in 2006. These blooms are clearly promoted by the anthropogenic inputs and internal load of phosphorous and nutrient reduction to date has been insufficient to break this cycle (Savchuk et al., 2008).

Harmful algal blooms are also a problem in other parts of Europe. In the North-East Atlantic, from Portugal to northern Norway and around the British Isles, the

Map 4.4 **Statistically significant trends of ocean colour intensity 1998–2009 at the 95 % confidence level (Mann-Kendall test)**



Note: Based on satellite observations (global data set, 1998–2009).

Source: Coppini et al., 2010.

gelatinous and colony-forming marine phytoplankton species *Phaeocystis* is common. Normally this is a fairly harmless single-celled organism present in relatively small numbers; however, excess of nitrogen causes *Phaeocystis* to form dense blooms (Lancelot et al., 1987). When the colony reaches a critical size, single cells clump together to form gelatinous foam that float. The foam is blown onto beaches and deposits in thick layers that are visually unattractive and emit a bad smell. Fisheries are also affected because nets become clogged and the foam taints the taste of fish.

Long-term monitoring has shown that the variability of the size of *Phaeocystis* blooms is mainly related to nutrient loads. In particular, an excess loading of nitrogen promotes *Phaeocystis* growth (Lancelot et al., 1998; Rousseau, 2000; Breton et al., 2006). Nutrient loading with 25 times more nitrogen than phosphorus promotes growth and accumulation of *Phaeocystis*. In this situation, normal nutrient cycling within the marine food-web is not able to control the growth (Lancelot et al., 2009). Reduction of nitrogen loads from both the Seine and the Scheldt is required to reduce these phytoplankton blooms in the Belgian coastal zone (Gypens et al., 2007).

Box 4.1 The role of European policy in macro regions

European Baltic Sea Regional Strategy and HELCOM Baltic Sea Action Plan
In the Baltic Sea, problems related to increasing nutrient enrichment have been observed for the past 100 years, and it has long been recognised that a solution to this problem requires international collaboration. Since the early 1980s, the Helsinki Commission (HELCOM) has been working to improve the Baltic marine environment, and its most recent and significant achievement, the Baltic Sea Action Plan (BSAP), adopted within HELCOM by all nine Baltic Sea States — eight Member States and Russia — and the European Community in 2007, is an ambitious programme to restore the good ecological status of the Baltic marine environment by 2021. The European Commission launched a regional strategy for the Baltic Sea in 2009 the first objective of which is the need to address the ecological and environmental decline of the Baltic Sea and achievement of this objective is linked to implementation of the BSAP. The plan has strong links to global and European legislative frameworks and is seen as a contribution towards implementing aspects of the WFD, Urban Waste Water Treatment Directive (UWWTD), Nitrates Directive (ND) and MSFD because these directives describe measures that all countries around the Baltic Sea — except Russia — are required to implement, adding hard legal requirements to the regional agreements. However, if countries were required to achieve the agreed objectives of the BSAP, it would be possible to demand stricter measures than those provided by the European legislation.

The strong maritime component of the European Baltic Strategy is also seen as an important first step towards the regional implementation of the Integrated Maritime Policy (IMP) in the Baltic Sea region. It will help meet the challenges in the region through strengthened internal co-ordination within Member States and through cross-border networks and good cooperation with Russia. Coherent and proactive implementation of maritime actions in the Strategy will therefore be an important test case for the sea-basin approach pursued in implementing the IMP. Cross-sectoral tools of the IMP — such as maritime spatial planning, integration of surveillance systems and marine knowledge, which are all being used in the Strategy's actions — can contribute substantially to improving the management of the Baltic Sea.

Horizon 2020 — a Mediterranean initiative
The Horizon 2020 (H2020) initiative to reduce the pollution of the Mediterranean Sea by 2020 was endorsed in 2005, at the 10th Anniversary Summit of the Euro-Mediterranean Process. Horizon 2020 is a Union for the Mediterranean initiative that aims at increasing efforts to reduce the pollution of the Mediterranean Sea by 2020. Its main objective is to accelerate ongoing activities to de-pollute the Mediterranean by reducing the most significant pollution sources, particularly focusing on industrial emissions, municipal waste and urban wastewater that are responsible for up to 80 % of pollution in the Mediterranean Sea.

A consultative H2020 Steering Group (SG), with a wide membership, was established in 2007. national Contact Points were identified from a wide range of other stakeholders, including international organisations and financial institutions, as well as representative networks of cities, local authorities, NGOs, business organisations, etc. Within the steering group, three thematic sub-groups were established, to oversee the implementation of the initiative in all its pillars:

- pollution reduction (EIB leader): to support the identification, prioritisation and implementation of the most significant pollution reduction projects tackling major priority sources of pollution;
- capacity building (DG Environment leader): to support to the implementation of the Horizon 2020 Initiative identifying key gaps and promoting capacity building actions at regional, national and local levels as appropriate;
- review, monitoring and research (EEA leader): to monitor progress of the implementation of the Horizon 2020 initiative, particularly through appropriate information sharing systems easily accessible to all Mediterranean partners, in cooperation with all partner organisations.

Black Sea synergy
For the Black Sea region, the EU has developed the Black Sea Synergy, with a number of initiatives for the marine and coastal environment. Earlier in 2010, the Black Sea Environmental Partnership was officially launched to develop the sustained and project-oriented regional measures that are needed to achieve the objectives of biodiversity conservation — and integrated coastal zone and river basin management. Measures are also necessary to tackle pollution sources and promote environmental integration, monitoring, research and eco-innovation. It is expected that the IMP and the MSFD both of which require collaboration between EU-Member and non-member States will foster increased regional cooperation (EC, 2010j).

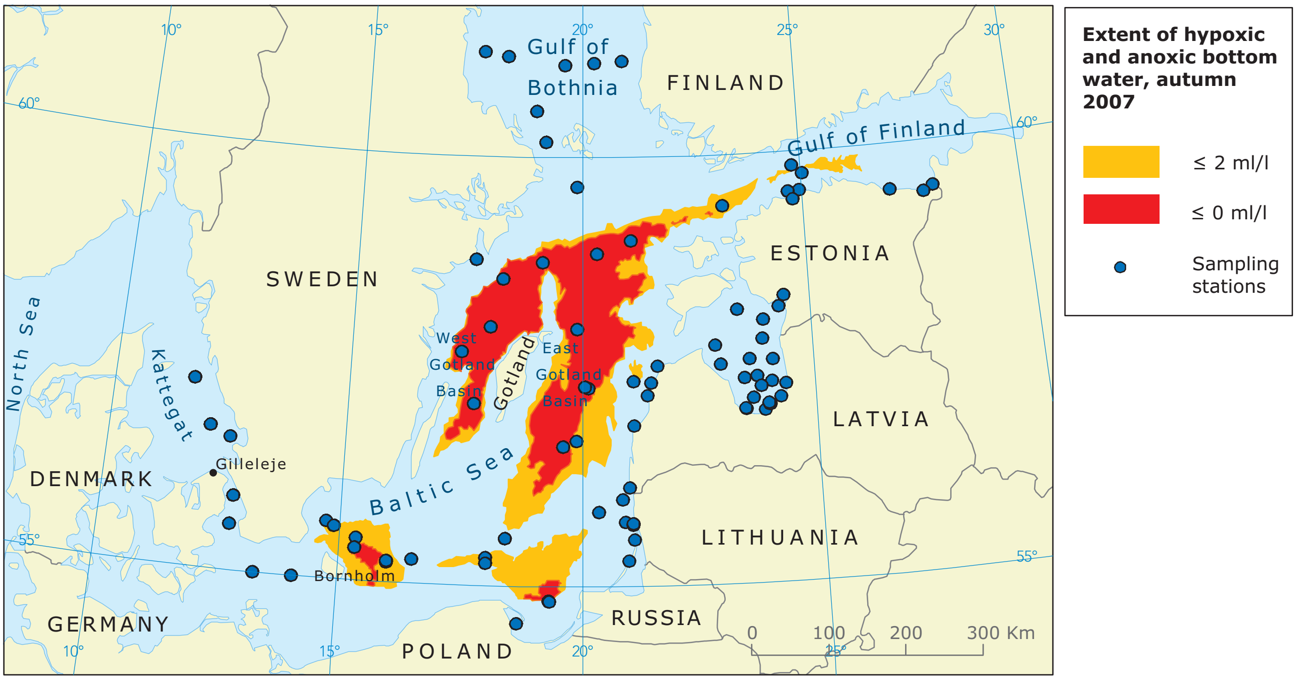
Northern Dimension Partnership
Although the EU has no Arctic coastline, close cooperation on marine issues exists with the EEA countries Norway and Iceland as well as the Russian Federation through the Northern Dimension partnership. The EU has three Member States who are members of the Arctic Council and an additional six member countries that are observers. The EU and Italy have applied for observer roles in the Arctic Council.

The EU has taken the first step towards an Arctic policy through an Arctic Communication from the European Commission (November 2008) and Council Conclusions (December 2008 and 2009). This policy focuses on

- protecting and preserving the Arctic in unison with its population;
- promoting sustainable use of resources; and
- contributing to enhanced Arctic multilateral governance.

This first step towards an Arctic policy holds a number of proposals for protecting the marine environment, fisheries, shipping routes, tourism, extraction of hydrocarbons and ongoing work in International Maritime Organization (IMO). The EEA supports the work of the Arctic Council's working group on Protecting the Arctic Marine Environment (PAME), including the work on an Arctic Oceans Review, an integrated ecosystem approach and the follow-up to the Arctic Marine Shipping Assessment.

Map 4.5 **Extent of hypoxic and anoxic and bottom water in the Baltic Sea, autumn 2007**



Source: HELCOM, 2007.

Box 4.2 Shellfish poisoning

At least four distinct shellfish-poisoning syndromes are associated with consumption of shellfish such as mussels, clams, oysters or scallops. Shellfish feed by filtering the water in their surroundings. When algal blooms that produce toxins occur in the surroundings of the shellfish, the toxins accumulate in then. Unfortunately some of these toxins give rise to:

- paralytic shellfish poisoning (PSP);
- neurologic shellfish poisoning (NSP);
- diarrhoeal shellfish poisoning (DSP);
- amnestic shellfish poisoning (ASP).

The algae responsible for the poisonings are naturally occurring and toxic even in very small quantities, but are not known to be associated with environmental pollution (Emedicine, 2010).

Box 4.3 Policy response to nutrient and chemical pollution: the WFD, UWWTD, ND and EQSD

The WFD aims to achieve good ecological and chemical status of Europe's fresh and coastal waters. Other legislation, directly related to the WFD, and providing its basic measures, targets particular groups of chemicals. In particular, the UWTD requires the collection and treatment of wastewater across Europe, with its implementation thus far leading to a reduction in nutrients, oxygen consuming substances and some chemicals discharged to freshwater. This in turn has reduced the loading of these pollutants to coastal waters. In addition, the ND targets agricultural sources of nitrate requiring the establishment of nitrate vulnerable zones and associated action programmes. Details of these pieces of legislation are provided in the SOER 2010 freshwater quality assessment, EEA, 2010i).

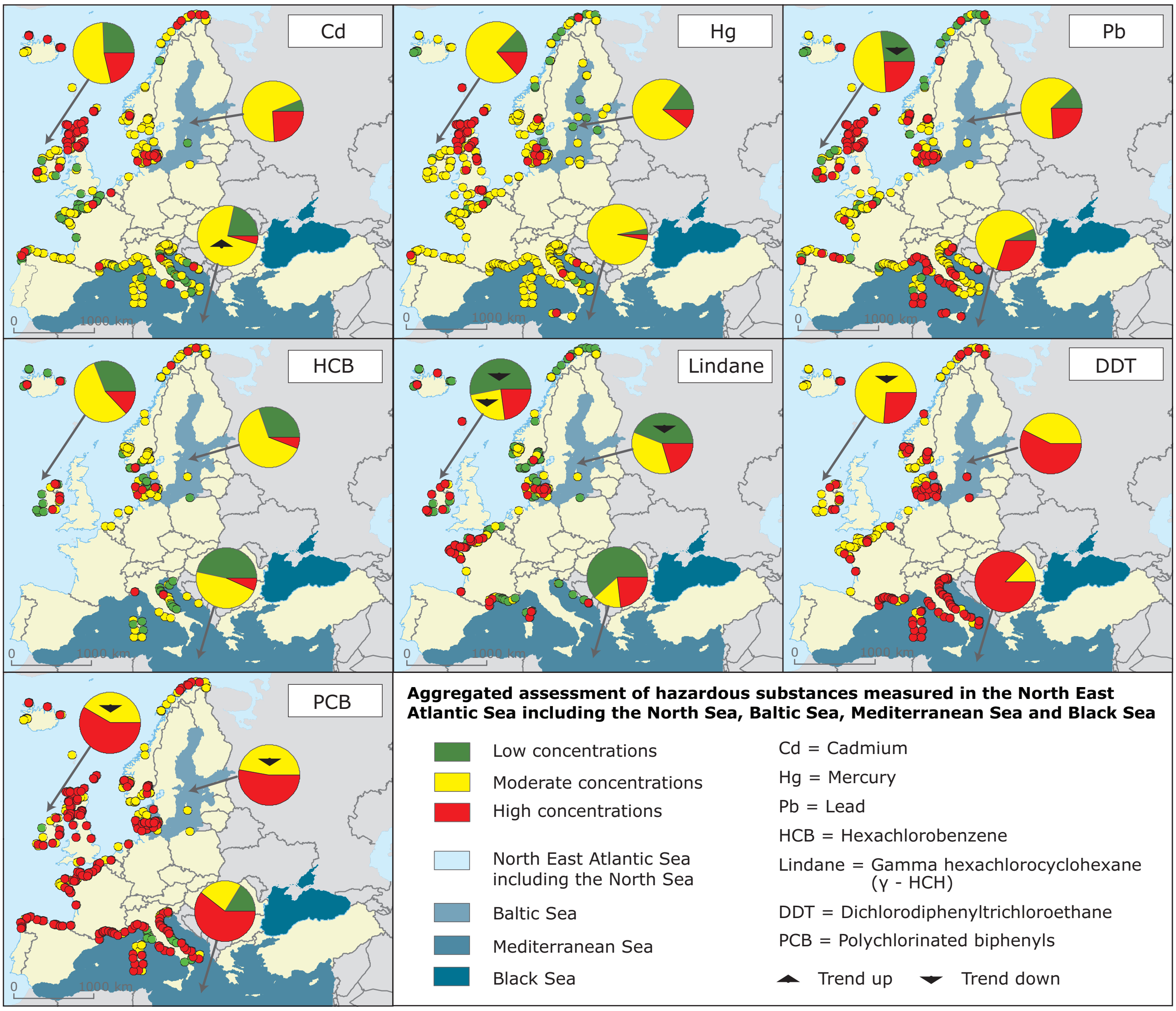
The chemical quality of Europe's surface waters, including coastal waters, is primarily addressed by the recently established Environmental Quality Standards Directive (EQSD, EC, 2008d). This daughter directive of the WFD defines concentration limits for pollutants of EU-wide relevance known as priority substances (PS). The directive provides Environmental Quality Standards for each of the 41 substances in water. Member States may opt for using biota or sediment as a matrix, but so far standards are only set for three PS in biota. However, more are expected in the future. The Registration, Evaluation, Authorisation and Restriction of Chemical substances regulation (REACH) also has an important role to play through its aim to improve the protection of human health and the environment from the risks of chemicals. REACH gives greater responsibility to industry to manage these risks and to provide safety information on substances used.

4.3 State of chemical pollution

Chemical pollution of the marine environment arises from a range of land and sea based activities, including the discharge of wastewater to the coastal environment, as a result of riverine inputs, or as deposition to the sea surface from the atmosphere. In addition, chemical pollution of the marine environment can arise from human activities at sea such as oil exploration and extraction, accidents, or shipping (Chapter 5). In general, hot spots of contamination can be directly linked to a particular source; other less acute levels of pollution are also often observed, at times some distance from any particular source. Although the use of chemicals has been regulated for some time, such pollution is widely detected in fish and shellfish in most of Europe and not only threatens marine life directly but also human health, through the consumption of contaminated seafood.

The EEA has collated time series of selected chemicals in fish and shellfish into a combined indicator of chemical pollution in marine biota in Europe (Map 4.6). The chemicals were selected based on their ability to bio-accumulate, their toxicity, and data availability. The selected chemicals are the metals: mercury, cadmium and lead, and persistent organic contaminants: the fungicide

Map 4.6 **Aggregated assessment of hazardous substances in biota measured in the North East Atlantic, Baltic Sea, and Mediterranean Sea**



Note: The pies show the proportion of stations on map with low (green), moderate (yellow) and high (red) concentrations in the latest monitoring year for each of the seven hazardous substances. In the case of the three metals the boundary between moderate and high is set using foodstuff limits. The arrow indicates the general trend for each category where one can be identified

Source: EEA, 2010f.

hexachlorobenzene (HCB), the insecticides lindane, and dichlorodiphenyltrichloroethane (DDT) and a group of chemicals used as a cooling and insulating fluid for industrial transformers and capacitors (PCB7). Cadmium, lead and mercury are found at low concentrations in the Earth's crust and occur naturally in seawater, but the concentrations observed in marine biota exceed natural levels (EEA, 2010f).

The EEA indicator of chemical pollution in marine biota shows that all seven chemicals are found at high concentrations in the Baltic and Mediterranean Seas as well as the North East Atlantic with, in the case of cadmium, mercury and lead, foodstuff limits exceeded (Map 2.7). In the overall assessment of changes, the stations with the highest observed concentrations do not show any over all reduction or increase in concentrations of any of the substances in any of the seas. In the Mediterranean Sea, cadmium concentrations in fish and shellfish are moderate overall but increasing. In the North East Atlantic, concentrations of lead and lindane, DDT, and PCB7 in fish and shellfish are decreasing. In the Baltic, low concentrations of lindane and moderate concentrations of PCB7 are also decreasing.

In the Black Sea, chemical pollution is monitored in sediments, rather than in biota and chemical pollution in the sea is serious. For example petroleum hydrocarbon pollution in Romanian and Turkish waters exceeds threshold values by a factor of 16. Concentrations of lindane and DDT are found to be five times greater than the Russian standards for extremely high pollution. Metal pollution is a problem particularly around the Danube Estuarine Region and around the large ports although in some areas concentrations appears to be decreasing (Korshenko, 2008).

4.4 Impacts of chemical pollution on marine mammals

Chemicals in the marine environment impact marine life often by reducing the reproductive success or increasing vulnerability to disease. These impacts are observed at different levels of the marine food chain, and often accumulate in mammals that have a longer life span than other species.

An early and illustrative example of the likely negative effects of environmental contaminants on marine mammals was given by the seals in the Baltic. Here, seal populations diminished more and more during the 1960s and 1970s. This decline was a result of lowered reproductive success since many females had lost the ability to give birth because of occlusions in the uterus. These pathological changes in seal uteri were correlated with organochlorine concentrations (Helle et al., 1976). High levels of organochlorines did not only result in pathological uterus lesions, but likely led to a larger disease complex including lesions on skin, claws, intestines, kidneys, the adrenal gland and skeleton (Bergman and Olsson, 1985; Mortensen et al., 1992). It was hypothesized that methyl sulphone metabolites of DDE or PCBs (Bakke et al., 1982) were largely responsible for the predicament of the seals, because of the chemicals' disposition to accumulate in the adrenal cortex (endocrine tissue; causing adrenocortical hyperplasia; Bergman and Olsson 1985).

In harbour porpoises (*Phocoena phocoena*) high levels of persistent organic pollutants also tended to be associated with lower ovarian scar numbers, possibly indicating inhibition of ovulation, or that some females may go through a number of infertile ovulations prior to successful pregnancy, birth and survival of their first offspring during early lactation (Murphy et al., 2010).

It has also been shown that exposure of marine mammals to contaminants has been associated with biological effects mediated through the disruption of endocrine processes. Alteration of thyroid hormones and thyroid hormone receptor gene expression by environmental contaminants is shown in harbour seals (*Phoca vitulina*; Tabuchi et al., 2006). This suggests that the thyroid hormone system in harbour seals is sensitive to disruption by environmental contaminants, something that may lead to adverse effects on growth and development, as well as lipid metabolism and energetics.

Exposure to persistent organic pollutants has also been associated with altered circulating vitamin A (retinol) in harbour seals (Simms et al., 2000). It was shown that circulatory levels of vitamin A in harbour seal pups were likely determined by PCBs exposure, and this contaminant-related disruption occurred at a life stage when vitamin A is required for growth and development. Plasma retinol (Jenssen et al., 2003) and thyroid hormones (Sørmo et al., 2005) in grey seal pups (*Halichoerus grypus*) have also been shown to correlate negatively with organochlorine concentrations.

The immunomodulatory effect of environmental contaminants on marine mammals was suggested by the association of changes in lymphocyte proliferation in harbour seal pups with, particularly, PCBs (Levin et al., 2005). Such effects could result in susceptibility to infections. Furthermore, it has been shown that concentrations of PCBs were higher in harbour porpoises that had died of infectious disease, compared to healthy porpoises that died due to physical trauma, mainly by-catch (Jepson et al., 1999), suggesting immunosuppressive effects. Similarly, it was shown that mercury (Hg) liver concentrations and the mercury:selenium (Se) molar ratio were higher in porpoises that died of infectious diseases caused by parasitic, bacterial, fungal and viral pathogens when compared to healthy animals that died from physical trauma (Bennett et al., 2001). However, these results may have been confounded by other variables, such as age (Bennett et al., 2001). Correlating concentrations of mercury and selenium has earlier been observed in marine mammals, and it has been suggested that selenium plays a protective role against the toxic effects of inorganic and organic mercury (Teigen et al., 1993; Skaare et al., 1994).

4.5 State and impact of marine litter pollution

Marine litter is increasingly recognised as a modern source of pollution. For example, large-scale accumulations of floating waste, particularly microscopic pieces of plastic — degraded micro particles from larger pieces of plastic have been observed in very large areas of the central Pacific in an area known as the Great Pacific Garbage Patch. This is increasingly being recognised as a problem also in the North East Atlantic, although observations are still sparse.

Litter washed ashore is the most obvious sign of marine litter. Litter is also found floating in the water column, and at the sea floor of both shallow and deep water. Litter has numerous sources and consist of many different materials: plastics, wood, metal, glass, rubber, or clothing.

More widely recognised problems arising from marine litter are associated with entanglement, ingestion, suffocation and general debilitation (Gregory, 2009). Microscopic plastics cause harm to animals because plastics are ingested as part of their foraging, which creates nutritional problems. For example, it has been documented that around 95 % of fulmars in the North Sea have plastics in their stomachs (Van Franeker et al., 2005) that affects their body condition and reduces their ability to reproduce and even survive. Further chemicals with a broad range of toxic, carcinogenic or hormone disturbing effects sorbs to the surface of micro plastics and thus enter into the marine food chain with their ingestion (Thompson et al., 2009).

In Europe, surveys of litter on beaches or at sea are starting to be carried out in response to a requirement in the MSFD which uses marine litter as one of its descriptors of good environmental status. The quantities of litter found on beaches are listed in Table 4.1.

Plastics were the most common type of litter found on all of the beaches surveyed. On the Greek beaches, three dominant litter sources were identified: land-based sources, 69 %; vessel-based sources, 26 %; and fishery-based sources, 5 % (Koutsodendris et al., 2008).

Photo: Bottlenose dolphin, Amvrakikos Gulf, Greece
© Nikolaj Bock

Table 4.1 Quantities of marine litter found on Europe's beaches

Region	Sea	Litter (items/100 meter beach)
North East Atlantic (OSPAR, 2009b)	Northern North Sea	600–1 400
	Southern North Sea	200–600
	Celtic Seas	600–800
	Bay of Biscay and Iberian coasts	100–300
		Most common items on all beaches in this region were small plastic/polystyrene pieces
Baltic Sea (HELCOM/UNEP/RSP 2007)		High: 700–1 200 Low: 6–16 30–60 % were plastics
Sea	**Location**	**Litter (kg/km²)**
Mediterranean (Koutsodendris et al., 2008)	Greek Gulfs of Patras, Corinth, Echinades and Lakonikos	6.7–47.4 Plastic litter: 56 % Metal: 17 % Glass: 11 %
Black Sea		Plastics: 333–6 250 Glass litter: 222–1 455

Box 4.4 State and impact of noise pollution

Noise has recently become an issue of concern. Noise from ships' propellers and engines, construction, airguns used for seismic surveys and high intensity military sonar have resulted in increased underwater background noise levels in the world's oceans. Shipping noise now dominates the low frequency background noise in many parts of the world's oceans and seems to be growing by about 3–5 decibels per decade in deep offshore waters and there is concern that this is having an impact on marine life, particularly marine mammals.

The implementation of the MSFD will increase monitoring of noise and focus on reducing amounts because it is one of its descriptors of good environmental status. It will, however, be difficult to precisely characterize what noise is of concern. Noise may be impulsive or continuous. Impulsive noise, for example associated with construction, is often also repetitive but at a distance from its source, it becomes indistinguishable from continuous noise. The distance travelled by noise depends on the frequency of its sound. The lower the frequency, the greater the distance it can travel. Organisms that are exposed to noise can suffer from acute effects or chronic effects. Adverse effects range form subtle behavioural change to death, but it is currently not understood which type of noise or which part of the noise spectrum has the most serious effects on marine life (OSPAR, 2009c).

The increase in noise is of particular concern for large baleen whales that are thought to rely on low-frequency sound for communication over large distances: it may cause these species to leave important feeding and breeding areas and interfere with their ability to find prey, escape predators and communicate with others. The use of sonar, particularly mid-frequency sonar in military exercises, has been strongly linked to a series of mass mortalities of whales in the Greek and Canary Islands (Talpalar and Grossman, 2005). In the Canary Islands, 14 beaked whales were stranded at the same time as nearby naval exercises using mid-frequency sonar and showed haemorrhage around acoustic tissues and fat emboli and lesions in vital organs consistent with modified dive behaviour in response to the sonar (Talpalar and Grossman, 2005).

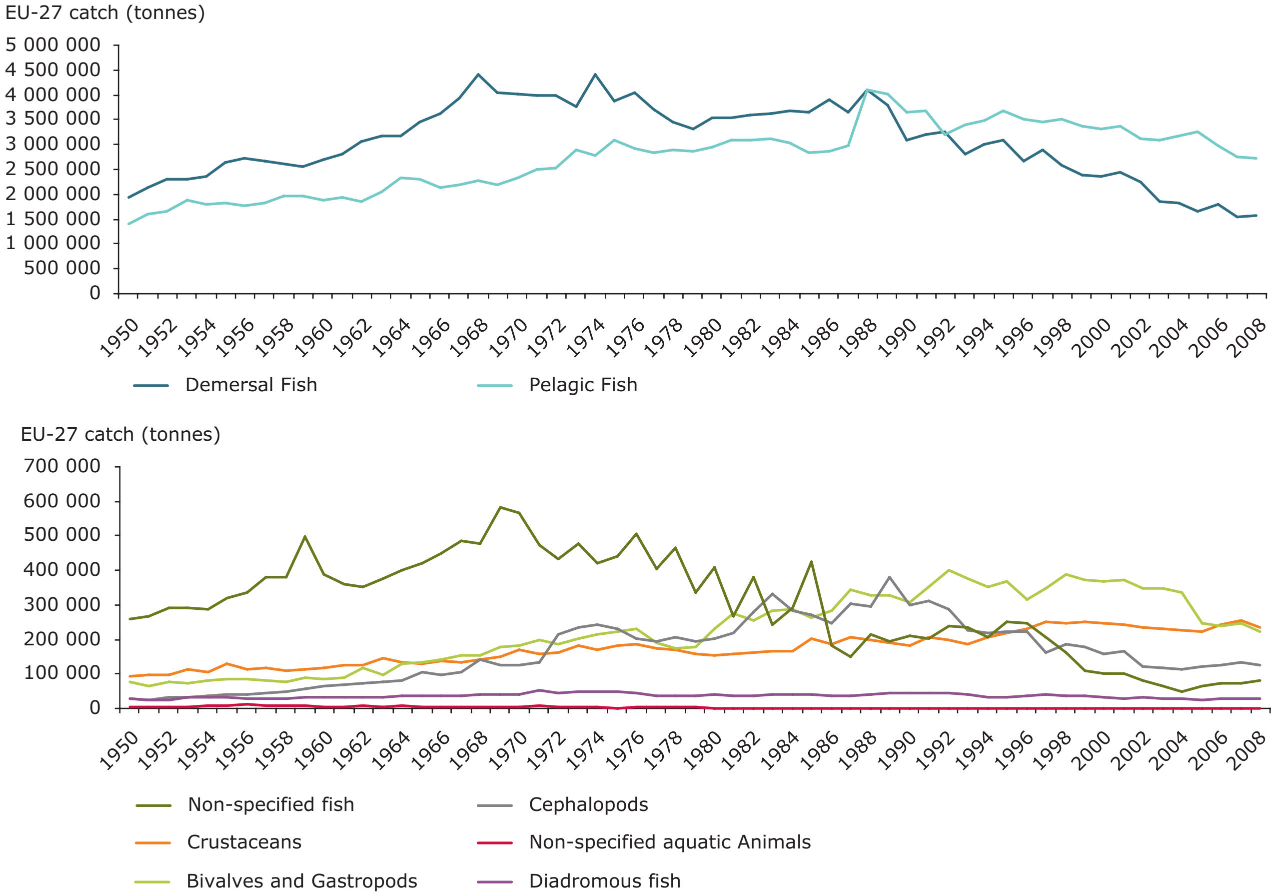
5 Maritime sectors

Activities considered as part of the maritime sectors include fisheries and aquaculture; maritime transport; off-shore renewable energy; shipbuilding; oil, gas and mineral extraction, tourism (see SOER 2010 consumption and the environment assessment, EEA, 2010j) and marine research. In the future it is expected that targeted extraction of marine organisms will be extended as marine biotechnology begins to exploit the potential of living organisms such as sponges in pharmaceutical products. This is expected to impact deep sea organisms more.

5.1 State and impact of fisheries and aquaculture

Fishing acts to remove fish, which in many cases have an ecosystem function as top predator, from the marine ecosystem, and fishing pressures in most of Europe's seas exceed sustainable levels. This has led to a general decline in fish catches since 1985. This decline is particularly pronounced for demersal species such as cod, with catches falling by an approximate average of 100 000 tonnes per year between 1985 and 2008 (Figure 5.1). Presently, 93 %

Figure 5.1 **Fish catches by the EU-27, 1950–2008 (tonnes) for different categories of fish and invertebrates**



Note: Dermersal fish are those living close to sea floor such as cod. Diadromous fish are species that live partly in the sea and partly in fresh water such as salmon and eel. Catch statistics are not available for all EU-27 Member States throughout the period. In 1988, the catch of pelagic fish increased because data from Estonia, Latvia and Lithuania were included from that year onwards. Data from Slovenia were included from 1992 onwards.

Source: FAO Fishstat, 2010.

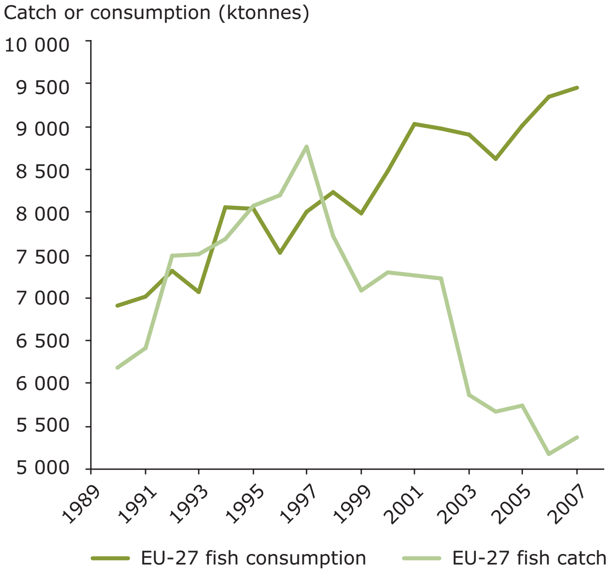
of the fish caught are immature; the average age of cod caught in the North Sea is 1.6 years with a weight of less than one kilo (EC, 2008a) — a clear indicator that the quality of the marine pelagic ecosystem is declining.

In the same period that fish catches have declined, the consumption of fish in Europe has been increasing. This has lead to a gap between supply and demand of fish of roughly 4 200 tonnes per year (Figure 5.2). Approximately 25–30 % of this gap is being met by increasing marine aquaculture production within Europe; the remaining 70–75 % of the demand is met by importing fish from other countries. In this way Europe is exporting a drive to over-exploitation to other seas of the world unless European fisheries become managed to more sustainably provide a greater proportion of the EU market demand for fish.

State of fisheries

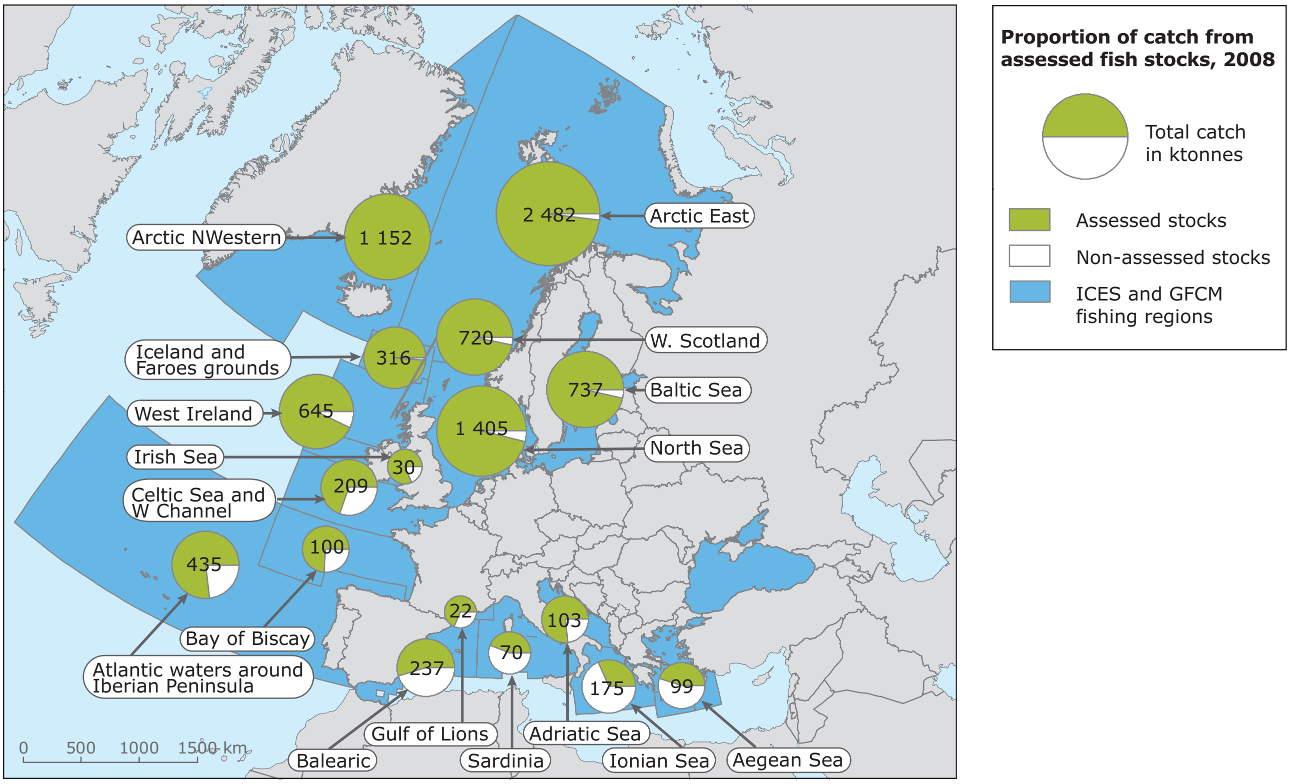
The largest fish catches in European seas occur in ICES areas of the North Sea, Arctic West and East, Iceland and Faroese grounds and West Scotland. Approximately 70 % of the European catch is from these areas. Only about 10 % of the European fish catch is from the Mediterranean Sea.

Figure 5.2 **Comparison of total EU fish catches and consumption**



Source: FAO FISHSTAT, 2010. EU-27 Consumption is calculated as the sum of EU-27 fish catch and aquaculture production and imports minus EU-27 exports.

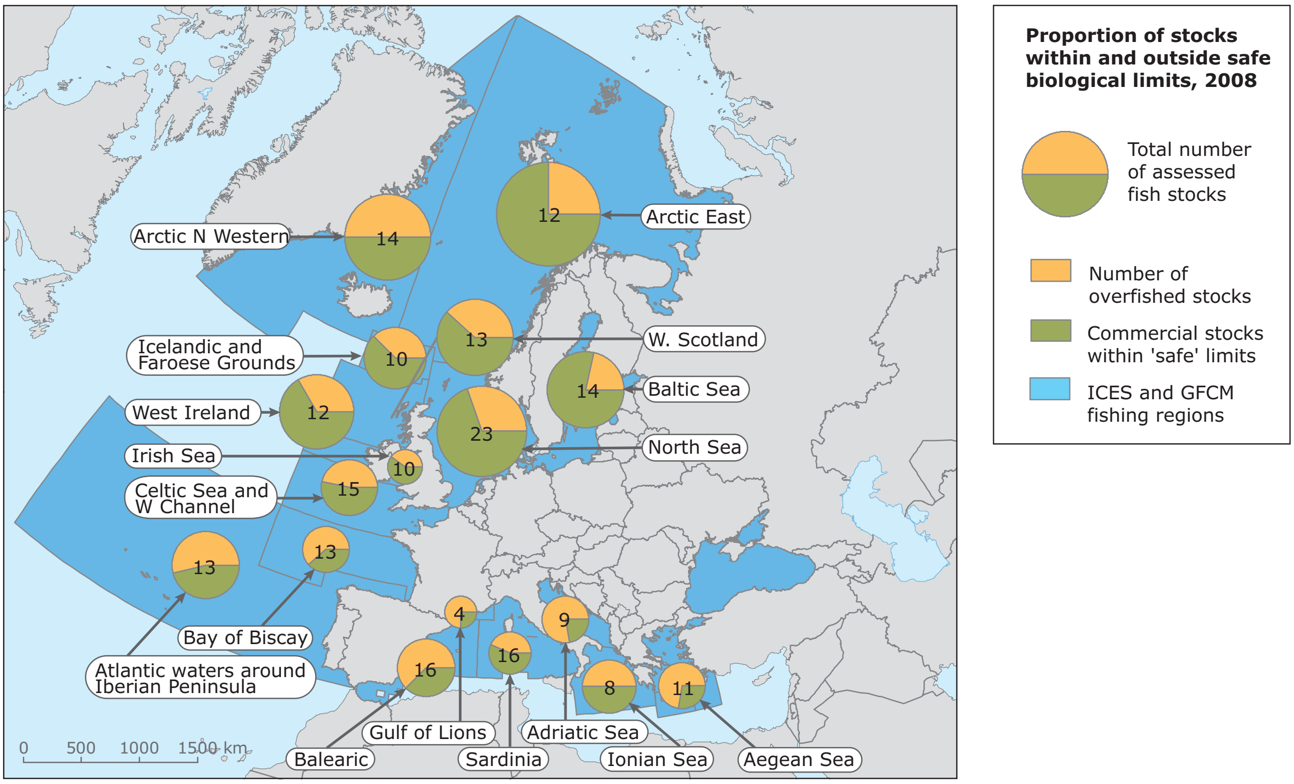
Map 5.1 **Total catch in International Council for Exploration of the Sea (ICES) and General Fisheries Commission for the Mediterranean (GFCM) fishing regions in Europe, 2008**



Note: Numbers in the circles are the total regional catch in thousand tonnes. In the ICES fishing regions catch is by all countries fishing in the region including non-EU countries: Iceland, Norway, USA, Canada and Russia.

Source: EEA, 2010a.

Map 5.2 **Status of fish stocks in International Council for Exploration of the Sea (ICES) and General Fisheries Commission for the Mediterranean (GFCM) fishing regions of Europe, 2008**



Note: The numbers in the circles are the number of stocks assessed within the given region. The size of the circles is scaled proportional to the size of the regional catch.

Source: EEA, 2010a.

In Europe, fisheries are managed by annually agreeing total allowable catches (TACs), some times referred to as quotas. Stock assessments are produced to identify the scientific basis for fish catches. These assessments form the basis of advice provided on the maximum catch that can be allowed within sustainable limits. Based on this input, fisheries ministers then agree on the TAC for each species, which are commonly higher than the advised level. At present there is a move to more conservative targets in the advice to enable restoration of overexploited fish stocks (Box 5.1).

The EEA indicator of the status of commercial fish stocks shows that over fishing in Europe's Seas continues to be a problem. Although many commercial fish stocks are assessed (Map 5.1), there is a tendency of assessing more stocks in the north than in the south. In the Arctic Northwest 99.5 % of commercial stocks are assessed, whereas only 25 % of commercial stocks in the Ionian Sea are assessed. However, in spite of having assessed most of the stocks in the Arctic Northwest, 50 % are fished outside safe biological limits — those stocks are knowingly not managed sustainably. In general, the percentage of assessed stocks decreases in the Mediterranean. In the Black Sea stock assessments are sporadic and only beginning to be internationally coordinated.

At present, 30 % of the stocks for which information exists are fished outside safe biological levels (Map 5.2). This means that the harvest from 30 % of our stocks has for many years been so intense that the future productivity of these stocks is now threatened. Of the assessed commercial stocks in the North East Atlantic, 25 % in the Arctic East to 62 % in the Bay of Biscay are outside safe biological limits (Map 5.2). In the Baltic Sea, 21 % of fish stocks are outside their safe biological limits. The pelagic stocks — fish living well above the sea bottom and sometimes close to the sea surface — like herring and mackerel usually are in better condition than demersal fish stocks — those living close to the sea bottom — like cod, plaice and sole (EEA, 2010a). In fact, almost all demersal stocks have declined and are currently not being managed sustainably. In addition, some stocks of industrial species like capelin in the Arctic and sandeel in the North Sea are in a poor state (ICES, 2009). In addition, 80 % of stocks are fished so heavily — above MSY — that the yield is

Box 5.1 Changing targets for fisheries management

The target used for advice in the North East Atlantic has to date been based on a criterion of maintaining stocks within safe biological limits, which corresponds to maintaining roughly 17 % of the unexploited stock biomass. It has, however, been agreed by the contracting parties to the Johannesburg conference on sustainable development in 2002, which include EU Member States, that the target should be changed to the spawning stock biomass producing maximum sustainable yield (MSY). Fish stocks capable of producing an MSY better fulfill their functions in the marine ecosystem and thus this measure is more in line with the precautionary approach and ecosystem-based management. The spawning stock biomass producing MSY is approximately 50 % of an unexploited stock, and is thus more conservative than the currently used safe biological limit. The MSY target is applied in the Descriptor 3 of the MSFD (EC, 2010e), and the Commission's Green Paper on the CFP reform suggests that it should be used as an objective of the CFP following its 2012 reform. The EEA is expecting to change its indicator to one based on MSY within the next year.

Based on data available from the European Commission, the proportion of fish stocks presently at MSY is less than 30 % in 2010 which is an improvement compared to earlier (Figure 5.3). In addition, the difference between TACs and sustainable catch is shown as share of catch above the MSY level, showing that agreed quotas are consistently set above the agreed sustainable level (EC, 2010b).

Figure 5.3 **Status of fish stocks and catch quotas in relation to MSY**

reduced, even though considerable effort is required to fish with such intensity. For comparison, 25 % of stocks are fished above MSY globally (FAO, 2005). Comparable values in other countries are 25 % in the United States, 40 % in Australia and 15 % in New Zealand.

Mediterranean reports on status of fish stocks are sporadic and irregularly updated. The percentage of stocks outside safe biological limits ranges from 50 % to 78 %, with the Adriatic Sea being in the worst condition (EEA, 2010a). The small pelagic stocks like anchovy and pilchard-sardines are fully exploited in the Balearic Sea and pilchard sardines are also fully exploited in the Adriatic Sea. Demersal stocks like hake and red mullet are fully exploited throughout the Mediterranean (EEA, 2010a). Concern also remains about the over-exploitation of tuna and swordfish, both top-predators, throughout the Mediterranean Sea. Uncertainties in stock assessment and a lack of documented reporting, including by EU Member States, still affect the management of these highly migratory species. Blue fin tuna catches continue to exceed the sustainable rate and an assessment from 2008 the International Commission for the Conservation of Atlantic Tunas (ICCAT) states: 'it is apparent that the total allowable catch is not respected and is largely ineffective in controlling overall catch'. The Committee's evaluation of the current regulatory scheme is that, 'unless it is adjusted to impose greater control over the fisheries by improving compliance and to reduce fishing mortality rates, it will lead to further reduction in spawning stock biomass with high risk of fisheries and stock collapse' (Box 5.2).

Impact of fisheries

Impacts of fisheries include changes in the marine food web due to removal of top predators, decreases in the size of fish caught, and targeting of more vulnerable stocks, socio-economic impacts such as reduced fishing opportunities and their associated economic consequences, a high level of illegal fishing, and reduced profitability leading to a high level of government subsidy to the sector.

The size and trophic level of the populations of commercial fish species appears to be changing because fishing has focused on large fish and large fish species for many years, often referred to as fishing down the marine food web. This is of concern because it may have a cascading impact on ecosystem functioning and in the end on ecosystem resilience. As top predators are removed, fishers target smaller fish lower in the food web, reducing their numbers and hence the average trophic level of the

Box 5.2 Bluefin tuna — on the edge of a stock collapse in the Atlantic and Mediterranean Seas

The bluefin tuna, *Thunnus thynnus* is a highly migratory fish found in the Pacific, Indian and North Atlantic Oceans, and the Mediterranean Sea. It is considered a delicacy in many countries, in particular in Japan that is driving a large part of the demand. A single fish has a very high market value, allegedly between USD 2 000 and EUR 20 000, but the BBC reported a single 232 kg fish being sold in Japan for USD 175 000 in January 2010 (BBC, 2010).

Over-fishing is particularly severe for East Atlantic and Mediterranean stocks which have decreased in recent decades and currently they are estimated to be only 15 % of their pre-industrial-fishing levels, a seriously low level possibly threatening the survival of the species (ICCAT, 2008). For some period, fishing pressure has been at least three times greater than the level needed to achieve MSY (ICCAT, 2008). In 2010, the Convention of International Trade of Endangered Species (CITES) attempted to make an agreement to completely ban all international trade of Atlantic blue fin tuna. Although the European Community and the United States supported a ban on trade, it was rejected in the final vote by Japan and Canada.

The International Commission for the Conservation of Atlantic Tunas (ICCAT) is responsible for the conservation of tunas and tuna-like species in the Atlantic Ocean and its adjacent seas. It sets the total allowable catches for the species, and it has a long term objective to achieve recovery of the stock by 2022, but the biomass of the stock nevertheless continues to decline. It has been generally accepted that a target catch of 15 000 tonnes in the East Atlantic and Mediterranean would be sustainable. For example, in 2009 the target catch was 22 000 tonnes, but as illegal landings were high the actual catch is likely to have been much higher. The target was reduced to 13 500 tonnes in 2010, but the continued exploitation of the species means that even a reduction of the TAC to 8 000 tonnes would only leave the tuna stock a 50 % chance of achieving the ICCAT recovery goals.

In addition to fishing, the bluefin tuna is also threatened by tuna ranching. Juvenile tuna are caught in the wild and raised in cages. Ranched tuna are fed on large amounts of small pelagic fish such as sardines and anchovies — which are also over-fished in the Mediterranean — taking as much as 20 kg of wild fish to produce 1 kg of tuna. The tuna ranching is another result of long-term over-fishing: there are now fewer large fish left to exploit and the industry is therefore shifting to taking smaller fish and then raising them to market size in aquaculture. After several months, when the tuna have reached optimal market size, they are harvested and sold primarily for the sushi and sashimi markets in Japan. European tuna ranching is based mainly in Spain and Croatia (Ottolenghi, 2008).

Photo: The bluefin tuna, *Thunnus thynnus*
Courtesy of United Nations Food and Agriculture Organization

food web (Pauly et al., 1998). An often-used indicator of this effect is the Marine Trophic Index (MTI), (Figure 5.5).

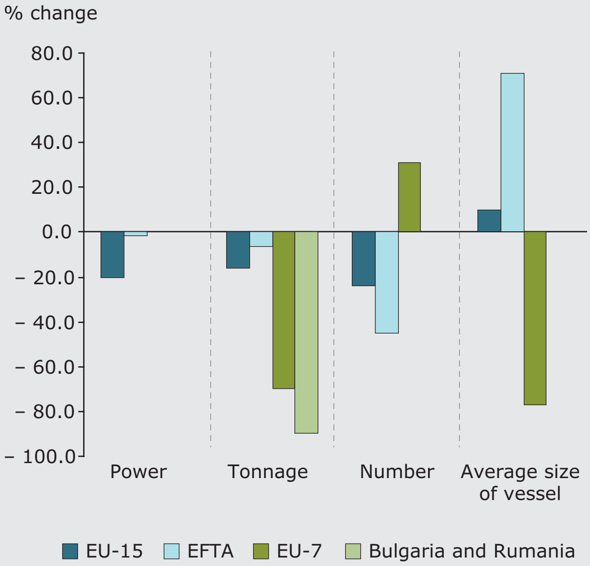
A side-effect of fishing is the destruction of sea-floor habitats that occurs when fishing gear such as trawls are dragged along the sea floor damaging or killing plants and animals living in or on the seafloor sediments. Sea-floor disturbance has been shown to reduce benthic production and diversity (Jennings and Kaiser, 1998; Tillin et al., 2006; Callaway et al., 2007). An analysis of long-term data from the North Sea indicated that the observed temporal changes in benthic community structure were driven by fishing impacts (Frid et al., 2009) and that the most impacted species were the more vulnerable ones (Robinson and Frid, 2008). Slow-growing large biota such as sponges and soft corals take much longer to recover than those with shorter life-spans such as polychaetes (Kaiser et al., 2006). In the most extreme case the disturbance can lead to irreversible changes such as damage to cold water coral reefs; for example, in the eastern shelf areas of the Norwegian Sea, damage to such reefs has led to areas being closed for bottom trawling. It is estimated that 30–50 % of the coral areas may be damaged or negatively impacted (Fosså et al., 2002; ICES, 2008b). A recent study comparing human activities on deep-sea ecosystems concluded that the impact of bottom trawling was at least an order of magnitude greater than the combined effect of other activities (Benn et al., 2010).

Another side-effect of fishing is by-catch, the catch of non-targeted species. By-catch affects nearly all marine species including animals living on the seabed, marine mammals, reptiles such as turtles and seabirds. By-catch and discards of non-target fish species can be substantial — in some cases 50 % of the total catch (Daan et al., 1990; ICES, 2008a). In the Mediterranean Sea, by-catch is considered to be the main threat to some of the most threatened shark and ray populations in the world with 42 % critically endangered, endangered, or vulnerable. Mediterranean fisheries also have an important impact

Box 5.3 Fishing fleet capacity

A key factor for the pressure towards increasing TACs and hence high fishing pressure is linked to excess capacity of the fishing fleet. Capacity is the amount of fish that could be caught within a year or a fishing season by a vessel or fleet if fully used and for a given resource condition. Excess capacity means that the fleet can remove so much fish that the future productivity of the stock is jeopardized.The current capacity of the EU fishing fleet could, in most cases, result in the annual catch being two to three times the sustainable level (EC, 2009a*).* The 2002 CFP reform requires the monitoring of numbers, tonnage and power of vessels with the aim of reducing the capacity of the fleet. Technological development, in the range of 3 % per year in many fisheries, leads to excessive harvest capacity unless the fleet size is reduced proportionally. The effective harvest capacity of European fishing fleets has therefore, in spite of many years political effort to reduce the capacity, not been reduced as much as needed to bring the effective capacity in balance with the resources available (EC, 2009b). Although the number of vessels has been reduced in EU-15 and EFTA between 1998 and 2007, the power of vessels has not been reduced equivalently. This results in an increase of the average vessel size, and it is likely that these countries have moved to larger more efficient vessels rather than reducing their fishing capacity. In contrast the average vessel size in the EU-7 has decreased.

Figure 5.4 Changes in fishing fleet capacity



Changes in fishing fleet capacity — defined as power, tonnage, number of vessels and average vessel size in 1998–2007 for EU-15 and EFTA, and 1995–2007 for EU-7 and Bulgaria and Romania. Time periods have been chosen to allow comparison between country groupings but there may not be data for each year for EU-7 and Bulgaria and Romania (EEA, 2010b).

Note: EU-15: Group of Member States that joined the EU before 2004 (Belgium, Denmark, Germany, Greece, Spain, France, Ireland, Italy, Luxembourg, the Netherlands, Austria, Portugal, Finland, Sweden, the United Kingdom), EU-7: Group of Member States that joined the EU in 2004 with a fishing fleet (Estonia, Cyprus, Lithuania, Latvia, Malta, Poland, and Slovenia).

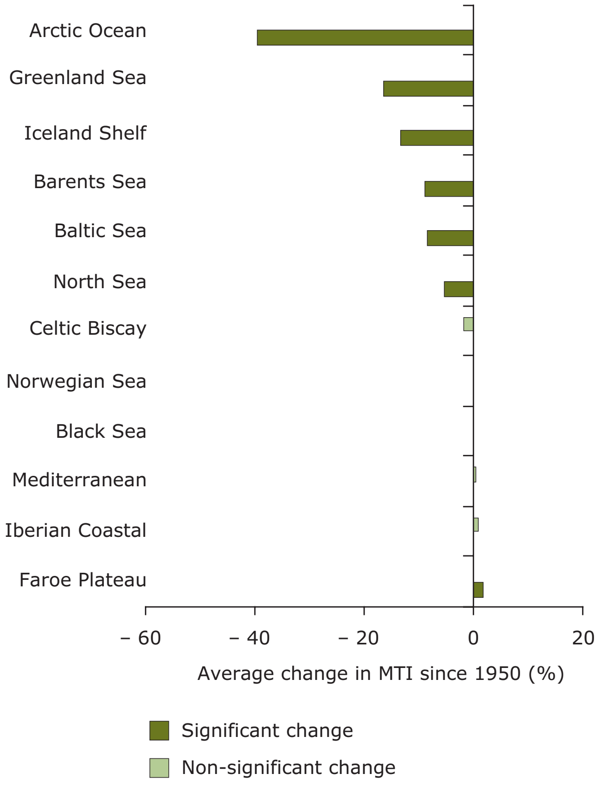
Source: EEA, 2010b.

on the local turtle stock: more than 60 000 turtles are caught annually, with mortality rates of 10–50 % of the turtles caught (Tudela, 2000). Data on harbour porpoise in the Baltic Sea indicate that the by-catch percentage of this protected species lies between 2 % and 18 % of the population (Scheidat et al., 2008). In Europe sampling of discards became mandatory under EU legislation in 2009 and it is being considered as one of the elements under which Member States will have to report on to achieve a healthy food-web structure under the MSFD.

Due to decreasing catches in areas like the North Sea, fisheries are targeting new species, which have different life cycles from those traditionally caught and has resulted in rapid over exploitation. Some stocks in deep-sea areas — more than 400 meters deep — are being over-exploited due to a combination of reduced fish stocks on the continental shelf and technological improvements of the fishing fleet (see below). Some deep-sea species are highly sensitive because they do not mature until they are 40 years old but then may live for a few hundred years. For example, deep-sea species like Greenland halibut and redfish stocks are outside safe biological limits in the Arctic Sea and stocks of ling in the Bay of Biscay are uncertain (EEA, 2010a). Deep-sea fishers are also catching large amounts of non-target species, whose survival is low due to the large pressure difference between their usual deep habitat and the sea surface (ICES, 2008a).

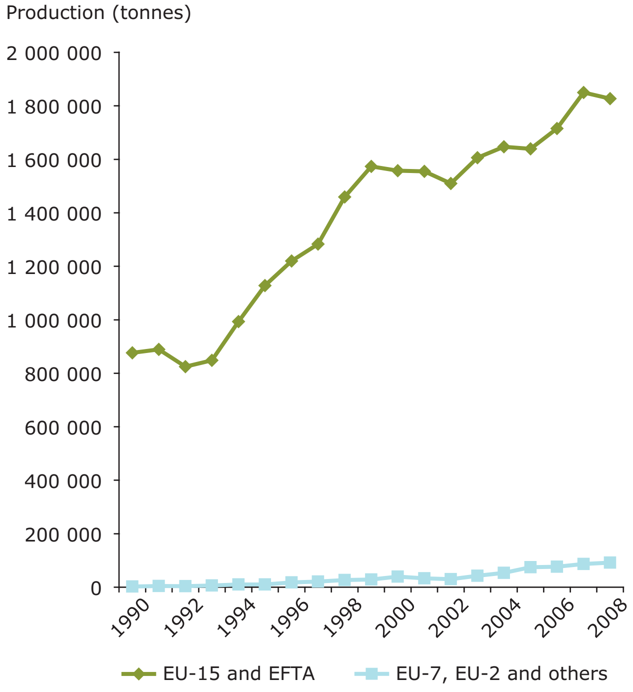
The socio-economic impacts of the decline in fisheries and the increased efficiency of the industry are significant. Employment in the EU fisheries sector has decreased, particularly in communities that are traditionally highly dependent on fishing — for example, in Portugal, employment in the fisheries sector fell by 55 % between 1990 and 2006 (Eurostat, 2008). The economy of many communities, however, depends on fisheries and the profitability of the EU's fishing fleet has been maintained by EU and national subsidies. In some Member States these have reached a level, where the national budget for managing and subsidising fisheries exceeds the economic value of the catches (EC, 2008a and 2009a). With reduced fishing opportunities, rising fuel prices, profitability could be further reduced (EC, 2009a).

Figure 5.5 **Average change in Marine Trophic Index in seas in Europe**



Source: Seas Around Us, 2010.

Figure 5.6 **Annual aquaculture production by major area (EU-15 + EFTA and EU-7, EU-2 + others), 1990–2008**



Note: Aquaculture production includes marine and brackish environments. Grouping used in CSI 033: Countries have been grouped into the following categories: EU-15: Belgium, Denmark, Germany, Greece, Spain, France, Ireland, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden, United Kingdom, EFTA: Iceland and Norway. EU-7: Estonia, Cyprus, Lithuania, Latvia, Malta, Poland, and Slovenia, EU-2: Bulgaria and Romania, others: Turkey and Slovakia.

Source: FAO FISHSTAT Plus, 2010, Global Aquaculture Production 1950–2008.

An additional consequence of reduced legal fishing opportunities is thought to be illegal, unreported, and unregulated fishing (IUUF), such as fishing without a licence, misreporting of catches, fishing in closed areas or with illegal gear, and taking undersized fish (EC, 2008b). Figures for IUUF are uncertain but up to 49 % of the total catch in EU waters — with some variation depending on the stock — may be caught illegally. For example, 20–30 % of all cod catches in the Northeast Arctic and about 40 % of bluefin tuna catches in the Mediterranean and East Atlantic could be from IUUF (Stokke, 2009).

State of aquaculture

In response to increased demand for fish products and the reduced supply of wild caught fish, a large increase in total European aquaculture production has been observed over the past 15 years (Figure 5.6). Today, EU and EFTA aquaculture production is at a level of 1.8 million tonnes of fish, shellfish and crustaceans, generating a turnover of around EUR 3.2 billion, while supporting 65 000 jobs. EU-15 and EFTA countries produce approximately 95 % of the total European aquaculture products. The largest aquaculture producer in Europe is Norway where its production of Atlantic salmon accounts for about 40 % of Europe's total aquaculture production. Spain is second largest with its production dominated by blue mussel followed by France's production dominated by the Pacific cupped oyster (*Crassostrea gigas*). Turkish production consists mainly of trout, sea bream and sea bass (EEA, 2010c).

Impacts of aquaculture

Different types of aquaculture generate very different pressures on the environment, the main pressures being discharges of nutrients, antibiotics and fungicides.
The main environmental pressures are associated with intensive finfish production — mainly salmonids in marine, brackish and freshwaters, and sea bass and sea bream in the marine environment. These are also the sectors that have experienced the highest growth rate in recent years. The pressures associated with the cultivation of bivalve molluscs, which include the removal of plankton and a local concentration and accumulation of organic matter and metabolites, are generally considered

to be less severe than those from intensive finfish cultivation.

The precise level of local impact will vary according to production scale and farming practices as well as local and regional hydrodynamics, and chemical characteristics. Escaped farm fish can interact with wild fish populations and compete for resources. The introduction of new aquaculture species provides a pathway for non-indigenous or non-native species — and their associated parasites and pathogens — to enter the marine environment impacting on local wildlife. Marine finfish aquaculture contributes to the nutrient loads in coastal waters, particularly in the case of areas with relatively small total nutrient discharges.

There is also increasing concern that aquaculture in some places is increasingly shifting from a focus on low trophic level invertebrates such as shellfish to high trophic level species. This has been referred to as farming up the foodweb (Pauly et al., 2001). In the Mediterranean Sea, this has lead to an increase of trophic level from 2.0 to 3.0 between 1990 and 2004, particularly due to the increase in bluefin tuna capture production which in 2007 had an estimated capacity of 55 000 tones (Stergiou et al., 2009; CIESM, 2007). As for fisheries, aquaculture is sometimes performed illegally without appropriate permits and therefore there is some uncertainty regarding actual numbers.

Finally, it is of concern that the European aquaculture industry is moving towards raising higher trophic level species, especially those that require large quantities of food based on small pelagic fish. It has been assessed that it takes 4 kg of small pelagic fish to raise 1 kg of salmon, and in the case of tuna the ratio is much greater. Although the industry is working on reducing this ratio, particularly for salmon, it is of concern because aquaculture introduces a large demand for smaller pelagic fish and may further disrupt ecosystem functioning. Further it may introduce a competition between demands for human consumption and aquaculture production (Naylor et al., 2000).

5.2 Maritime transport

Within Europe, short sea shipping — the transport of goods among European countries comprises about 60 % of maritime transport and is a major alternative to the road transport of goods. In total, in the EU-27, 1 720 million tonnes of cargo was moved by sea in 2007, amounting to roughly 40 % of EU cargo. Liquid bulk which includes liquefied gas, crude oil and oil products, 896 million tonnes, accounted for about half the total tonnage carried at sea. Transport grew approximately 7 % between 2002 and 2007. The ship traffic is largely along major shipping routes. Shipping is an example of a major maritime activity which primarily impacts supporting ecosystem services while being of great economic and practical importance to humans.

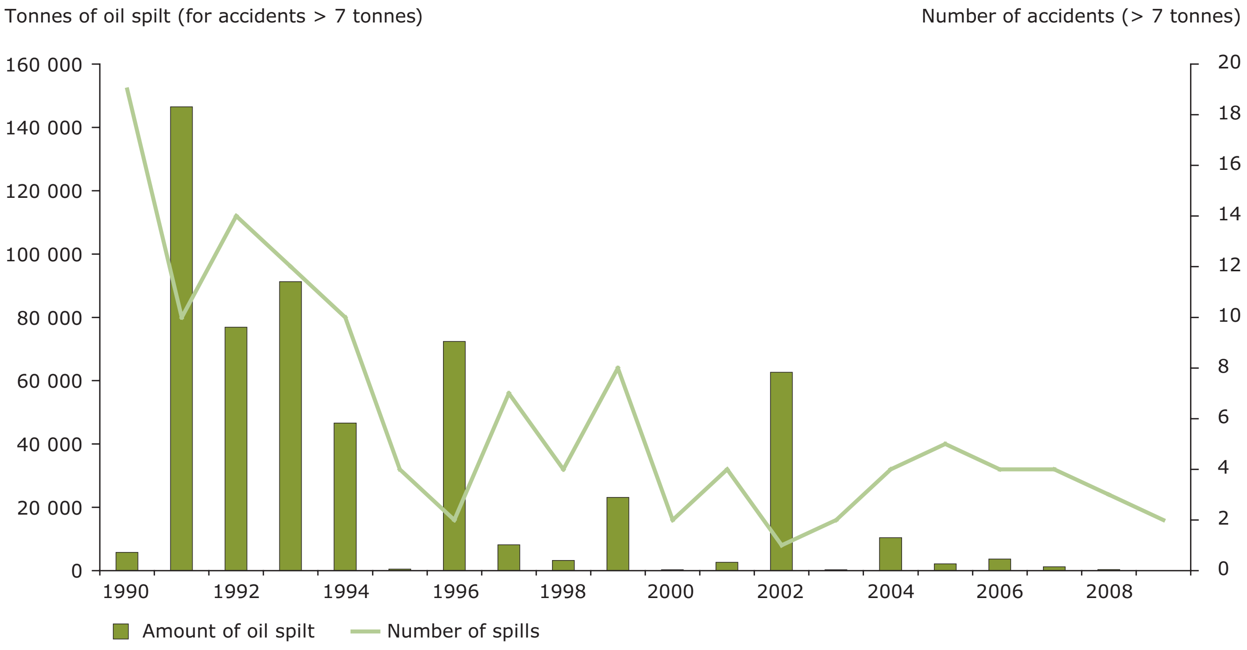
Some chemical pollution is caused by the transport of goods by sea. This is diffuse and unevenly distributed; it is mostly observed in ports and along the major waterways. In these areas it is common, although illegal, for ships to discharge oil operationally. The transport of oil also carries a risk of accidents that have serious environmental impacts. Pollution by anti-fouling paint containing tributyltin (TBT) compounds that have been shown to cause imposex in sensitive species is also widespread. Furthermore, the practice of discharging ballast water used for stabilizing ships is considered a major vector for the introduction of alien species. Ship emissions also contain particulate matter, NO_x and sulphide and are a major contributor to air pollution (see SOER 2010 air pollution assessment, EEA, 2010k).

State and impact of oil spills

Illegal, operational oil discharges can result from the discharge of bilge-water from machinery spaces, fuel-oil sludge and oily ballast water from fuel tanks. It is estimated that at least 3 000 major illegal oil discharge incidents take place in European seas each year. Although each discharge is small, they are numerous (Redondo and Platonov, 2008) and together they could be of the same order of magnitude as the largest accidental oil spills. In the Baltic Sea the surveillance of illegal operational discharges is based on a combination of satellite detection and aerial confirmation, and this intense monitoring has helped reduce the number of observed incidents (HELCOM, 2010).

Accidental oil spills from tankers occur at irregular intervals. Of these, 44 % of the total tonnage spilt worldwide is due to grounding of ships; 27 % to fire or explosion; 15 % to hull failure; and 14 % are due to collisions. Major spills, those of more than 20 000 tonnes, account for about 10–15 % of all oil that enters the oceans worldwide, a percentage that will decrease following the 2010 Deepwater Horizon accident in the Mexican Gulf where approximately 1 billion tonnes of oil were released. During 1990–2005, there were 106 accidental spills, and although only seven of them resulted in spills of 20 000 tonnes or more, they accounted for 89 % of the total volume of oil spilt (Figure 5.7). Large accidental oil spills, where more than 7 tonnes of oil is spilt, and thus the amount of oil spilt into EU-25 marine waters has decreased significantly over the past 17 years. This is attributed to the gradual phase-out of single hulled tankers to be completed in 2015. The most significant recent spill in the Black Sea was from the *Volgoneft-139* in 2007 on the Kerch Strait between the Black and Azov Seas, where at least 1 300 tonnes of fuel oil was split (UNEP, 2008). However, increasing energy demand will probably

Figure 5.7 **Annual number of accidents (with > 7 tonnes of oil spilt) and volume of oil spilt in EU-25 for accidental oil spills where > 7 tonnes of oil was spilt**



Note: Figures include all EU Member States except for Romania and Bulgaria.

Source: ITOPF 2008.

increase the transport of bulk liquids and can be expected to increase the risk of accidental oil spills.

Oil discharges and spills to marine areas can have significant impacts on livelihoods and human health as well as on marine ecosystems. Discharges and spills in areas where fish spawn or feed or in or near aquaculture sites may lead to closure of the fishery or fish farms, and in coastal areas to a decline in tourism. Human health can be adversely affected by oil either as a result of inhaling or touching oil products, or from eating contaminated seafood. This may cause an associated loss of income and livelihoods — particularly relevant in the Gulf of Mexico where the Deepwater Horizon accident has caused a spill larger than any accident previously imaginable.

Marine ecosystems are affected because the consistency of oil affects surface water and can smother marine animals and plants and its chemical components including polycyclic aromatic hydrocarbons (PAHs) can cause acute toxic effects and long-term accumulative impacts. The environmental damage caused by oil depends on the composition and amount of oil discharged, the duration and season of the spill, and site specific conditions.

For example, the oil spill resulting from the accident of the oil tanker *Prestige* in November 2002 did not become the environmental catastrophe that was expected at the time of the spill. About 50 000 tonnes of drifting heavy oil (type M-100) was released off the coast of Northern Spain covering 30 000 km^2 of the surface of the Cantabrian Sea and Galician waters (Sanchez et al., 2006). Several studies showed a strong biological impact on inter-tidal communities and fishing resources during the first year following the spill, but by 2004 most of the areas had recovered (Penela-Arenaz, 2009). For example, it was not possible to detect PAH concentrations above the baseline pollution of coastal areas that were impacted by the spill, (Franco et al., 2006). The high PAHs concentrations in wild mussels had also declined to background levels two years after the spill (Fernandez et al., 2010). Food-chain impacts were studied on populations of demersal fish such as hake and four-spot megrim, and the crustaceans Norway lobster and pandalid shrimp that feed on organisms living in the sea floor, but it was not possible to detect impacts exceeding those of natural variability or commercial fisheries (Sanchez et al., 2006). This was thought to be due to the heavy nature of the oil spilled. Although long-term impacts appear slight, it is important to note that an estimated EUR 2.5 billion was spent on the clean-up operation on the Galician coast between 2002 and 2003, and the remaining cargo oil was removed from the wreck in 2004 at an estimated cost of more than EUR 100 million.

In other cases where the type of oil spilt is lighter impacts can be much greater as with the *Exxon Valdez* oil spill in 1989. This accident stressed the importance of extending the conduct of environmental impact assessments beyond the traditionally accepted period of the few years following the spill event. Here impacts have been documented up to 20 years after the spill, much longer than previously assumed (Esler et al., 2002).

TBT

Due to the serious negative effects of TBT which were first noted in the 1960s, its use has gradually been phased out. The Anti-fouling Systems on Ships Convention implemented in EU legislation (EC, 2003) applies to approximately 70 % of the global ship tonnage. As a consequence of this legislation a general downward trend in the North-East Atlantic has been observed (OSPAR, 2009a). Of the 134 time series from Denmark, France, the Netherlands, Norway, Sweden and the United Kingdom, 108 were downwards and 24 statistically insignificant. In the future, the effects of alternatives containing copper and biocides should be followed closely

Non-indigenous and invasive alien species

The marine food web can also be threatened by the introduction of non-indigenous species for example from ships' ballast-water discharges and hull fouling. Ballast water is needed to provide stability and manoeuvrability. It is estimated that 3 000–4 000 million tons of untreated ballast water are discharged from ships every year in ports, and in coastal regions. Furthermore, it is estimated that more than 10 000 marine species each day may be transported across the oceans in the ballast water of cargo ships and introduced into a non-native environment. As ballast water may be fresh, brackish or saline, the coastal environment, estuaries and navigable inland waters, are at risk of receiving introduced species.

The opening of the Suez Canal resulted in a large number of new species entering the Mediterranean, and more recently aquaculture has introduced new species both intentionally and unintentionally. Sometimes these species, such as the Red King Crab which was deliberately introduced, are able to establish themselves in large numbers or act as carriers of harmful parasites.

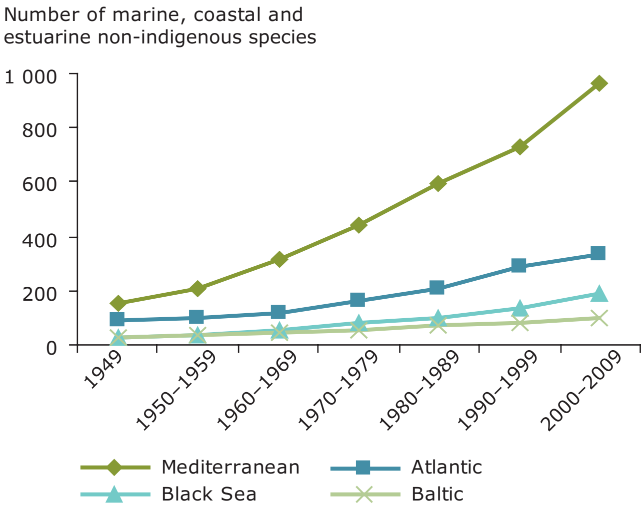
Marine, coastal and estuarine ecosystems across all European seas are potentially threatened by invasions of non-indigenous species. In some cases, these species find an ecological niche in which they do not have natural predators, cause serious ecosystem damage by altering food web structure and bring large costs to humans.

The biggest group of non-indigenous marine species are invertebrate animals such as jellyfish, shellfish and barnacles, followed by plants — including micro algae — and then vertebrate animals — mostly fish. The cumulative number of non-indigenous marine species has grown steadily since records began and risen dramatically in the last decade (EEA, 2007): it was estimated to have reached 1 376 by May 2009. Of these, 108 species were recorded in the Baltic Sea, 164 in the Black Sea, 376 in the North East Atlantic and 931 in the Mediterranean Sea. Some species are recorded in more than one sea (Figure 5.8).

5.3 Renewable energy

In December 2008, the EU adopted an ambitious and far-reaching climate change and energy package which, *inter alia*, commits the EU-27 countries to increasing the share of renewable energy to 20 % of Europe's total energy production by 2020 (see also the SOER 2010 climate change mitigation assessment, EEA, 2010l). Reaching this target requires the development of renewable energy platforms, and as a clean, renewable source of electricity, wind energy is destined to make a significant contribution. Due to the size and higher efficiency it is often advantageous to place

Figure 5.8 **Cumulative number of marine, coastal and estuarine non-indigenous species in Europe, of which 869 are invertebrate animals, followed by 326 plants and 181 vertebrate animals**



Note: The number of invasive species may be influenced by increased scientific interest over the past decades, which has lead to a corresponding increase of recordings.

Source: HCMR database updated for 2009 using NOBANIS, DAISIE, NEMO & BSEPR data. For the Mediterranean Sea (Zenetos, 2010), North East Atlantic (Zenetos, 2009; S. Gollasch, pers. com.), Black Sea (BSEPR, V. Todorova, D.Micu, pers. com.), and Baltic Sea (S. Olenin and A. Zaiko pers. com.).

Box 5.4 Two examples of invasive species in Europe

The Red King crab (*Paralithodes camtschaticus*) was deliberately introduced into the Eastern Barents Sea during the 1960s for commercial purposes and has subsequently thrived in its new environment, spreading eastwards along the Kola Peninsula and westwards into the Norwegian zone (EEA, 2007). This crab has an enormous impact on local species because it is an opportunistic omnivorous feeder and competes with other animals for food. According to local divers, scallop-beds (*Chlamys islandica*) and flatfish populations along the Norwegian coast have being reduced due to their predation. For example, a single mature crab has been found to consume an impressive 400–700 g of scallops in 48 hours (ICES, 2003).

Fortunately this crab has a high market value: the Red King crab fishery has increased in value from NOK 1.3 million in 1994 to NOK 75 million in 2004 (Jørgensen, 2006), and in areas where fishing pressure is high the population does not appear to be increasing (ICES, 2009).

Photo: *Paralithodes camtschaticus*
© Lis Lindal Jørgensen

First observed in 1990, the round goby (*Apollonia melanostoma* or *Neogobius melanostomus*) has now become widespread in the Bay of Gdansk and is one of the most common near-shore fish in the southern Baltic Sea. It was observed in Finnish and Swedish coastal waters in 2005 and 2009 respectively. Introduced with ballast water from the Black Sea, it has rapidly adapted to Baltic conditions and can locally dominate coastal fish populations, such as the flounder. It has also become a significant contributor to the diet of important predatory fish, such as cod and perch. It may promote bioaccumulation of persistent toxic pollutants by transferring toxic substances, accumulated in common mussels, to cod and ultimately to humans. There is also concern that parasites carried by the round goby may spread diseases to other fish species and birds (Kvach and Skóra, 2007) as observed in the Great Lakes in the United States.

Photo: *Apollonia melanostoma*
© Gustaf Almqvist

wind turbines at sea. Off-shore wind energy production has increased rapidly in the past 10 years (Figure 5.9); in 2009 it accounted for some 4.8 % of the EU's total electricity consumption. This is expected to at least triple by 2020. This could imply an annual expansion in wind farms, both onshore and offshore, of more than 10 GW per year until 2020. A minority of Member States are currently responsible for the bulk of the EU's wind power (Figure 5.9). Off-shore platforms are primarily located in the North and Baltic Seas where wind energy potential is the greatest, which is also reflected by the geographical location of countries with high relative share of this type of energy production. Even accepting the variations in wind resources, the availability of other renewable energy and different national priorities, wind energy is likely to grow in most if not all countries (EC, 2010g).

The seas around Europe have considerable energy potential also for wave and tidal amplitude or current platforms. These platforms are however less mature and are presently not used commercially. This might however change with improved technologies. There is some concern regarding the environmental impacts of these platforms, because they involve large structures, often in coastal areas where the sea has many other uses.

The latest EU commitments towards renewable energy create a favorable legislative environment for wind power development whilst ensuring that it is done in accordance with EU environmental legislation.The increase in off-shore wind energy production expected within the next 20 years will require considerable space allocation particularly in the North and Baltic Seas. The environmental impact of individual wind parks has been studied in numerous environmental impact assessments, and is generally found to be small and in some cases even favourable because of the ability of the platforms to become artificial reefs. Evidence to date shows that,

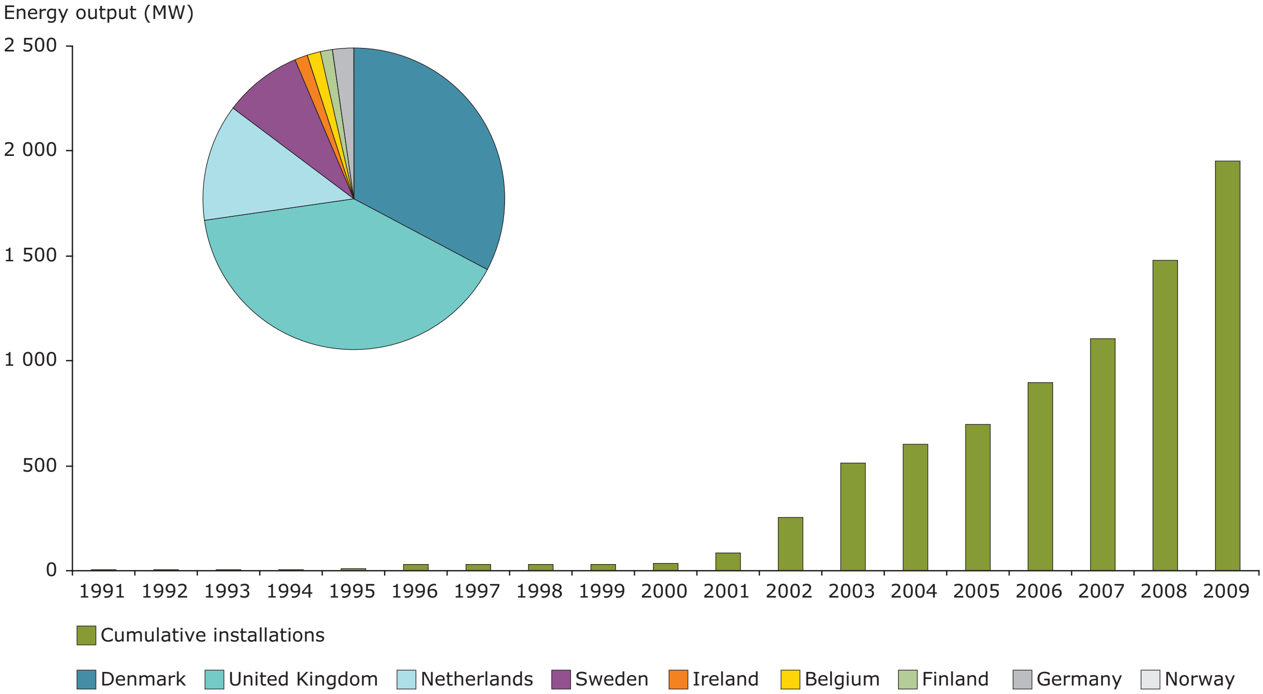
Box 5.5 Policy responses

Accidental oilspills
The severity of large oil spills such as the Erika in 1999 highlighted problems in the way oil transportation was managed in the EU, which promoted rapid changes in policy to minimise risks to the environment and livelihoods. A series of wide-ranging measures has since been adopted, including port state control, including pollution prevention, ship inspections, and a gradual phase-out of single-hull oil tankers from EU waters by 2015. The phase-out of single-hull oil tankers is considered the most important explanation for the decrease in accidental oil spills. In addition, a system for monitoring, control of and information on maritime traffic and a victim compensation fund for oil pollution were established. In 2009, further measures related to accident investigation and liability of carriers were adopted to restore the competitiveness of the sector by benefiting only those operators that respect the safety standards and increasing the pressure on owners of sub-standard ships.

Illegal operational oil discharges
Illegal operational oil discharges are ideally monitored by a combination of observation from space (CleanSeaNet EMSA, 2010) and control aerial surveillance. A decrease has been registered in the North and the Baltic Seas: 210 discharges were confirmed by aerial surveillance in 2008, compared with 488 in 1999 (HELCOM 2009b, 2008 report on discharges). This type of surveillance is not yet practiced in the Mediterranean Sea at the regional level although France and Italy do so for their areas of responsibility. However, Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) intends to develop surveillance under the framework of the Barcelona Convention.

Ballast water
All European regional seas have voluntary ballast-water management guidelines and/or other strategies but, because shipping is a global activity, there is still an urgent need for a global approach. Unfortunately, the International Convention for the Control and Management of Ships' Ballast Water and Sediments adopted by the International Maritime Organisation (IMO) in 2004, which requires ships to exchange their ballast water in the open rather than in coastal areas and introduces ballast water quality standards, has only been ratified by two EU-27 Member States, France and Spain; one EFTA country, Norway; and one Western Balkan country, Albania. The Convention is not yet in force as this requires that 30 countries worldwide to ratify it or the equivalent to 35 % of global tonnage. On 1 September, 2010 it had been signed by 24 countries with the equivalent of 24 % of the global tonnage. The European Maritime and Safety Agency (EMSA) and the European Commission are developing an EU Action Plan for ballast water management, considering also existing environmental and maritime-related EU laws, which would support Member States' contributions to the existing regional sea initiatives and the ratification of the IMO Convention.

Figure 5.9 **Off-shore wind energy production and relative share of off-shore wind energy production by country**



Source: EWEA 2009 and EWEA 2009a.

Box 5.6 Carbon capture and storage

Carbon capture and storage (CCS), is a means of mitigating CO_2 emissions by capturing CO_2 from fossil fuel power plants, and storing it in such a way that it does not enter the atmosphere. Storage of the CO_2 is, among other places, envisaged and allowed in the sea floor in abandoned oil and gas fields that can act as natural reservoirs for CO_2. To be transported into the sea floor, the CO_2 needs to be compressed which requires energy and thus reduces energy efficiency. An environmental concern is whether the stored CO_2 will remain in the sea floor — the time scale for storage is thousands of years. If it is released into the sea, it would increase the problem of ocean acidification, and could destroy large areas of unique and valuable ecosystems on the sea floor.

whereas, in general, wind energy does not represent a serious threat to wildlife, poorly sited or designed wind farms can pose a potential threat to vulnerable species and habitats, including those protected under the Habitats and Birds Directives. Also the platforms create conflicts with other uses of the sea such as fisheries because trawling is not possible within a wind farm area. Conversely, permission is usually not given to develop wind farms in designated Natura 2000 sites. This means that there is a potential for increasing fisheries in Natura 2000 sites.

Birds, bats and marine mammals may be displaced from areas within and surrounding wind farms due to noise and vibration impacts. The scale and degree of disturbance determines the significance of the impact, as does the availability and quality of other suitable habitats nearby that can accommodate the displaced animals. During the construction phase, noise and vibration from pile driving and other works may affect the animals over a large area. The operational noise of wind farms will be clearly audible to some marine mammals, but, unlike pile-driving, the impact of this noise is expected to be small and localized. However, knowledge in this area is still limited (EC, 2010g).

5.4 Oil and gas exploration

Oil and gas exploration is also a major maritime activity. Discharges of oil from offshore installations can occur from the production water, drill cuttings, spills and flaring operations. Despite the one-off increase of oil discharges from offshore installations in 1997, which was mainly due to an exceptional accidental spillage, it is expected that further reductions of oil discharges will continue into the future, partly as a result of the new regulation on drill cuttings (OSPAR, 2000) which entered into force in 2000 (EEA, 2008a). Following the Deepwater Horizon accident in the Gulf of Mexico, new EU legislation focusing on harmonising European laws governing environmental liability, drilling safety and oil spill remediation will be proposed early 2011. In the future, as oil reservoirs become depleted, proper decommissioning of off-shore platforms will become important. There is at present no EU regulation covering the decommissioning of off-shore platforms but OSPAR has a decommissioning policy which will be reviewed in 2013 and a future tightening of regulation in the EU is possible (ENDS, 2010).
A comprehensive programme of removal and disposal of 15 platforms is under way on the Ekofisk field complex in the Norwegian North Sea.

6 Outlooks and response

This assessment has provided a large amount of the information extracted from a growing body of evidence showing that human activities are having significant and severe impacts on coastal and marine ecosystems in Europe and that many activities at sea creating these impacts are expected to increase. For this reason it is very timely that the European Integrated Maritime Policy (IMP) (EC, 2007), with its environmental pillar the MSFD and its ambition to achieve a coherent policy framework to better allow for sustainable development of sea related activities, is in place. This policy framework is expected to lead to a more collaborative and integrated approach to decision making between the areas of maritime transport, fisheries, energy, surveillance and policing of the seas, tourism, the marine environment and marine research. The MSFD is the overarching environmental legislation for the marine environment and has links to the WFD, the Habitats and Birds Directives and to the CFP, all discussed earlier in this assessment, and it has a future target to deliver good environmental status of Europe's seas in 2020 while development of environmentally responsible strategies for the use of space at sea and on the coast could be developed under Maritime Spatial Planning and Integrated Coastal Zone Management.

6.1 The Marine Strategy Framework Directive

The fundamental objective of the MSFD is to achieve good environmental status (GES) in Europe's seas by 2020. This is intended to be achieved through the application of an ecosystem-based approach to management of human activities, while allowing the sustainable use of marine goods and services that not lead to further environmental deterioration or violation of the precautionary principle. Good environmental status is defined by 11 qualitative descriptors of the marine ecosystem (Box 6.1). They are designed to address the environmental impacts on the marine environment discussed in this assessment, including biological diversity, non-indigenous species, the status of commercial fish stocks, food-web structure, eutrophication, sea-floor integrity, permanent alterations of hydrographical conditions, effects of contaminants, quantities of marine litter and noise in the sea. They have been further refined in a Commission Decision (EC, 2010e).

The ecosystem-based approach to management follows from the cyclical and therefore adaptive approach of the MSFD which identifies four steps for developing national strategies:

1. perform an initial assessment and determination of status;
2. identify of targets for GES;
3. development of a monitoring programme to show progress towards targets;
4. development of a programme of measures needed to follow-up on progress to achieve good environmental status.

The national strategies are to be updated every six years. The MSFD does not directly address climate-change impacts through the criteria of good environmental status, but indirectly through this adaptive management approach.

There are clear elements in the criteria that reflect the impacts discussed in this assessment:

- The target for the fishing mortality on commercial fish stocks (descriptor 3, see Box 6.1) will require the achievement that spawning stock biomass is able to produce an MSY or better. This criterion creates a link between the MSFD and the CFP which regulates fisheries in Europe and the Commission's Green Paper on the CFP reform suggests that it should be used as an objective of the CFP following its 2012 reform. The MSY target implies that the current status of fish stocks will not allow any of the European seas to achieve good environmental status according to the MSFD definition.
- Food-webs (descriptor 4, see Box 6.1) will include criteria to describe the energy flow and structure of the food-web. The criterion will both aim to better describe the abundance of and the role of large fish and also there will be a criterion linked to describing the magnitude of by-catch and discards.
- It is expected that there will be an increased focus on mapping the main pathways of introduction of new

species into Europe's seas (descriptor 2, Box 6.1) that should allow for the establishment of better strategies for reducing new introductions of alien species.

- Managing the impacts of eutrophication on coastal and transitional waters is targeted by the WFD that has the objective of achieving good ecological status by 2015 for chemical and biological elements in Europe's coastal and transitional waters (see SOER 2010 freshwater quality assessment, EEA, 2010i). Paramount to this will be a marked reduction in the excessive nutrient levels currently observed in water bodies across much of Europe. River basin management plans under the WFD due to be operational by 2012, will incorporate a suite of cost-effective measures to tackle all sources of nutrient pollution. The MSFD also has a requirement that to achieve good environmental status, eutrophication effects in open sea areas have to be minimized. This is relevant in the Baltic Sea and in the Black Sea (descriptor 5, Box 6.1).

- One of the responses to the declining state of the coastal and marine environment has been to establish a network of protected areas. The extent of designation of Natura 2000 sites is therefore considered a measure of the level of biodiversity protection and it is of concern that both designation and assessment of marine sites are lagging (see Section 2.2). The MSFD supports implementation of the Habitats and Birds Directives. The designation of new special areas of conservation and special protection areas is included as one of the measures to be taken to achieve good environmental status (descriptor 1, Box 6.1).

- The impacts of chemical pollution including oil are expected to receive increasing attention particularly for the priority substances under Annex X of the WFD. Currently most information available is on the quantities of chemical pollution and less on impacts. With the MSFD there will be an increased focus on ecological effects and human impacts (GES descriptors 8 and 9, Box 6.1).

- Some of the criteria for achieving good environmental status will be related to establishing whether or not increasing quantities of marine litter will cause harm to the coastal and marine environment (descriptor 10), an environmental pressure not previously considered in environmental management but which has been shown to be of increasing concern. A second new indicator is linked to establishing whether or not noise levels in the sea cause adverse effects (GES descriptor 11, Box 6.1).

6.2 Integrated Coastal Zone Management and Maritime Spatial Planning

One of the elements required to achieve the IMP objective of a coherent policy framework that better allows for the development of sea related activities in a sustainable manner, is a more collaborative and integrated approach to decision making between the many different users of

Box 6.1 Qualitative descriptors for determining good environmental status

(1) Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.
(2) Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.
(3) Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.
(4) All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.
(5) Human-induced eutrophication is minimised, especially its adverse effects, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters.
(6) Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.
(7) Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.
(8) Concentrations of contaminants are at levels that do not give rise to adverse effects.
(9) Contaminants in fish and other seafood for human consumption do not exceed levels established by EU legislation or other relevant standards.
(10) Properties and quantities of marine litter do not cause harm to the coastal and marine environment.
(11) Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

the sea. The approaches designated for this in the EU are Integrated Coastal Zone Management and Maritime Spatial Planning. These tools are currently under ongoing development, but will be under increased policy focus in the coming 2–3 years.

The EU Integrated Coastal Zone Management approach, together with the protection of habitat types and species of Community interest, can significantly contribute to safeguarding the prosperity and ecological status of Europe's coastal ecosystems. The EU Recommendation for Integrated Coastal Zone Management principle of working with natural processes and respecting the carrying capacity of ecosystems, which will make human activities more environmentally friendly, socially responsible and economically sound in the long run (EC, 2002) should also lead to the better management of other ecosystems in Europe.

Maritime spatial planning is a process designed to promote rational and sustainable use of the sea, balance different interests including the environmental aspects and improve the quality of decisions. It is based on 10 principles relevant to the development of a maritime spatial plan and puts great emphasis on follow-up actions, evaluations and reviews. EU Member States are not obliged to carry out maritime spatial planning. However, the Commission is promoting this process as a stable and transparent way to improve the competitiveness of the EU maritime economy and to deal with complex trans-national issues such as the effects of climate change (EC, 2010f).

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