2003

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

ICES CIEM

ENVIRONMENTAL STATUS OF THE EUROPEAN SEAS

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

The International Council for the Exploration of the Sea (ICES) coordinates and promotes marine research in the North Atlantic. This includes adjacent seas such as the Baltic Sea and the North Sea. ICES acts as a meeting point for a community of more than 1,600 marine scientists from its 19 member countries around the North Atlantic (Belgium, Canada, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Latvia, The Netherlands, Norway, Poland, Portugal, Russia, Spain, Sweden, the UK, and the USA).

Drawing on its scientific community, ICES runs more than 100 working groups, symposia, and an Annual Science Conference. All aspects of the marine ecosystem are studied and evaluated in order to gain knowledge about physical processes, water chemistry and pollutants, fish and fisheries, seabirds and marine mammals. As well as filling gaps in existing knowledge, this information is also developed into unbiased, non-political advice. This advice is then used by the 19 member countries, which fund and support ICES, to help them manage fisheries and other activities affecting the North Atlantic Ocean and adjacent seas. ICES also provides scientific advice on the protection of the marine environment and ecosystem issues to the OSPAR Commission and the Helsinki Commission, and on the management of living resources to the European Commission, NEAFC, IBFSC, and NASCO.

For more information, visit the website at: www.ices.dk

The 1992 OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic requires its Contracting Parties to prevent and eliminate pollution and take the necessary measures to protect the maritime area of the Northeast Atlantic from the adverse effects of human activities, so as to safeguard and conserve marine ecosystems. Contracting Parties to the OSPAR Convention are Belgium, Denmark, European Community, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the UK.

For more information, visit the website at: www.ospar.org

The 1992 Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area requires its Contracting Parties to prevent and eliminate pollution to promote the ecological restoration of the Baltic Sea Area and the preservation of its ecological balance. Contracting Parties to the Helsinki Convention are Denmark, Estonia, European Community, Finland, Germany, Latvia, Lithuania, Poland, the Russian Federation, and Sweden.

For more information, visit the website at: www.helcom.fi

It falls under the duties of the OSPAR Commission (OSPAR) and the Helsinki Commission (HELCOM) to prepare assessments of the quality status of the marine environment and its development in the maritime area covered by the two Conventions. The present report draws, amongst others, on the OSPAR Quality Status Report for the Northeast Atlantic, published in the year 2000 (QSR 2000), and on the HELCOM Fourth Periodic Assessment of the State of the Marine Environment of the Baltic Sea, 1994-1998.

Funding for this report was provided by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

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TABLE OF CONTENTS

Section 1

Preface

The first joint meeting at Ministerial Level of the OSPAR Commission (OSPAR) for the Protection of the Marine Environment of the North-East Atlantic and the Helsinki Commission (HELCOM) for the Protection of the Marine Environment of the Baltic Sea Area will be hosted by Germany in June 2003.

As a basis for this meeting and for the information of the public, the German Ministry for the Environment, Nature Conservation and Nuclear Safety invited ICES to prepare a report on the environmental status of European seas. Since the meeting will also discuss a European Strategy for the Marine Environment, the report is intended to inform on the overall environmental status and on issues of concern, focused on the maritime areas covered by these two Commissions, and to provide brief overviews also for the Arctic, the Mediterranean Sea, and the Black Sea.

Introduction

The seas around Europe are of vital importance to the people living there. They are used for fishing, with some of the world's richest fishing grounds occurring in the Northeast Atlantic, for transport, for recreation, and for many other activities of economic importance. With the large population that lives near the coast or near rivers that drain into the Baltic Sea, the North Sea, or the other areas of the Northeast Atlantic, as well as the Mediterranean and Black Seas, many contaminants are discharged into the sea areas and are taken up by the plants and animals living in the sea.

The sea also receives contaminants and nutrients from the atmosphere, which carries some contaminants far from their original source, depositing them in the sea according to air currents. This is especially the case for the Arctic, which receives many man-made chemicals produced thousands of kilometres away. Man's impact on the atmosphere also affects the sea in a more physical way: the build-up of carbon dioxide and other greenhouse gases in the atmosphere is contributing to an increase in temperature, both in the air and in the sea. This is seen most clearly in the Arctic, where the thickness of the ice is decreasing and the southern edge of the ice cover is receding northwards. The distribution of marine organisms is also beginning to reflect the change in water temperature, with some southern species moving northwards.

Some of the chemical contaminants reaching the sea from land and from the atmosphere build up in the food chain, concentrating in top predators such as fish and marine mammals. While the effects of many of these contaminants are often subtle, they can be detected in some marine mammals, particularly in the Arctic, and also in the Baltic Sea, where the situation is now improving.

Fishing is a major activity, creating jobs and an economic basis for many coastal communities. It also has many impacts on marine ecosystems, primarily from the catch of large amounts of fish and shellfish, and the resulting changes associated with their removal from food chains. Fishing also impacts other marine animals, from non-target fish and invertebrates to seabirds and marine mammals that are incidentally caught in the fishing gear. There are also physical impacts on the bottom-living organisms and the seabed from bottom trawls. Our understanding of the overall ecosystem effects of fishing is still in an early phase and there is much to be learned about how the ecosystem functions to be able to fully realise all the impacts of fishing.

Shipping is another important activity affecting the marine environment, with some of the busiest shipping lanes in the world found in the North Sea, Baltic Sea, and Mediterranean Sea. Despite mandatory global regulations against discharges of oil and litter from ships, such discharges nevertheless represent a source of chronic impact from shipping. There is also the risk of accidents, which can be particularly serious if oil tankers are involved, and there have been several serious oil spills off the northwest coast of Europe in recent years.

There are many human activities that impact the habitats on the coast and in the sea. These range from bathers disturbing nesting seabirds on the coast to wind farms and large port installations on coasts and in estuaries. Many cities and towns are located near the coast, and urbanisation claims large expanses of coastline in northwestern Europe and on the northern coast of the Mediterranean Sea.

Tourism and recreational activities are growing sources of disturbance in coastal areas, particularly as they often prefer areas that are also of importance to the local flora and fauna. Another coastal or estuarine activity is fish and shellfish farming, which often takes place in sheltered bays or quiet coastal areas.

This report will provide an overview of the key environmental conditions in the Northeast Atlantic including the North Sea, which together constitute the OSPAR Maritime Area, and the Baltic Sea, which is the area under the Helsinki Commission. Some attention will also be given to the Mediterranean and Black Seas. The report includes a brief description of the physical environment of the sea areas, and then continues with a description of the marine organisms living in these seas and the communities that they form. In the third section, the various human activities and their effects on the sea and its living resources are covered. It addresses important uses of the sea such as fisheries and mariculture, shipping and transportation, recreation and tourism, impacts from offshore and land-based industries, impacts from industrial and municipal discharges and agriculture but also global forces that impact the marine environment, with climate variability as the most important. Section 4 synthesises the results and draws conclusions about the present state of, and the main threats to, European seas, along with a brief mention of some of the management measures that are now in effect or are being considered to reduce the impacts of human activities.

Biodiversity is a theme running throughout the document, both in the descriptions of the various types of marine organisms and their interactions as well as in the impact that man has on biodiversity through activities such as fishing and discharges of oil and other contaminants.

The OSPAR Convention Area covers the Northeast Atlantic, including parts of the Arctic, as shown in Figure 1.1. The OSPAR Convention Area has a surface area of approximately 13 million km^2 and a volume of approximately 30 million km^3, of which about 750,000 km^2 of surface area and 94,000 km^3 of

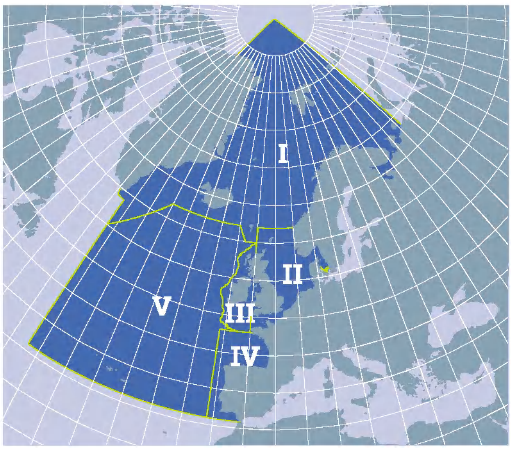


Figure 1.1. The OSPAR Convention Area.

I – Arctic Waters:
Lead country: Norway
Other participating countries: Denmark (incl. Faroe Islands) & Iceland

II – Greater North Sea:
Lead country: The Netherlands
Other participating countries: Belgium, Denmark, France, Germany, Norway, Sweden & UK

III – Celtic Seas:
Lead countries: Ireland and UK

IV – Bay of Biscay & Iberian Coast:
Lead countries: France and Spain
Other participating countries: Portugal

V – Wider Atlantic:
Lead countries: Iceland & Portugal
Other participating countries: Belgium, Denmark, France, Germany, Ireland, The Netherlands, Norway, Spain, Sweden & UK

volume are in the North Sea. The total catchment area covers approximately 5 million km^2 with an overall population of about 307 million people. Of this, the North Sea catchment area amounts to 841,500 km^2, with a population of about 184 million people.

The Baltic Marine Environment Protection Commission (Helsinki Commission) concerns the Baltic Sea, which is the largest brackish water area in the world. The Baltic marine area (Figure 1.2) has a surface area of 415,000 km^2 and a volume of 22,000 km^3. The total catchment area is over 1.7 million km^2. The population living in the catchment area of the Baltic Sea comprises nearly 85 million people.

The Mediterranean Sea has a surface area of 2.5 million km^2. It is about 3,800 km wide from east to west and has a maximum north–south distance of around 900 km between France and Algeria. The population in the countries surrounding the Mediterranean catchment area is approximately 450 million inhabitants, with an increasing trend particularly in the southern countries. The Barcelona Convention has been established to prevent pollution and protect the marine environment of the Mediterranean Sea.

The Black Sea has a surface area of 461,000 km^2 and an average depth of 1,240 m. About 171 million people live in its catchment area. The Black Sea Environment Programme has been established to restore and protect the marine environment of this sea.

Figure 1.2. Map showing the Baltic marine area.


Section
2

Status of the European seas

In this section we start by describing the major physical characteristics of the area including the main oceanic currents and a description of each of the sea areas. We then discuss the influence of the North Atlantic Oscillation on the ocean climate as a prelude to discussions in Section 3, which deals with human impacts. After discussing the physical characteristics, we describe the marine biodiversity, starting at the bottom of the food chain with the microscopic marine plants and moving up to fish, marine mammals, and seabirds.

2.1 Geology and sediments

The North Atlantic began to form around 200 million years ago as the European and North American plates separated on either side of the mid-oceanic ridge. This area can be divided into three distinct geological regimes: the oceanic basins (about 2,400–5,000 m deep), the continental margin, and the continental shelf (which extends down to about 200–400 m depth).

Oceanic basin: In the deep ocean basin, an abyssal plain extends on either side of the Mid-Atlantic Ridge to the continental margins. Here, sediments 100 m–2 km thick overlie the seabed. This sediment consists mainly of the remains of microscopic organisms from the overlying waters, with small amounts of mineral particles.
Continental margin: At the continental margins, large wedges of sandy to muddy sediments extend down into the deep-sea basin, resulting from submarine landslides. The deposits, which can be up to 10 km thick, consist of a mix of mud from the land and oceanic sediments; they are sometimes rich in hydrocarbons.
Continental shelf: Shelf-sea sediments are of mainly terrestrial origin. In northern latitudes, including the North Sea and Irish Sea, much of the sea floor sediment is of glacial origin.

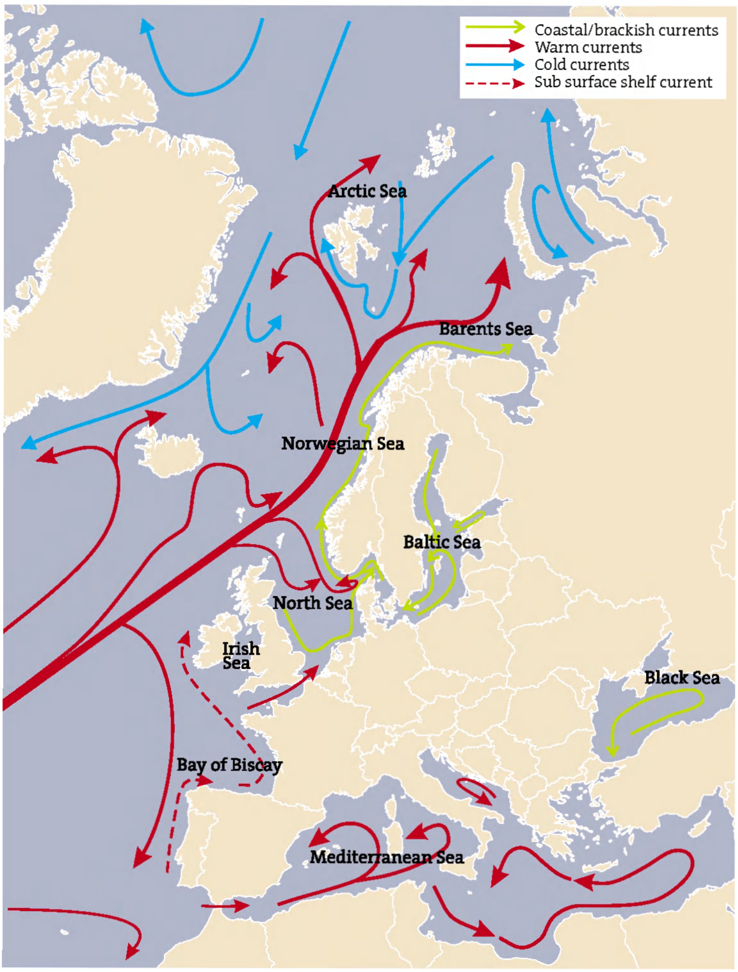


Figure 2.2.1. Simplified map of the surface currents of the Northeast Atlantic, including the Baltic Sea, the Mediterranean Sea, and the Black Sea. (Source: Institute of Marine Research, Bergen).

2.2 Hydrography

The North Atlantic Ocean is constantly on the move. On the surface, we see its restlessness in the form of tides that alternately hide or uncover the shore and storms that send huge waves crashing into the coastline. But the real power is less visible and lies with the vast ocean currents that cross thousands of miles of ocean bringing warm water up from the tropics to European shores and taking cold water back down south.

The main driver of the ocean current "highway" is the Gulf Stream System that draws warm water up from the Gulf of Mexico and over to the Northeast Atlantic via the North Atlantic Current (Figure 2.2.1). As the warm seawater reaches colder climes, it releases its heat and cools. As saltwater cools, it becomes denser and thus heavier and so it then sinks down to join deeper southbound cold-water currents that come from the Arctic. This system of warm water travelling north losing its heat, sinking, and joining southbound cold currents is part of what is known as the global conveyor belt.

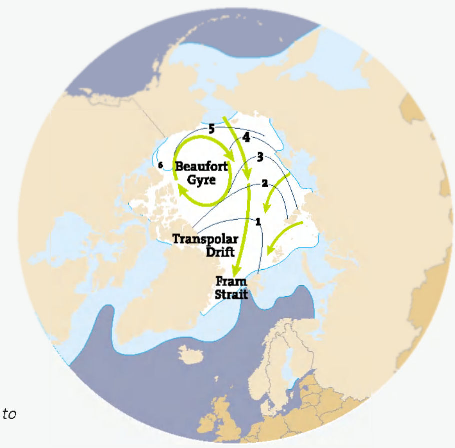
The global conveyor belt keeps the European seas moving. It blends warm water with cold water, mixes nutrient-poor with nutrient-rich water, and generally helps to support the rich marine ecosystems that we have in European seas.

EUROPEAN SEAS

THE ARCTIC OCEAN

The Arctic Ocean consists of the Arctic Basins, the surrounding continental shelf seas (including the Barents and Kara Seas) and the Canadian Archipelago. The Arctic Basin is composed of two main basins, separated by a large ridge. The dominant surface circulation features are a clockwise current system or gyre (the Beaufort Gyre) and the Transpolar Drift Stream that flows from off the Siberian coast out through the Fram Strait (Figure 2.2.2).

Figure 2.2.2. Arctic ocean currents. (Source: AMAP, Arctic Pollution 2002).



THE BARENTS SEA

The Barents Sea is a shallow shelf sea with an average depth of 230 m, situated at the northern European shelf north of Norway. It is one of two major pathways for Atlantic water to enter the Arctic Ocean. The main circulation pattern in the Barents Sea consists of relatively warm coastal and Atlantic waters flowing eastward in the southern part, and cold Arctic water flowing southwestward in the northern areas.

THE NORDIC SEAS

The Nordic Seas consist of the Greenland, Norwegian, and Iceland Seas and are a mixing zone for warm and saline water on its way from the Atlantic Ocean to the Arctic Ocean, and for cold and less saline water from the Arctic Ocean to the Atlantic Ocean. The Greenland-Scotland Ridge forms a barrier between the deep waters of the Nordic Seas and the North Atlantic, which constrains the exchange of deep water.

MORE THAN 200 LARGE RIVERS BRING FRESH WATER INTO THE BALTIC, MAKING IT THE WORLD'S BIGGEST BRACKISH (LOW SALINITY) SEA

The surface waters of the Norwegian Sea are dominated by the warm, saline Atlantic water – except for the coastal area of Norway, where coastal water with low salinity and variable temperature is transported northward by the Norwegian Coastal Current (Figure 2.2.1). This low-salinity water originates in the Baltic and is increased by runoff from Norwegian rivers.

The dominant circulation pattern in the Greenland Sea is the counter-clockwise Greenland Sea Gyre. The East Greenland Current transports cold water from the Arctic Ocean southwards through the Denmark Strait (Figure 2.2.1) and is the main pathway for sea ice leaving the Arctic Ocean. The Greenland Sea is one of the major sources for deep-water formation in the North Atlantic and is part of the driving force of the global ocean circulation. The Iceland Sea is located at the boundary between warm Atlantic water from the south and cold Arctic water from the north.

THE NORTH SEA

The North Sea is relatively shallow; large areas of the southern North Sea reach only 30 m depth, although it does have deeper areas, the deepest being the Norwegian Trench that goes down to 700 m.

The North Sea is strongly influenced by the adjacent North Atlantic Ocean. The North Atlantic Current brings oceanic water of high salinity into the northern North Sea in two branches: an inflow through the Fair Isle channel off the north of Scotland, and a more significant inflow along the western slope of the Norwegian Trench. This branch also supplies saline water for the deep inflow through the Skagerrak into the Baltic Sea. The Norwegian Coastal Current forms a contrasting outflow along the eastern side of the Trench, carrying less saline surface water from fjords and rivers northward. In addition to the oceanic inflow to the northern North Sea, the saline water of Atlantic origin also penetrates into the southern North Sea through the Dover Straits.

Currents in the shallower parts of the North Sea are mainly driven by the tide. The tide enters as a wave from the North Atlantic, and travels anti-clockwise around the North Sea basin. Wind-driven currents also have a major effect, particularly in the winter months.

THE BALTIC SEA

The Baltic Sea is almost totally enclosed by land, and is connected to the North Sea by the narrow and shallow straits between Denmark and Sweden. This, and shallow sills near the entrance to the Baltic, limit the exchange of water with the open sea. More than 200 large rivers bring fresh water into the Baltic, making it the world's biggest brackish (low salinity) sea.

The topography is characterised by several basins separated by sills of different depths. The major basins, the Gulf of Riga and the Gulf of Bothnia, are internal fjords, while the Baltic Proper and the Gulf of Finland consist of several deeper basins with more open connections.. The average depth of the Baltic Sea is 56 m, with a maximum depth of 459 m in the Landsort Deep.

The water circulation consists of a surface current with brackish water that flows out of the Baltic through the Kattegat, to the Skagerrak and the North Sea, and a counter-current in deeper layers with higher salinity water going into the Baltic Sea. The fresh water largely comes from rivers in the Baltic catchment, an area that is several times larger than the Baltic Sea itself. Rainfall on the sea surface is almost entirely balanced during the year by evaporation.

An important feature of the Baltic Sea is the permanent halocline (zone of rapid salinity change) between well-mixed surface water and the deeper water. The permanent halocline limits mixing between the surface water and deep water, which means that the deeper water is poorly ventilated. As a result, the available oxygen in the deeper water is consumed by the breakdown of organic material and, when it is used up, toxic hydrogen sulphide is formed. This lack of oxygen kills most forms of life in the bottom waters, including fish and their prey.

Halocline: A halocline is a layer of water in which the salinity changes rapidly with depth (relative to the layers above and below).

Sporadically, the Baltic deep water is refreshed when a rapidly increasing and strong air pressure gradient builds up over the transition area between the North Sea and the Baltic, in combination with a preceding longer period of high pressure over the Baltic Sea. This pushes and sucks a volume of a few hundred cubic kilometres of highly saline water into the Baltic which refreshes the deeper waters with salt and oxygen, thus improving the living conditions for marine life. The successful spawning of Baltic cod is particularly dependent on these inflows, which boost salinity and oxygen levels.

Unfortunately, since the mid-1970's, the occurrence of these major inflows has decreased drastically, as shown in Figure 2.2.3. The few major inflows occurred in 1976, 1983, and 1993/1994. The 1976 inflow had a very good effect on the year classes of cod for several years. In the deepest basins, the last inflow improved the bottom-living marine life to a level that had not been observed since the 1930's but it did not benefit the cod reproduction as expected. Deeper areas of the Baltic today have low levels of oxygen or are anoxic (lacking in oxygen).

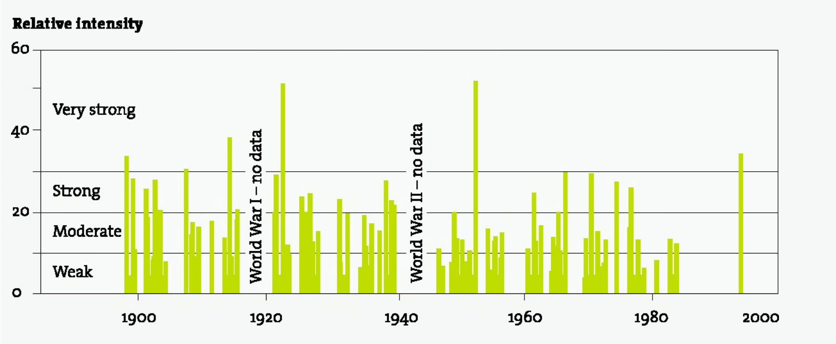


Figure 2.2.3. Major inflows to the Baltic Sea during the twentieth century. (Source: HELCOM 4th Periodic Assessment, based on W. Matthäus, IOW).

THE IRISH SEA

The topography of the Irish Sea resembles that of a channel with gentle slopes on either side. The Irish Sea has an open connection with the Atlantic Ocean at both ends, and is dominated by strong tidal currents at the eastern side. Its circulation is also strongly influenced by wind. The main input of water occurs at the southern end and the mean flow through the Irish Sea is weak, but generally towards the north.

THE CELTIC SEA, BAY OF BISCAY AND IBERIAN COAST

This area comprises the southern Celtic shelf, the Channel, the Bay of Biscay, the western Iberian and the European sector of the Gulf of Cadiz. Water depths range from 200 m on the continental shelf, down to around 5,000 m in the western Bay of Biscay.

Most of the water masses found in the region either have a North Atlantic source, or result from interactions between waters formed in the Atlantic with water of Mediterranean origin. Salty, dense water from the Mediterranean Sea enters the Atlantic Ocean through the Gibraltar Straits. The Mediterranean Sea water mixes with Atlantic water and some flows northwards along the western Iberian slope at depths from 600 m to 1,300 m. Water circulation

over the shallower continental shelf areas is controlled by the combined effects of tides, density differences, and the wind.

In the centre of the Celtic Sea, the water flow is weak and during summer it is strongly stratified (or layered) and some pronounced surface fronts are formed. Fronts are relatively narrow regions of the sea where seawater with different properties—such as temperature, salinity, or water density—meet. They tend to concentrate nutrients and are often hotspots of marine life.

A key feature of the area is the upwelling of cold, nutrient-rich water from deeper layers to the surface in coastal areas, particularly along the west Iberian coast. Upwelling is caused by the persistent alongshore winds in the spring and summer that push warm surface water away from the coast, whereupon it is replaced by deeper water. The coastal upwelling begins off the Iberian Peninsula in late spring and reaches a maximum in summer, by which time it also occurs in the southeastern Bay of Biscay.

THE BLACK SEA IS LAYERED LIKE A CAKE, WITH FRESHER WATER AT THE SURFACE, A PERMANENT HALOCLINE IN THE MIDDLE AND DENSER, SALTIER WATER BELOW

Upwelling brings nutrients from deep water to the surface and enhances the mixing of warm and cold water. This creates excellent growing conditions for phytoplankton (microscopic marine plants). Under moderate upwelling conditions, the inner 25 km of coastal waters are ten times more productive than offshore waters, and the centres of upwelling areas are approximately twenty times more productive.

> **Productivity:** the total biomass generated by a marine population, stock or species in a given time period as a result of growth and reproduction.

THE MEDITERRANEAN SEA

The Mediterranean Sea is a semi-enclosed sea, adjacent to the Atlantic Ocean. Communication with the Atlantic Ocean is through the Straits of Gibraltar, which are only 22 km wide and 320 m deep. The Atlantic water enters at the surface of the Gibraltar Straits and a little less flows the other way—from the Mediterranean to the Atlantic Ocean—at a depth of 100 m to 300 m.

Over most of the Mediterranean Sea, annual evaporation exceeds rainfall and river runoff, to the extent that the outflow from the Mediterranean Sea to the Atlantic Ocean is 10% less than the inflow. The Adriatic Sea, which receives a large amount of fresh water from the River Po, is the only part of the Mediterranean Sea that receives more freshwater than it loses through evaporation.

THE BLACK SEA

The Black Sea is linked to the Mediterranean Sea via the Bosporus and Dardanelles Straits. It is the world's largest inland water basin and the total land area draining fresh water into the Black Sea is over five times the size of the sea. The fresh water surplus leaves the Black Sea at the surface, while water from the Mediterranean Sea enters in the deep layer of the Bosporus and Dardanelles Straits.

The Black Sea is layered like a cake, with fresher water at the surface, a permanent halocline (see definition box) in the middle and denser, saltier water below. The difference in density between the upper and lower water masses, coupled with the absence of strong vertical currents, prevents mixing between the two layers. This means that the circulation of oxygen from the surface to the bottom is reduced, and at depths greater than 150 m to 200 m, the waters are permanently anoxic. In fact 90% of the water in the Black Sea is anoxic.

2.3 Meteorology

Climate is one of the big influences on the ocean, since it interacts with, amongst other things, wind speed, evaporation rates, rainfall levels, and the heat exchange between the air and the sea. In the case of the North Atlantic, the main climatic influence is a system called the North Atlantic Oscillation (NAO). The NAO is the difference between two, persistent, sets of contrasting air pressure – high pressure over the Azores and low pressure over Iceland. When the barometer readings in the Azores register a consistent, stronger-than-usual high pressure, whilst in Iceland they show deeper-than-usual low pressures, then the NAO is said to be in positive phase. For Europeans this means warm and wet winters. When the barometers register weak monthly averages in the Azores and Iceland, then the NAO is said to be in negative phase. This leads to colder, drier winters in northern Europe and wet winters in the Mediterranean.

THE NAO HAS NOW BEEN IN POSITIVE PHASE FOR A NUMBER OF YEARS AND SCIENTISTS ARE CONCERNED THAT THE WARMER, WETTER CONDITIONS IT BRINGS COULD BE SLOWING DOWN THE GREAT OCEAN CONVEYOR BELT

The NAO has mostly been in positive phase for a number of years and scientists are concerned that the warmer, wetter conditions it brings could be slowing down the great ocean conveyor belt. An essential part of the conveyor belt is that seawater needs to cool in colder climes where it can then sink and join the deep cold currents. But warm winters, as a result of the NAO being in positive phase, mean that less cooling is taking place and there is therefore less water to drive the southward part of the conveyor belt. There are also concerns that global warming could have a similar effect and this is discussed in Section 3.

POSITIVE NAO INDEX (Figure 2.3.1)

- The positive NAO index phase shows a stronger-than-usual subtropical high-pressure centre and a deeper-than-normal Icelandic low.
- The increased pressure difference results in more and stronger winter storms crossing the Atlantic Ocean on a more northerly track.
- This results in warm and wet winters in Europe and in cold and dry winters in northern Canada and Greenland.

NEGATIVE NAO INDEX (Figure 2.3.2)

- The negative NAO index phase shows a weak subtropical high and a weak Icelandic low pressure.
- The reduced pressure gradient results in fewer and weaker winter storms crossing on a more west–east pathway.
- Brings moist air into the Mediterranean and cold air to northern Europe.
- The US east coast experiences more cold air periods and hence snowy weather conditions.

Figure 2.3.1. Positive NAO Index.

Figure 2.3.2. Negative NAO Index.

Source - Martin Visbeck, Columbia University

2.4 Marine biodiversity

The marine ecosystem is a term that is generally used to refer to all the marine life in an area and the physical, chemical, and structural features of its environment. In the previous pages we have discussed some of the physical properties of the ecosystems in European seas and we now describe the diversity of marine life that inhabits these waters.

We start by describing the microscopic marine plants that form the basis for the marine food chain and then move on to discuss the habitats and marine life on or near the seabed – so-called benthic marine life. We then describe the various fish stocks that swim the seas, and finish off at the top of the food chain with the marine mammals and seabirds. Human impacts on marine biodiversity are discussed in Section 3.

THE ROLE OF PHYTOPLANKTON

The main energy that drives the marine food chain comes from tiny plants, which float in the surface layers of the sea. These microscopic, single-celled algae are called phytoplankton and like all plants they require light, carbon dioxide, and nutrients (primarily nitrogen and phosphorus) to grow. Carbon dioxide dissolves in seawater and is always available, but variations in the amount of light and the quantity and types of nutrients play a major part in controlling the growth of the phytoplankton.

THE MAIN ENERGY THAT DRIVES THE MARINE FOOD CHAIN COMES FROM TINY PLANTS, WHICH FLOAT IN THE SURFACE LAYERS OF THE SEA

Phytoplankton forms the basis of the food chain in the surface waters and dead phytoplankton and other dead animals, faecal pellets, moulted shells—collectively known as Particulate Organic Matter (POM)—fulfil the same role in the deeper parts of the water column and on the sea floor.

In the water, the phytoplankton/POM is grazed by tiny animals (called zooplankton), which are then food for small fish such as herring and sprat. These small fish are then prey for larger fish such as mackerel, or birds, marine mammals, and man, via fisheries. Down on the seabed, animals feed on the POM and are, in turn, fed on by other animals and bottom-living fish such as cod. This is a very simplified version of events as in reality animals do not always stick to their prescribed feeding levels – for instance, sardines feed on phytoplankton when they are young, switch to zooplankton when they grow older, and then finish by feeding on phytoplankton as adults.

Biodiversity: means the variability among living organisms and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.
Plankton: Passively floating or only weakly swimming organisms in a body of water, which drift in the ocean along with the water currents; planktonic organisms range in size from tiny plants and animals to rather large jellyfish, and include the larval stages of many fishes.
Phytoplankton: Microscopic plants in the plankton.
Zooplankton: Animals (mostly very small) that drift freely in the water.
Thermocline: Horizontal layer of rapidly changing water temperature separating warm surface waters from cooler, deeper waters.
POM: Particulate Organic Matter is a mixture of dead marine life, faecal pellets, and moulted shells.
Benthos: Organisms that live in, on, or near the seabed.

2.4.1 Plankton

The plankton community in the Northeast Atlantic, which includes the phytoplankton and zooplankton, has changed in the last 40 years. Cold-water plankton have retreated northwards and the warm-water species have moved north by as much as 10° of latitude (see Figure 2.4.1.1). The northward shift has been linked to the general rise in temperature in the northern hemisphere along with the additional effect of the North Atlantic Oscillation, which in recent years has brought warmer conditions to the region (see Section 2.3). There is also considerable evidence that it is not just planktonic species that are moving north but also other marine organisms, including individual visits by warm-water fish such as sailfin dory, blue marlin and even barracuda, which have recently been caught in UK waters.

NORTH SEA

Since the 1970's, the growing season for phytoplankton has extended from March to early winter, providing food that can be passed upwards to other parts of the food web for all but the winter months. Prior to the 1970's, there were thought to be just two peaks annually in phytoplankton growth, one in spring and one in autumn. The gap in between was thought to happen when the spring bloom of phytoplankton had used up all the nutrients in the upper water column, and to persist until autumn storms mixed the surface waters more deeply and brought up fresh nutrients. If the change in the pattern of the phytoplankton growth period, since the 1970's, reflects a true change in mixing in the North Sea then many other dynamics of the food web may also have changed in recent decades.

As well as alterations in the growing season, the actual species that make up the phytoplankton have also changed. Long-term North Sea trends in both phytoplankton and zooplankton show a parallel decline in abundance from 1955 to a trough in 1979–1980, followed by a marked recovery after 1980. After the recovery, the phytoplankton community also changed, with a decrease in the proportion of diatoms and an increase in flagellates. These changes represent a major shift in the composition of this component of the ecosystem. They have major implications for the food chain because the newly dominant flagellates may be of poorer food value and in some cases are not even eaten by the zooplankton.

OTHER SEA AREAS

At higher latitudes, phytoplankton growth is limited by low light during the long winter, but in the summer there is a massive growth burst. In some areas this is sustained until light levels fall, but in other areas it may outstrip the available nutrients, causing productivity to decline during mid-to late summer.

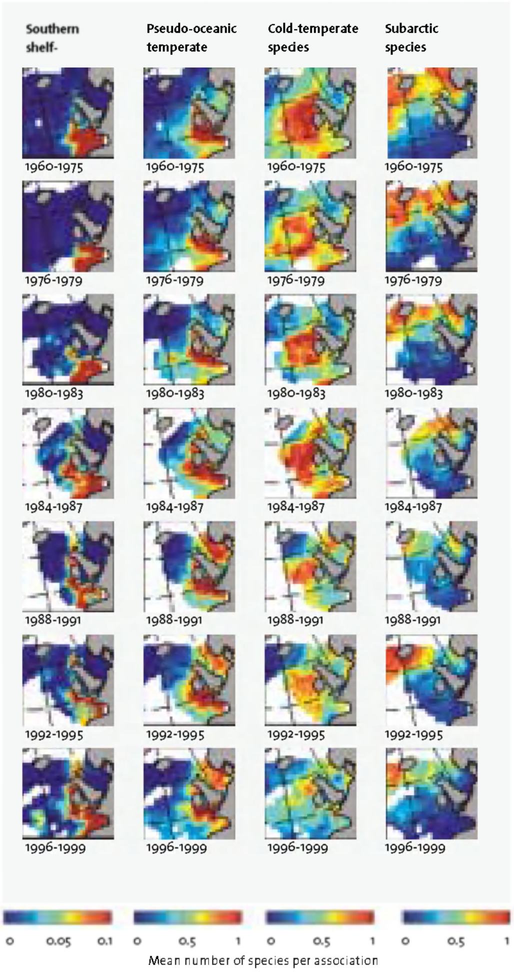


Figure 2.4.1.1. Maps showing the northward shift of communities of both cold-water and warm-water zooplankton in the Northeast Atlantic. (Reprinted with permission from Beaugrand et al., Science, 296: 1692. Copyright (2002) American Association for the Advancement of Science).

THE PLANKTON COMMUNITY IN THE NORTHEAST ATLANTIC, WHICH INCLUDES THE PHYTOPLANKTON AND ZOOPLANKTON, HAS CHANGED IN THE LAST 40 YEARS

Nutrients are even more of a limiting factor in the warm waters of the Mediterranean Sea, where there is high species diversity, but biological productivity is among the lowest in the world due to extremely low nutrient concentrations. It is the opposite case in the Black Sea, where excessive enrichment of nutrients has stimulated large algal blooms and reduced the diversity of plankton species. Attempts are now being made to reduce the amount of nutrients that enter this area from human sources, to let it return to a more natural state. The Baltic Sea has also suffered from nutrient enrichment although the reduced plankton species diversity is mainly due to the low salinity, which is too low for many marine species and too high for many freshwater species.

2.4.2 Habitats

Leaving the surface waters and the plankton and moving down to the seabed, we come to the mosaic of different habitats that contribute to the enormous diversity of marine life that is found in the European seas. These habitats range from submerged tide-swept rocky reefs where crowded beds of colourful anemones vie with sponges for

the available space, to seemingly barren areas of sediment, which under the surface are actually teeming with marine life such as worms, bivalve molluscs, and crustaceans.

In deeper waters off Norway and from the Iberian Peninsula up to the Faroe Islands and Iceland, we find cold-water coral reefs that act as mini-oases for diverse communities of marine life. Other deep-water habitats include natural structures such as carbonate mounds and mid-ocean ridges. A particularly specialised deep-water habitat exists around hydrothermal vents where superheated water escapes from the earth's crust. Conditions are harsh, with low oxygen levels and high concentrations of hydrogen sulphide, but these areas are still colonised by specialised marine life, including giant tube-dwelling worms and bivalves.

Entering shallower areas, which the tide uncovers twice a day, we find rocky reefs that are covered with the fronds of hardy marine algae such as bladderwrack, and animals such as barnacles and limpets and mussels. On mudflats, low tide reveals a surface pockmarked with thousands of burrows of worms and bivalve molluscs such as cockles. These provide a huge "buffet" for local birds and large

ENTERING SHALLOWER AREAS, WHICH THE TIDE UNCOVERS TWICE A DAY, WE FIND ROCKY REEFS THAT ARE COVERED WITH THE FRONDS OF HARDY MARINE ALGAE SUCH AS BLADDERWRACK, AND ANIMALS SUCH AS BARNACLES, LIMPETS AND MUSSELS

numbers of migratory birds that use these areas as stopover feeding grounds on their cross-continental travels. In more sheltered areas, seagrasses are able to gain a hold in the sediment and these can form vast "meadows" that act as a perfect hiding place for juvenile fish which are stalked by cuttlefish and other predators. At the uppermost limits of the tidal range, the eelgrass gives way to special saltmarsh plants that are able to cope with the occasional dousing in seawater.

Life in the Baltic Sea is more challenging for marine species due to the lower salinity. This is illustrated by the fact that the number of recorded marine species (bigger than 1 cm) in the low-salinity southern Baltic is around 150 while in the Kattegat, nearer fully marine conditions, the species count rises to 1,500. Habitats in the Baltic Sea range from the rocky archipelagos of the central and northern Baltic to the sandy beaches and shallow seagrass meadows along the southern shores.

In the Mediterranean, seagrass beds and areas where natural upwellings exist are the most productive marine ecosystems. Extensive seagrass beds lie in a fringe along the major part of the Mediterranean coastline, occurring in the subtidal shallows down to 40 m deep. They are at their widest in the Gulf of Gabes off Tunisia and the Gulf of Sirte off Libya.

They provide feeding and shelter for over 650 marine species, including fish, crustaceans, and turtles and they also act as a breakwater and stabiliser, protecting the coast. Beyond the seagrass beds on the sea floor, coral-like algae grow in colonies on hard surfaces, forming concretions of sea debris. These are best developed off the coasts of France and Spain. Seaweed communities occur in areas of sub-tidal sand or rocky coast, especially along the Aegean and Adriatic coastlines. They support economically important populations of sponges, molluscs, and crustaceans.

These and other examples of the tremendous range of habitats in the Northeast Atlantic are listed in the following table.

Table 2.4.2.1. Examples of habitat types in the Northeast Atlantic and adjoining seas. Many of these habitats are under consideration for inclusion on the OSPAR Priority List of Threatened and Declining Species and Habitats.

Habitat	Description
Carbonate mounds	Carbonate mounds occur in small, localised clusters, mainly on the eastern margin of the North Atlantic. Most are dominated by filter-feeding communities and can support rich deep-sea coral communities, which form a secondary hard substrate for an abundant and diverse range of marine organisms.
Deep-sea sponge aggregations	Deep-sea sponge aggregations support a rich, diverse epibenthic fauna. Dense aggregations are known to occur in various places in the Northeast Atlantic. Deep-sea sponge aggregations are reported to occur close to the shelf break (250 m to 500 m depth) around the Faroe Islands, as well as along the Norwegian coast up to West Spitzbergen and Bear Island and in the Porcupine Seabight.
Lophelia pertusa cold-water reefs	*L. pertusa* has a wide geographical distribution, ranging from 55°S to 70°N and is present in the Atlantic, the Mediterranean, and in the Pacific and Indian Oceans, although most of the records come from the Northeast Atlantic. In Norwegian waters, *L. pertusa* reefs occur on the shelf and shelf break off the western and northern parts on local elevations of the sea floor and on the edges of escarpments. The biological diversity associated with the reefs is around three times as high as that of the surrounding soft sediment seabed, indicating that these reefs create biodiversity hotspots and increased densities of associated species.
Oceanic ridges with hydrothermal effects	The hydrothermal vent fields of Menez Gwen, Lucky Strike, Rainbow, and Saldanha are known important locations for these features. They cover very small areas in depths of 850-2,300 m. All are located on, or adjacent to, the Mid-Atlantic Ridge.
Seamounts	Surrounded by abyssal plains, seamounts have special hydrographic/substrate conditions and act as “islands” for marine life. They have high numbers of endemic species, and are used as “stepping stones” for the trans-oceanic dispersion of shelf species and as reproduction/feeding grounds for migratory species. Being of volcanic origin, the majority of seamounts lie along the Mid-Atlantic Ridge.
Littoral chalk communities	The erosion of coastal chalk exposures has resulted in the formation of vertical cliffs and gently sloping shore platforms with a range of micro-habitats of biological importance. At the upper limits and above the tidal range, chalk cliffs and sea caves support algal communities unique to the substrate. The generally soft nature of the chalk results in the presence of a characteristic flora and fauna, notably rock-boring invertebrates such as piddocks. Coastal exposures of chalk are rare in Europe, with the greatest proportion (57%) located on the south and east coasts of England.

Habitat	Description
Marine intertidal mudflats	Mudflats are intertidal habitats created by deposition in calm coastal environments, particularly estuaries and other sheltered areas. Their sediment consists mostly of silts and clays with a high organic content. They are characterised by high biological productivity and abundance of organisms, but low diversity. The largest continuous area of intertidal mudflats in the Northeast Atlantic extends along the North Sea coasts of Denmark, Germany and The Netherlands, covering around 500,000 ha.
Ampharete falcata sublittoral mud community	This habitat is characterised by dense stands of *A. falcata* tubes, which protrude from muddy sediments, appearing as a turf or meadow in localised areas. Dense populations of the small cockle *Parvicardium ovale* occur in the upper sediment. Substantial populations of mobile species such as the shrimp *Pandalus montagui* and small fish also occur.
Intertidal mussel beds	Intertidal mussel beds of *Mytilus edulis* are specific to the Northeast Atlantic, with the majority in the Wadden Sea and in British and Irish coastal waters. Elsewhere, different species form mussel beds, e.g., *Mytilus galloprovincialis* along the Iberian coast. The beds are important in the sediment dynamics of coastal systems as well as being an important food source for birds. Mussel beds also provide shelter for a large number of organisms and form a rare hard substrate in a soft-bottom environment.
Maerl beds	Maerl is a collective term for several species of calcified red seaweed. It grows as unattached nodules or branching structures on the seabed and can form extensive beds in favourable conditions. Live maerl has been found at depths of 40 m, but it typically occurs in waters above 20 m and extending to the low tide level. Maerl beds are an important habitat for a wide variety of marine animals and plants which live amongst or are attached to the branches, or which burrow in the coarse gravel or dead maerl beneath the living top layer.
Modiolus modiolus beds	The horse mussel *(M. modiolus)* forms dense beds at depths of 5–70 m in fully saline, often moderately tide-swept, areas. Although it is a widespread and common species, true beds forming a distinctive habitat are much more limited. Where they do exist, they are considered to support one of the most diverse sublittoral (depths greater than low tide level) communities in north west Europe.
Ostrea edulis beds	Oyster beds are found in estuarine areas from 0–6 m depth on sheltered but not muddy sediments, where clean and hard substrates are available for settlement, e.g., along the French, British, Irish, and Iberian coasts. Juveniles usually settle on the shells of adult oysters, so their decline reduces suitable settlement areas for subsequent generations.
Sabellaria spinulosa reefs	Dense subtidal aggregations of this small, tube-building worm can form reefs at least several centimetres thick, raised above the surrounding seabed, and persisting for many years. They provide a habitat that allows many other associated species to become established and can act to stabilise cobble, pebble, and gravel habitats. They are of particular nature conservation significance when they occur on sediment or mixed sediment areas, where they enable the establishment of a range of species that would not otherwise be found in the area.

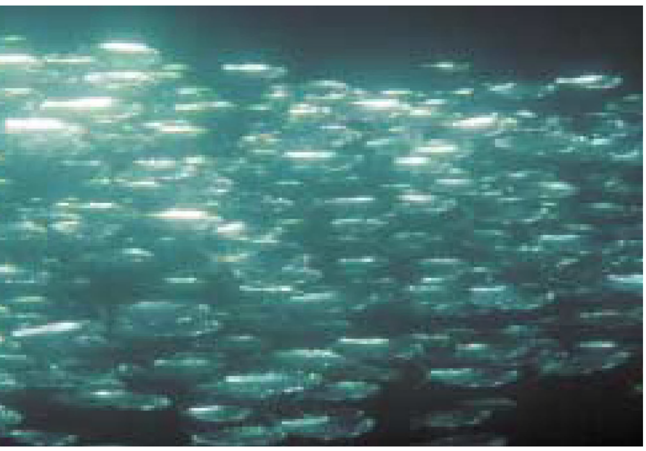
Habitat	Description
Sublittoral mud with burrowing invertebrates	The burrowing activity of the large organisms (megafauna) creates a complex habitat, providing for surface enlargement and deep oxygenation. It is assumed that this type of habitat supports a much richer and/or higher biomass community of species living in the mud.
Zostera beds (*Z. marina, Z. angustifolia,* and *Z. noltii)*	Seagrass beds develop in intertidal and shallow subtidal areas on sands and muds. They may be found in marine inlets and bays but also in other areas, such as lagoons and channels, which are sheltered from significant wave action. They can survive and reproduce under conditions of occasional inundation or total submergence, with different species being found at different shore levels or on different substrata. Seagrass stabilises the substratum as well as providing shelter and a substrate for many organisms. They are an important source of organic matter and may also be important nursery grounds, providing shelter for young fish.

2.4.3 Status of the fish stocks

This section describes the status of the prominent commercial fish stocks in the European seas. The impacts of fisheries on marine ecosystems will be discussed in Section 3.

OVERVIEW

In the Bay of Biscay and the waters off the Iberian Peninsula, the fisheries are characterised by a large number of species of commercial interest, of which the following are of most importance: tuna and tuna-like species, hake, sardine, anchovy, mackerel and horse mackerel, and crustaceans and molluscs. In the North Sea and the areas around the British Isles, the main commercial species are cod, haddock, whiting, saithe, plaice, sole, herring, mackerel, shrimps, Norway lobster, and industrial species like sandeel, Norway pout and sprat. In the Baltic Sea, fisheries are almost exclusively for cod, herring, and sprat. The commercial species in the northern areas around Iceland and Norway are mainly cod, haddock, saithe, herring, capelin, and blue whiting, shrimps, and deep-water species such as redfish.



GENERALLY, THE DEMERSAL STOCKS LIKE COD, HADDOCK, AND PLAICE HAVE DECLINED DURING THE LAST TWO DECADES

Generally, the demersal stocks like cod, haddock, and plaice have declined during the last two decades, while pelagic stocks like herring and blue whiting have increased, as have the smaller, but economically very important, stocks of shrimps and Norway lobster.

THE STATE OF THE STOCKS IN THE NORTHEAST ATLANTIC AND THE BALTIC SEA

With an annual harvest of fish and shellfish of about 10 million t a year (Figure 2.4.3.1) from a large diversity of species and stocks, the Northeast Atlantic is a main contributor to the world's marine fish production. The catches taken in the area originate from demersal and pelagic stocks used for human consumption, and a variety of demersal and pelagic fish landed as raw material for the production of fishmeal and fish oil (industrial fisheries).

The human consumption and industrial fisheries in the area are generally conducted with fishing fleets of larger vessels using bottom trawls, gillnets, longlines and seine nets for demersal species, and pelagic trawls and purse seines for pelagic species.

The effective fishing effort (fishing intensity) has been increasing in many fisheries, in spite of management schemes intended to reduce the capacity and control the fishing effort.

DEMERSAL STOCKS

Fluctuations in the catches from the North Atlantic mask considerable changes in the balance among the stocks. The most obvious change is the gradual decline of many demersal stocks, in particular gadoids such as cod and haddock, since the 1970's (Figure 2.4.3.2.).

WHILST DEMERSAL STOCKS HAVE DECLINED, LANDINGS OF PELAGIC STOCKS HAVE SHOWN AN INCREASING TREND OVER THE PAST TWO DECADES

The demersal stocks are diverse, dominated by a range of gadoid species, but also include flatfish such as sole, plaice, and Greenland halibut. However, most important in this group are the mosaic of cod stocks, which occur over much of the area from the Barents Sea to the Baltic Sea and in shelf waters from Greenland to Ireland.

PELAGIC STOCKS

Whilst demersal stocks have declined, landings of many pelagic stocks have shown an increasing trend over the past two decades (Figure 2.4.3.3).
In the 1980's, the increase was mainly due to increased landings of herring from the North Sea.
In the 1990's, landings from the Norwegian spring-spawning herring stock increased sharply, which not only counteracted the losses due to the reduction in the North Sea stock but also resulted in an overall increase in landings from the pelagic stocks. The pelagic stocks generally fluctuate more in

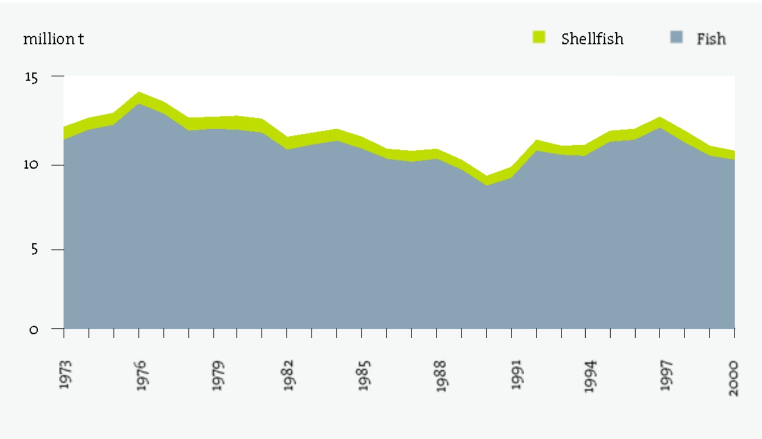


Figure 2.4.3.1. Total landings of fish and shellfish in the Northeast Atlantic and the Baltic Sea.

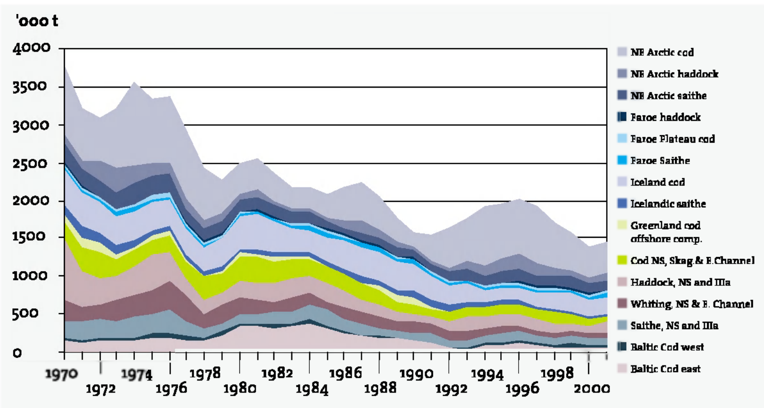


Figure 2.4.3.2. Landings of major gadoid stocks in the Northeast Atlantic and the Baltic Sea, excluding Norway pout and blue whiting. (See inside back cover for map of ICES fishing areas.)

Pelagic: Living and feeding in the open sea; associated with the surface or middle depths of a body of water; free swimming in the seas, oceans or open waters; not in association with the bottom.
Demersal: Living on or near the bottom and feeding on bottom-living organisms.
Industrial fisheries: Fisheries that catch fish for reduction to fishmeal or fish oil and not for human consumption.
Year class: The fish hatched or born in a given year.
Gadoid: Fishes of the cod family, e.g., cod, haddock, pollack, saithe, whiting, and others.

abundance—compared to the demersal stocks—due to a higher reproductive variability. In many pelagic stocks, a series of bad year classes are often followed by several years of very good reproduction.

INDUSTRIAL LANDINGS

The industrial landings are partly based on demersal stocks with a more stable reproductive rate, like sandeel and Norway pout, and pelagic stocks with a very variable reproduction such as capelin or horse mackerel. The overall landings for industrial use are very variable due to the large fluctuations of capelin and the horse mackerel stocks (Figure 2.4.3.4).

Spawning stock biomass: The total biomass of fish of reproductive age during the breeding season of a stock.
Recruitment: The number of young fish joining the stock each year.

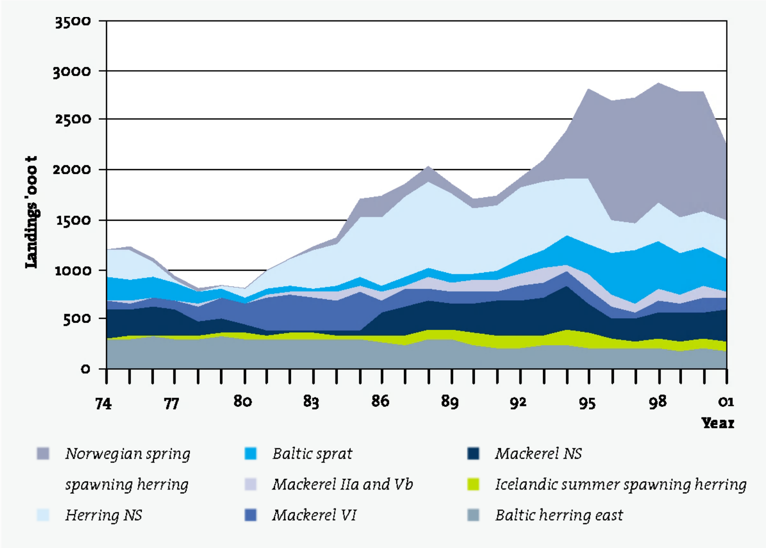


Figure 2.4.3.3. Landings of pelagic stocks in the Northeast Atlantic and the Baltic Sea, excluding industrial landings. Shows an increase in landings of pelagic stocks since 1980. (See inside back cover for map of ICES fishing areas.)

NORTH SEA STOCKS

Each year the North Sea supplies a total of about 2 million t of fish (Figure 2.4.3.5). A large part of this (more than 1 million t, mainly sprat, sandeel, Norway pout, blue whiting, and herring) is not directly consumed by humans, but is processed into fishmeal and fish oil. The next biggest proportion, about 700,000 t, is used for human consumption and comes from the pelagic fishery, which is mainly for herring or mackerel. Throughout recent years, the yield from the pelagic stocks has been stable, and they are generally in good shape.

NORTH SEA COD HAS BEEN FISHED DOWN TO THE LOWEST LEVEL EVER SEEN

Unfortunately the same cannot be said for the demersal stocks (300,000 t). Figure 2.4.3.5 shows that the landings of demersal species have been decreasing more or less continuously since the early 1980's. Many demersal stocks are seriously depleted. North Sea cod has been fished down to the lowest level ever seen.

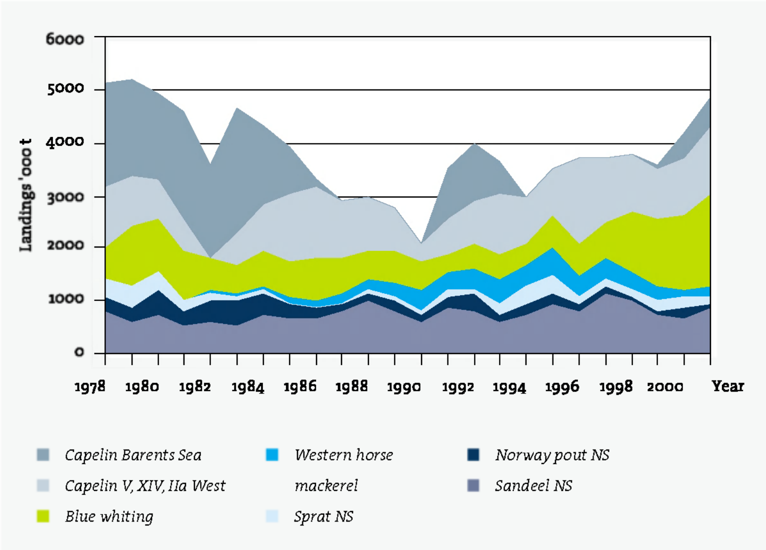


Figure 2.4.3.4. Industrial landings from the Northeast Atlantic. The graph includes stocks that are landed almost exclusively for industrial use; other stocks, such as sprat in the Baltic Sea have also sometimes been used for industrial purposes. (See inside back cover for map of ICES fishing areas.)

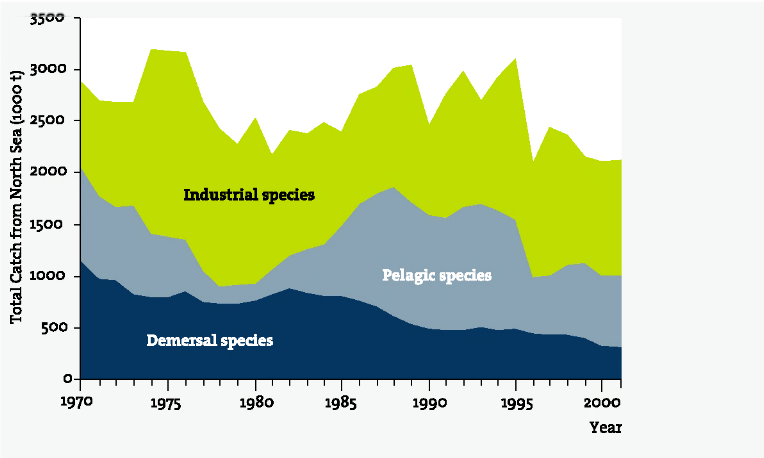


Figure 2.4.3.5. Total catch from the North Sea.

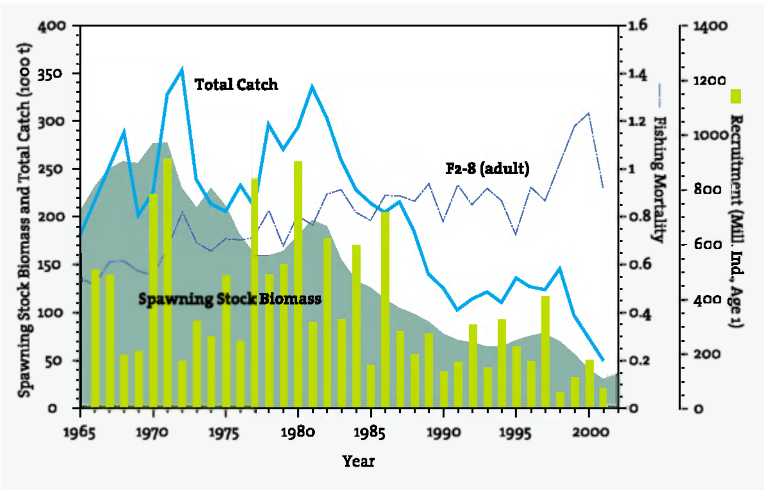


Figure 2.4.3.6. The decline of the North Sea cod stock and the increase in fishing pressure.

THE DECLINE OF NORTH SEA COD

The most prominent example of a stock under severe pressure in the North Sea at present is the cod. Figure 2.4.3.6 shows the decrease of the spawning stock biomass from a peak of some 250,000 t in the early 1970's to less than 40,000 t in 2001. The catches have also been declining strongly since the early 1980's.

While the spawning stock has declined, the fishing pressure has steadily increased and remains at an unsustainable level. A low spawning stock biomass means that the recruitment is strongly impaired.

Even if stringent recovery measures are implemented, the North Sea cod stock is not expected to recover within a decade or more.

And, as the last four recruiting year classes were exceptionally weak, there is little hope for recovery in the near future.

Some protection measures were applied in 2001 —such as the closure of a large area in the North Sea to protect the stock from being fished on the spawning grounds during the spawning season —but these measures have not been adequate to promote stock recovery. For the whole year, the fishing pressure was reduced only marginally. The stock is now in a precarious condition and there is a danger of stock collapse.

Even if stringent recovery measures are implemented, the North Sea cod stock is not expected to recover within a decade or more. This situation is not surprising and was previously predicted by ICES. Another complicating factor is that adequate protection measures for cod are difficult to impose because cod is also caught in mixed fisheries, which take other species as well as cod. For this reason, effective protection measures for cod will inevitably have an effect on the other fisheries as well.

Northeast Atlantic cod declines but shrimps and Norway lobster increase

While generally the cod stocks in the Northeast Atlantic area have declined in the past two decades, the shrimp and Norway lobster stocks have increased during the same period. Cod eat a lot of shrimps and Norway lobster in many areas and it is possible that the decline in the gadoid stocks has contributed to the increase in the shrimp and Norway lobster fisheries. Even though the quantitative gain in the shrimp and Norway lobster fisheries is much less than the loss of quantity in the gadoid fishery, they are often similar in commercial value.

Norway lobster

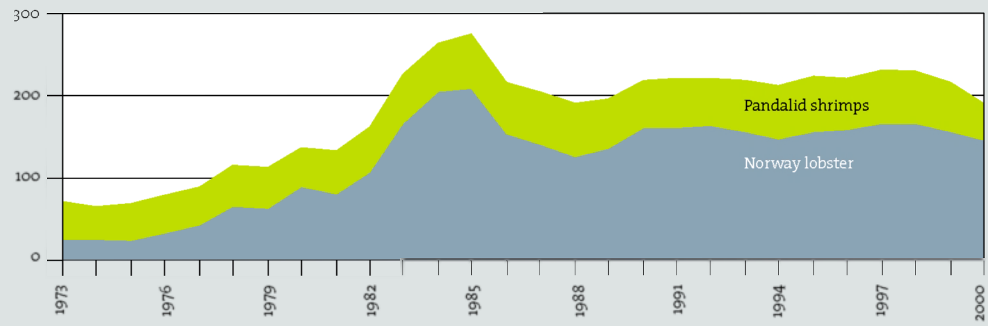


Figure 2.4.3.7. Landings of shrimps and Norway lobster in the Northeast Atlantic

THE RISE OF NORTH SEA HERRING

The North Sea herring is a more positive example of a stock with good management in recent years and presently in a state of rapid recovery. Figure 2.4.3.8 shows the collapse of this stock in the mid-1970's that led to the closure of the fishery for four years. In the following years the stock recovered rapidly, but so did the fishery. As a result, the stock started to quickly decline again during the early 1990's.

A new international management regime was agreed and implemented in 1996, and the subsequent steep recovery of the North Sea herring stock is to some degree the result of this – assisted by a series of strong recruiting year classes. At present, the stock is again within safe biological limits and the trend is still upwards.

THE STATE OF BALTIC SEA STOCKS – THE BIG THREE

The Baltic Sea ecosystem has a comparatively simple biological structure. The fish community is dominated by three species: cod, herring, and sprat. Their overall abundance is greatly determined by the specific hydrographic conditions in the Baltic (see Section 2.2).

BALTIC COD

The breeding success of Baltic cod is very dependent on environmental conditions. After spawning, their eggs sink low into the Baltic depths where they drift during incubation. However, as discussed in Section 2.2, the deep water of the Baltic is often low in oxygen and if cod eggs sink into such a region, they will inevitably die.

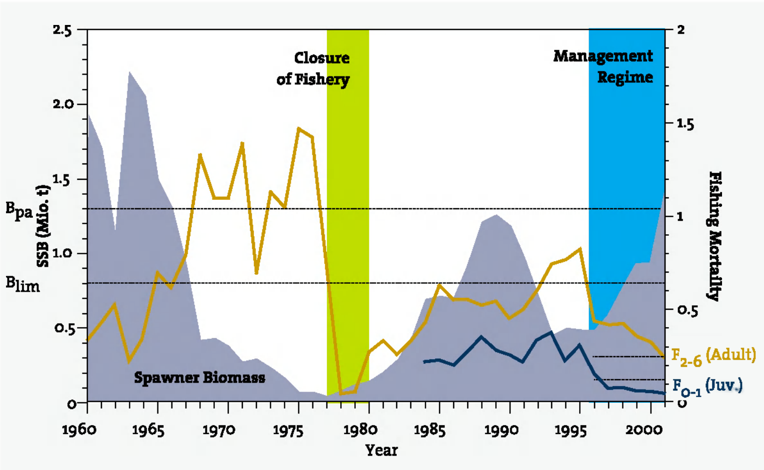


Figure 2.4.3.8. Development of the herring stock in the North Sea.

Unfortunately, conditions with oxygen-depleted deep water have prevailed throughout recent years in the central Baltic area, and this has inhibited the successful development of cod eggs in two of the three local cod spawning sites in the central Baltic Sea. Only in the most western spawning site, east of Bornholm, have smaller inflow events brought sufficient oxygen into the area to allow cod eggs to develop successfully.

This is a major reason why the recruitment of cod in the central Baltic Sea has been very low for the past decade or more. The other reason is the severe fishing pressure on the stock, with many young fish being caught before they have reproduced for the first time. The number of fish of reproductive age is estimated to be far below the sustainable limit. At such low levels as this, the stock is unlikely to produce good year classes, even under favourable environmental conditions.

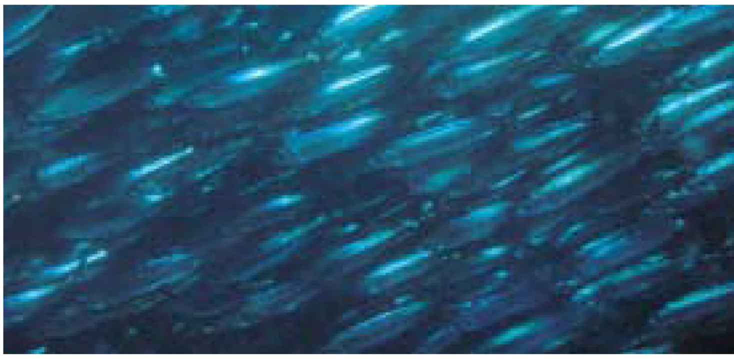
For several years ICES has recommended a total ban or revised recovery plan for fishing this depleted stock. But this was not followed and instead an existing recovery plan, which was first implemented in 2001, was continued. This recovery plan allows some fishing on Baltic cod (76,000 t in 2002). At such an exploitation rate, recovery of the stock in the medium term is unlikely, particularly if discarding and under-reporting of catches continue.

BALTIC HERRING AND SPRAT

Due to the very particular hydrographic situation in the Baltic Sea and the low saltwater inflow in recent years, the primary food source of the herring in the central Baltic Sea (the copepod *Pseudocalanus elongatus*) has become less abundant. This food decline started in the early 1980's and is probably one of the primary reasons why the herring stock has been declining. At the same time, the fishing pressure has been increasing, especially from the early 1990's onwards, even though the total catch has slowly declined.

Whilst the prey of the herring declined, another planktonic crustacean, *Temora longicornis* (the favourite prey of sprat), apparently did not suffer from the hydrographic situation and the sprat stock in the Baltic is in better shape than the herring – although the sprat stock has also been declining since the mid-1990's.

Both herring and sprat are likely to have benefited from reduced predation by the depleted Baltic Sea cod stock. At the same time, the growing sprat stock means that there are more sprat eating cod eggs and this is thought to be another factor impeding the recovery of the Baltic cod.



MEDITERRANEAN SEA AND BLACK SEA

The total annual catch of fish in the Mediterranean and Black Seas is around 1.4 million t. Catches of anchovy in recent years have been from 300,000 t to 500,000 t, much of which is from the Black Sea, while the sardine catch has been around 200,000 t, mostly from the eastern Mediterranean.

An estimated 500 species of fish occur in the Mediterranean. Of the 43 shark species occurring in the Mediterranean, eleven are globally threatened. Sharks are found throughout the Mediterranean, but are generally rare. Most species are of interest to fisheries and are caught for sale.

The most economically valuable fishery in the Mediterranean is for tuna, swordfish, and bonito. Catches of eastern Atlantic bluefin tuna are around 33,000 t, and they have been declining in recent years. It is estimated that fishing pressure on this stock is more than twice as high as it should be.

IT IS ESTIMATED THAT FISHING PRESSURE ON EASTERN ATLANTIC BLUEFIN TUNA IS MORE THAN TWICE AS HIGH AS IT SHOULD BE

Catches of swordfish are approximately 15,000 t annually. Other important fisheries in the Mediterranean are for mullet, red mullet, seabream, mackerel, jacks, and horse mackerel.

Four species of sturgeon are known to have occurred in the rivers and coastal waters of the Mediterranean, all of which are threatened. Only one species is believed to still breed in the Mediterranean, the Adriatic sturgeon, which inhabits the waters close to the shore from Venice to Greece.

DEEP-SEA SPECIES

The deep-water fish of the North Atlantic live in a cold and dark world. They are adapted to a life with very little food and at a very slow pace, as the small amount of energy available must be conserved as much as possible, with little used on swimming, searching for food, growth or reproduction. As a result, the fish grow extremely slowly and reproduce at a very slow rate – some species such as the orange roughy do not even reproduce every year. Many species become mature only at the age of 15–30 years and can live to over one hundred years old.

Because they grow and reproduce so slowly, deep-sea stocks cannot be fished and managed in the same way as the faster reproducing stocks in the North Sea. If a group of fish or stock in the deep sea is fished out, it is gone for good, at least on a human time scale. As a result, a fishery on such stocks sometimes appears for one or two seasons and then disappears for the next 20 or even 50 years. The only exceptions appear to be blue ling, alphonsino, tusk or redfish, which have faster reproduction and growth rates and so can sustain somewhat higher exploitation rates than other deep-sea species.

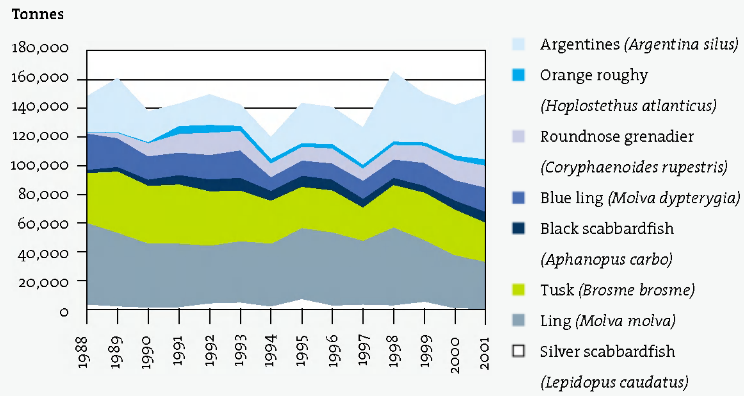


Figure 2.4.3.10. Catches of eight deep-water species in the Northeast Atlantic (ICES areas I–XIV), 1988–2001. (See inside back cover for map of ICES fishing areas.)

For many of the deep-water stocks in the Northeast Atlantic, the catches have been rapidly declining. This indicates a reduction in abundance of the fish and thus a reduction in stock size. This rapid decline should be seen as an alarm signal. ICES has advised for many years that deep-sea fisheries should not be allowed to expand until more knowledge is available about the biology of the stocks.

Orange roughy is one of the many deep-water stocks that are in decline.

Finding out more about deep-sea fish stocks

Firstly, the stock structure must be investigated. Which stock is found when and where? Do the different stock units mix; is there gene flow between them? What are their rates of reproduction and growth? Only when these basic biological questions have been answered can management units and plans be endorsed and implemented and, based on this, careful fishing could be sustained. The reality, however, is different.

Fishing on many deep-water stocks has been going on for many years and is still expanding. Despite the fact that fisheries are mobile and constantly looking for new sites, there has been a reduction (1991–2000) in the catches of several deep-water species such as tusk, ling, and silver scabbardfish.

ICES HAS ADVISED FOR MANY YEARS THAT DEEP-SEA FISHERIES SHOULD NOT BE ALLOWED TO EXPAND UNTIL MORE KNOWLEDGE IS AVAILABLE ABOUT THE BIOLOGY OF THE STOCKS

ATLANTIC SALMON

Atlantic salmon stocks, generally speaking, are in decline, despite fairly restrictive management measures and reductions in fishery exploitation rates. The main decreases have been in the "non-maturing" salmon that remain at sea for more than one winter before returning to their native rivers to spawn, compared to the maturing salmon that return after one winter at sea. The principal contributory factor in this decline has been lower survival at sea, during the time between the migration of the young salmon from freshwater and its return for spawning. Available evidence indicates a strong link between sea surface temperatures and recruitment in Atlantic salmon, but how this dependency operates is unclear.

BALTIC SALMON

Baltic salmon never leave the Baltic Sea. There are 40–50 rivers in the Baltic area with wild salmon production, but intensive exploitation, pollution, and the damming of rivers by hydroelectric schemes over a considerable period has reduced the stocks substantially. To compensate, many hatcheries were built in order to supply young fish for artificial re-stocking and today about 80–90% of the salmon in the Baltic are hatchery-reared fish. In addition to human impacts, the Baltic salmon stocks have also suffered from a disease called M74. The disease was discovered in 1974 and kills salmon larvae. Not much is known about its cause or mechanism, except that it is related to a deficit of vitamin B1. In 1998 the International Baltic Sea Fishery Commission (IBSFC) adopted a Salmon Action Plan with the goal of restoring the wild stocks to at least 50% of each river's natural production potential by 2010. Fisheries at sea and along the coast, as well as in some rivers, have been restricted and most of the larger stocks are showing clear signs of recovery.

2.4.4 Seabirds and marine mammals

For many people, seabirds and marine mammals are among the most obvious parts of the Northeast Atlantic ecosystems. In some cases, seabirds have been studied and counted at their colonies for more than a century, whereas interest in marine mammals

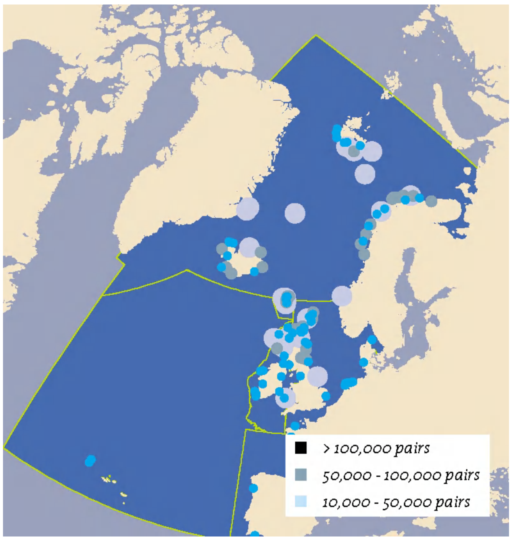


Figure 2.4.4.1. Location of large seabird breeding colonies in the OSPAR area. (Source: OSPAR, QSR 2000).

Table 2.4.4.1. Population figures for seabirds on Kattegat and Baltic Sea coasts (nesting pairs except for auks that are individuals).

Species	Breeding population
Great cormorant, *Phalacrocorax carbo*	71,500
European shag, *Phalacrocorax aristotelis*	1,000
Arctic skua, *Stercorarius parasiticus*	825
Black-headed gull, *Larus ridibundus*	141,000
Mew gull, *Larus canus*	80,400
Lesser black-backed gull, *Larus fuscus*	730
Herring gull, *Larus argentatus*	76,000
Great black-backed gull, *Larus marinus*	8,900
Sandwich tern, *Sterna sandvicensis*	1,800
Common tern, *Sterna hirundo*	40,300
Arctic tern, *Sterna paradisea*	36,600
Little tern, *Sterna albifrons*	1,000
Common guillemot, *Uria aalge*	12,000 individuals
Razorbill, *Alca torda*	12,000 individuals
Black guillemot, *Cepphus grille*	16,000 individuals

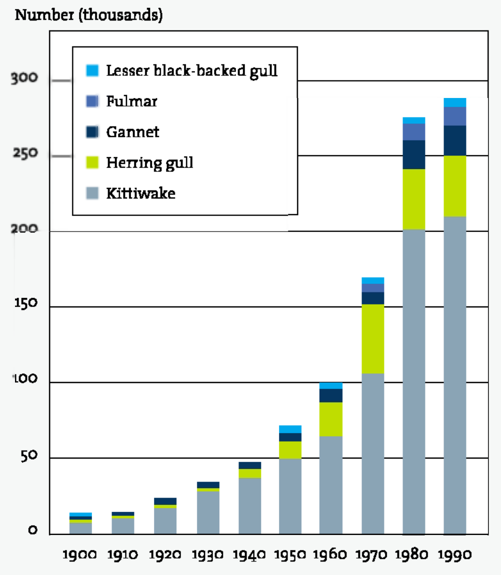


Figure 2.4.4.2. Number of breeding pairs of scavenging seabirds in Shetland, Orkney, Caithness to Banff and Buchan. (Source: OSPAR, QSR 2000, Region II).

Table 2.4.4.2. Population figures for seabirds on North Sea coasts (nesting pairs except for auks that are individuals). Recent (about the last decade) trends of breeding populations (where known or suspected) are indicated.

Species	Breeding population	Trend
Northern fulmar, *Fulmarus glacialis*	307,599	=
Manx shearwater, *Puffinus puffinus*	c. 250	=
European storm-petrel, *Hydrobates pelagicus*	low 1000's	
Leach's storm-petrel, *Oceanodroma leucorhoa*	low 100's?	
Northern gannet, *Sulla basana*	60,326	+
Great cormorant, *Phalacrocorax carbo*	2,222	+
European shag, *Phalacrocorax aristotelis*	19,804	+
Arctic skua, *Stercorarius parasiticus*	3,194	-
Great skua, *Stercorarius skua*	7,303	+
Mediterranean gull, *Larus melanocephalus*	c.150	+
Little gull, *Larus minutus*	40	+
Black-headed gull, *Larus ridibundus*	129,342	=
Mew gull, *Larus canus*	73,332	
Lesser black-backed gull, *Larus fuscus*	49,311	+
Herring gull, *Larus argentatus*	237,114	=
Yellow-legged gull, *Larus cacchinans*	10's	+
Great black-backed gull, *Larus marinus*	24,436	+
Black-legged kittiwake, *Rissa tridactyla*	415,427	-
Gull-billed tern, *Sterna nilotica*	<100	?-
Sandwich tern, *Sterna sandvicensis*	30,547	=
Roseate tern, *Sterna dougallii*	36	-
Common tern, *Sterna hirundo*	61,487	=
Arctic tern, *Sterna paradisea*	74,729	=
Little tern, *Sterna albifrons*	2,335	
Common guillemot, *Uria aalge*	680,434 individuals	+
Razorbill, *Alca torda*	73,115 individuals	+
Black guillemot, *Cepphus grille*	23,741 individuals	=
Atlantic puffin, *Fratercula arctica*	225,957 individuals	+

is more recent. Both feed near the top of the food chain, and may thus reflect conditions of the wider ecosystem both in terms of food availability and contamination.

SEABIRDS – POPULATION STATUS

In general, seabird populations have been increasing in the past 50 years. Figure 2.4.4.1 shows the locations of large seabird-breeding colonies in the Northeast Atlantic. A total of around 30 million pairs of seabirds nest in the wider Northeast Atlantic (including the North Sea and Baltic), with most of these being on Arctic coasts or on Iceland. Tables 2.4.4.1 and 2.4.4.2 indicate current populations of breeding seabirds in the Baltic and North Seas.

Trends in numbers in the Baltic Sea are not well known, but the numbers of great cormorants have increased greatly after being hunted to near extinction about 100 years ago.

The most notable change in population status over the past 150 years has been the spectacular increase in numbers and the geographical spread of the northern fulmar. In the mid-1800's, the species was known only from four sites in the Northeast Atlantic (one in the UK and three in Iceland). It is now one of the most common seabird species, nesting from France to northern Norway, including Helgoland in the German Bight. The causes of population changes are likely to vary between species and possibly geographical area. The most likely are reduced hunting pressure, increased food supply, and in some cases better protection of breeding grounds. Species of scavenging seabirds have particularly increased in some areas (Figure 2.4.4.2).

In addition to birds breeding on the coasts of the Baltic Sea and North Sea, substantial immigration to the area takes place in the non-breeding seasons by ducks, geese, and shorebirds. Numbers of ducks appear to be declining in several areas, with the impact of by-catch in fishing nets and reductions in some food supplies being prime causal factors.

The population sizes and diversity of seabirds are relatively low in the Mediterranean Sea, partly because of the low biological productivity and the nutrient scarcity. Audouin's gull and the Mediterranean shearwater breed solely in the Mediterranean and the Mediterranean gull is almost confined to the region for breeding. In addition, the European populations of the great black-headed gull and the slender-billed gull breed only in the Mediterranean and Black Seas.

PRODUCTIVITY

The productivity of seabirds is not monitored widely within the ICES area; however, a scheme covering all coasts of the UK and Ireland is the most systematic and long-term. For the species monitored, productivity in terms of chicks fledged per pair has been fluctuating around an average, with no apparent trend. Perhaps the most interesting results relate to the black-legged kittiwake. This surface-feeding gull is particularly sensitive to the availability of its prey, usually sandeels or sprat, within about 30 km from its colonies. Breeding failures in Shetland in the 1980's were traced back to a failure in the local sandeel stock, while similar declines in breeding performance were noted off eastern Scotland in the 1990's. In both cases, local fisheries for sandeels have been closed or managed in order to ensure that the fishery does not unduly affect the food supply of seabirds (and other sandeel predators).

MARINE MAMMALS – POPULATION STATUS

The status of marine mammals in the Northeast Atlantic is much less well known than that of seabirds. Out of the marine mammals, seal populations are better known than those of cetaceans (whales and dolphins) because seals spend time hauled out on beaches and so are easier to count.

The Baltic Sea has three resident seal species, ringed, grey, and harbour or common seals, and only one cetacean, the harbour porpoise. The seal populations are generally increasing following reductions in the past that were mainly due to hunting, but also because of the effects of contaminants on seal health and reproduction (Table 2.4.4.3). The harbour porpoise population in the Baltic Sea is less than 1,000 animals and has declined dramatically. It is not known precisely why this decline occurred, but the likely causes are by-catch in fishing nets, deliberate hunting, and

Seal Virus

Phocine distemper virus outbreaks have occurred twice in recent years in the North Sea and nearby. In 1988, an outbreak killed about 18,000 seals in the Kattegat, Skagerrak, and North Sea. Mostly harbour seals were affected and the cause of the outbreak was not known, but it seems very likely that the virus was spread from harp seals during an invasion in 1988. The population subsequently recovered until May 2002, when another outbreak was again detected in the Skagerrak. The disease spread rapidly, but not uniformly. It was detected in The Netherlands in June and in France in July, but not until mid-August in the UK and September in the Danish Limfjord. By the beginning of November 2002 it appeared that the outbreak was losing virulence in the areas where it started, but was still active in the UK and the Limfjord. Once again, harbour seals were the most affected and total numbers found dead by the end of October 2002 had reached 20,500 (25–30% of the population of harbour seals).

kills during winters when the Baltic freezes over. Whatever the cause of the decline, by-catch in fishing nets is likely to be causing further reductions at present.

Two seal species (grey and harbour) breed in the North Sea. Both species have increased in numbers over the past forty years at least, but the harbour seal has been subject to two bouts of a virus infection that greatly reduced their numbers. The most recent bout occurred in the spring and summer of 2002 (see box). The most abundant cetacean in the North Sea is the harbour porpoise. They are distributed throughout the North Sea, but are now rare in the Southern Bight and the Channel.

Other species of seals occur in the northern North Atlantic and the endangered monk seal *(Monachus monachus)* occurs in the Mediterranean and on the northwest African coasts. The monk seal is the most threatened species in the Mediterranean, and one of the ten most threatened species of mammals in the world. Around nine species of whales and dolphins are regularly found in the Mediterranean Sea, with the largest populations found off the southern coast of France and the northwest coast of Italy and Corsica. Three species of dolphins are found in the Black Sea.

Many other species of cetaceans occur in the Northeast Atlantic (Table 2.4.4.3), but are not known well enough to determine trends in numbers. Based on sightings, it seems likely that at least humpback whales are recovering from the whaling activity early in the 20th century that severely depleted their populations. By-catches of cetaceans, particularly harbour porpoises in the Baltic, North and Celtic Seas and common dolphins and other cetaceans in the Bay of Biscay and the western Channel, are a major concern.

By-catches of cetaceans, such as this common dolphin, are a major concern in European seas.

Table 2.4.4.3. Presence (P), abundance, and trends (+, –, =) of key marine mammals in the Baltic Sea, North Sea, and wider Northeast Atlantic. Seal population estimates were made before the recent virus outbreak (see box). At least 20 additional species of cetaceans occur in the Northeast Atlantic.

Species	Baltic Sea Abundance	Trend	North Sea Abundance	Trend	NE Atlantic Abundance	Trend
Grey seal, *Halichoerus grypus*	7,650	+, =	62,000	+	P	+
Harbour seal, *Phoca vitulina*	500	+	50,000	=	P	+
Ringed seal, *Phoca hispida*	5,500	=	o		o	
Hooded seal, *Cystophora cristata*	o					
Bearded seal, *Erignathus barbatus*	o					
Blue whale, *Balaenoptera musculus*	o		o		P	unknown
Fin whale, *Balaenoptera physalus*	o		o		P	unknown
Minke whale, *Balaenoptera acutorostrata*	o		7,300	unknown	P	unknown
Sei whale, *Balaenoptera borealis*	o		o		P	unknown
Humpback whale, *Megaptera novaeangliae*	o		o		P	+, unknown
Sperm whale, *Physeter macrocephalus*	o		o		P	unknown
Harbour porpoise, *Phocoena phocoena*	600	–	300,000	–, unknown	P	unknown
White-beaked dolphin, *Lagenorhynchus albirostris*	o		7,900	unknown	P	unknown
Atlantic white-sided dolphin, *Lagenorhynchus acutus*	o		P	unknown	P	unknown
Risso's dolphin, *Grampus griseus*	o		P	unknown	P	unknown
Bottlenose dolphin, *Tursiops truncatus*	o		120	–, unknown	P	unknown
Striped dolphin, *Stenella coeruleoalba*	o		o		P	unknown
(Short-beaked) common dolphin, *Delphinus delphis*	o		P	unknown	P	unknown
Killer whale, *Orcinus orca*	o		P	unknown	P	unknown
Long-finned pilot whale, *Globicephala melas*	o		P	unknown	P	unknown
Short-finned pilot whale, *Globicephala macrorhynchus*	o		o		P	unknown

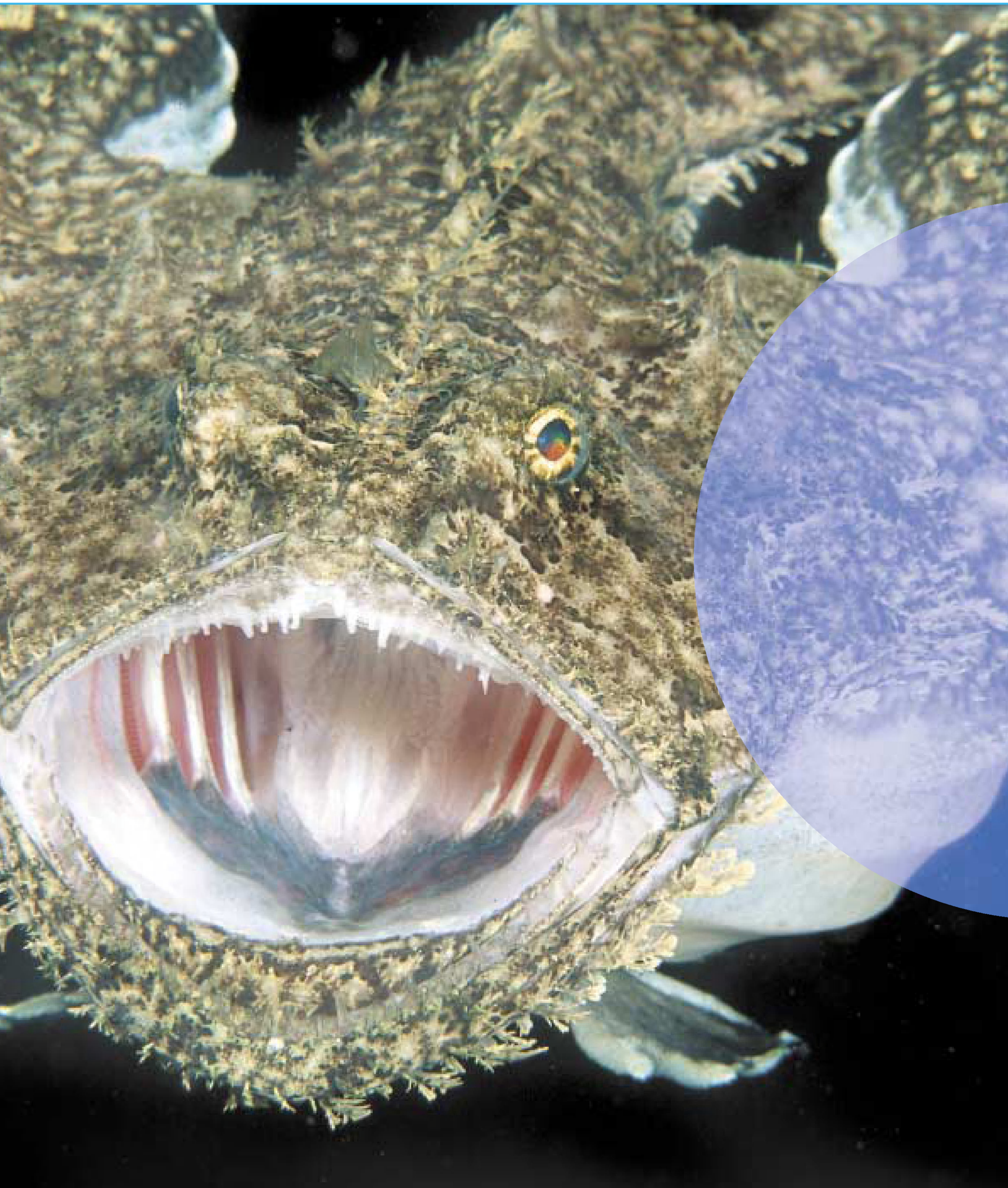
Changes in the North Sea ecosystem

The North Sea ecosystem has changed notably over the course of the 20th century. Some parts have increased their productivity or abundance (e.g., certain zooplankton, benthos off North-east England, some seabirds), whilst other eco-system components have exhibited long-term reductions (e.g., commercial fish stocks).

Alongside these long-term changes in producti-vity, changes have also occurred in the species composition of some of these communities. For example, there has been a general shift in the benthic community from long-lived species to more opportunistic species, whilst in the fish community, surveys have shown that some non-commercial species have increased at the same time that commercial species have declined. Some of the long-term changes have occurred in parallel. Phytoplankton, zooplankton, kittiwake breeding, and herring landings show similar long-term fluctuations.

What has caused the change?

Establishing which factors are responsible for changes in the North Sea is not easy because of the multitude of factors that affect the system. But on a North Sea scale, it appears that climatic factors, fishing and eutrophication (surplus of nutrients) are primarily responsible for many of the long-term changes (see Section 3 for more information).



Human impacts on marine biodiversity

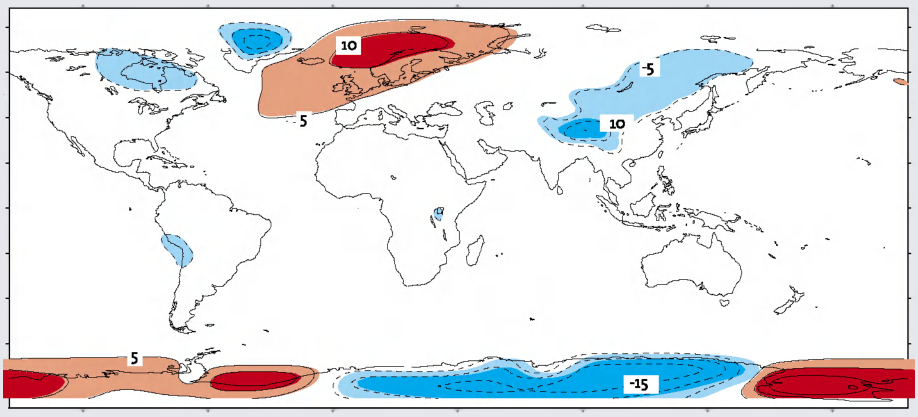
In this section, we discuss the impacts of human activities on the ecosystems of European seas. Topics covered include climate change, fisheries, nutrient inputs, eutrophication, harmful algal blooms, contaminants such as heavy metals and PCBs, impacts of shipping and activities in the coastal zone, and finally marine litter.

3.1 Evidence of climate change

Climate change has become an important issue in Europe over the past few decades. Although there are still more questions than answers about its effects, almost all global models agree that there will be a higher surface temperature in the future, given the build-up of greenhouse gases in the atmosphere to their present levels. The Intergovernmental Panel on Climate Change (IPCC) predicts that, by 2100, global warming will have led to an increase in the surface air temperature of the Northeast Atlantic by 1.5°C and a rise in sea level by 25 cm to 95 cm.

It is also fairly clear that any temperature increase will be more pronounced at high latitudes than closer to the equator (Figure 3.1.1). But disentangling the effects of human-induced climate change from natural variability is proving far from easy. This is particularly true when looking at the role of climate change on the oceans, a habitat that is constantly changing and does not have a “normal state”. Oceanographic conditions vary continuously and the length of the fluctuations varies from seconds to thousands of years. Scientists are also restricted by the short time scale of many oceanographic data sets.

Figure 3.1.1. Deviation of the annual average surface air temperature from its zonal average. Note the anomalously high temperatures over the Northeast Atlantic and northern Europe, and anomalously cold areas over Greenland. (Source: Potsdam Institute for Climate Impact Research, 1999).



The longest oceanographic time-series is from the Kola-section in the Barents Sea, where Russian scientists started an observation programme back in 1900. Although the temperatures vary by several degrees in the Northeast Atlantic area, the variability shown in Figure 3.1.2 is representative for all areas influenced by the Atlantic current. The results show that the 1990's have been the warmest decade ever measured. This finding is also backed up by evidence in the ICES Annual Ocean Climate Status Summary, which shows relatively high temperatures in the North Atlantic during the 1990's with most areas showing a warming trend, although the temperature has been going down between Greenland and Iceland. The question is, whether this warm period is just natural variability (see Figure 3.1.2) or due to global warming. We will have a better idea of the true picture in 10–15 years' time.

the North Atlantic Current, which would have a huge effect on marine ecosystems, while other models predict that the current will remain stable. In their most recent assessment, the IPCC stated: "a reduction of the Atlantic current is a likely response to increased greenhouse gas forcing based on currently available model simulations." They find that a complete shutdown of the current is "less likely, but not impossible."

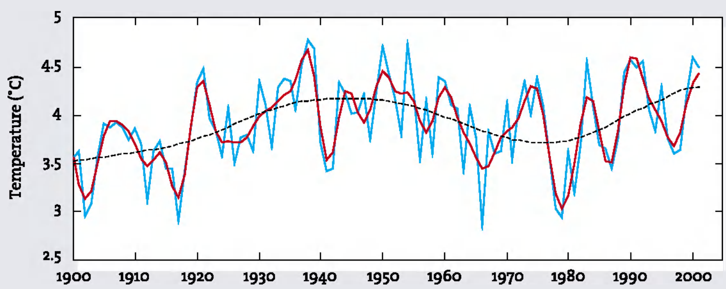


Figure 3.1.2. Annual mean temperature from the Russian Kola-section (blue); the red and black lines show the results after applying a 5-year (red) and 30-year (black) filter. (Source: Based on data from PINRO, Murmansk).

THE RESULTS SHOW THAT THE 1990'S HAVE BEEN THE WARMEST DECADE EVER MEASURED

IMPACTS OF CLIMATE CHANGE

At present, climate models are not able to give definite answers about the effects of climate change on marine ecosystems. For instance, some models predict significant weakening or even collapse of

Despite the uncertainty in the models, there is evidence of changes in ocean circulation and water mass characteristics that could be due to climate change. The amount of Atlantic water in the Arctic

Ocean has increased during recent years, as has the temperature in the deep Norwegian Sea. Observations indicate a reduction of deep-water mixing in the Greenland Sea since 1970, and there has been a steady decrease in ice coverage (3% per decade) in the Arctic since the 1970's. In addition, the ice over the deep-water Arctic has thinned from an average of about 3.1 m (1958–1976) to about 1.8 m (1993–1997), or about 15% per decade (Figure 3.1.3 shows the annual variability in sea ice cover). If the reduction in ice cover is natural, the loss of Arctic ice should eventually reverse, but if global warming is the cause, the entire ice pack could eventually disappear, with drastic climate implications for the northern hemisphere.

THE ICE OVER THE DEEP-WATER ARCTIC HAS THINNED FROM AN AVERAGE OF ABOUT 3.1 M (1958–1976) TO ABOUT 1.8 M (1993–1997)

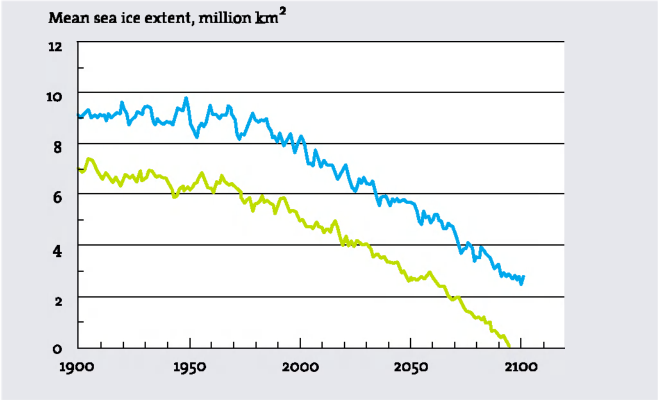


Figure 3.1.3. Model projections of the decline in sea ice cover for the Arctic Ocean. Annual mean sea ice extent in million km² is shown for the northern hemisphere as simulated by two different climate models. (Source: AMAP, 2000).

There has been a steady decrease in ice coverage (3% per decade) in the Arctic since the 1970's.

Anticipated impacts of further climate change include:

WITHIN THE ARCTIC

- There will be longer ice-free periods, which will lead to increased areas of open water. This, in turn, will increase wind mixing, upwelling, and wintertime convection, and thus increase the availability of nutrients to phytoplankton.
- Changes in the ocean structure and currents will affect fish migration and behaviour, and this redistribution will impact underlying foodwebs.
- Marine mammals (e.g., seals, bears) that depend on an ice platform will be seriously impacted by loss of habitat, or will have to migrate elsewhere (if possible), with serious consequences to their prey and predators.
- Whales that depend on open water for migration will expand their ranges in response to decreases in ice coverage.

ELSEWHERE IN THE NORTHEAST ATLANTIC AREA

- Increased rainfall, predicted under global warming, will increase the input of inorganic and organic terrestrial material to coastal areas.
- Rising sea level, combined with increased temperatures, will accelerate coastal erosion, affecting underwater light in coastal water and altering coastal habitats.
- More storms, especially in autumn, will lead to greater mixing, greater supply of nutrients, enhanced sediment transport and more rapid coastal erosion.

3.2 Ecosystem impacts of fisheries

The status of commercial fish stocks has acquired a high news profile, as shown by the recent concern over the state of North Sea cod stocks. The general public, politicians, and the scientific community believe that fishery resources should be managed in a sustainable way. In this section, we describe the impacts of fisheries on marine ecosystems and the development of the ecosystem approach in fisheries management.

Producing advice on fish stocks

A major advance in the development of sustainable management of fisheries came about with the development of the precautionary approach in the early 1990's. Article 15 of the Rio Declaration on Environment and Development states that:

"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation"

The precautionary approach in fishery management terms means trying to make sure that the number of spawning fish in a stock is not reduced to the point where reproduction is impaired.

Biomass Limit

The stock level at which reproduction is impaired is called the **biomass limit** or **B_{lim}.** The aim is to keep the fish stock above this limit. Stocks that fall below B_{lim} can still recover, but only over a long period of time and with severe conservation measures in place throughout the recovery period.

Precautionary Biomass

Unfortunately, judging the stock level or B_{lim} is difficult and it has to be estimated statistically. To allow for this uncertainty, a buffer zone is calculated above the B_{lim} level to act as a safety measure. This is called the **precautionary biomass** or **B_{pa}.**

The better the data on a stock, the smaller the buffer will be. With a stock such as North Sea herring that has had an eventful history with many highs and lows and is well monitored, the precautionary biomass is small as scientists are more confident at estimating B_{lim}.

Safe biological limits

- When a fish stock size is above the precautionary biomass, it is said to be **inside safe biological limits.**
- When the stock size is below the precautionary biomass level, it is said to be **outside safe biological limits,** regardless of the rate at which it is being fished.
- Even if the stock is inside safe biological limits, the fishing intensity may be high enough to drive the stock down towards (or below) the precautionary biomass. Under these circumstances, the stock is said to be **harvested outside safe biological limits.**

STATE OF THE FISH STOCKS – IN GENERAL

In general, the state of the stocks in the Northeast Atlantic is poor. A great number of stocks are outside safe biological limits and some, like cod in the North Sea, are in danger of collapsing (see Table 3.2.1).

Although "outside safe biological limits" does not mean that such stocks are necessarily in danger of becoming extinct, it does mean that their reproduction is impaired, and harvesting rates are unsustainable. Recovery of these stocks will be slow and great reductions in fishing pressure will be required.

Table 3.2.1. Overview of the state of fish stocks in the Northeast Atlantic and the Baltic Sea.

Area	Main stocks in order of size of recent landings	State of stocks
Northeast Arctic	Herring (Norwegian spring-spawning), cod, capelin, saithe, haddock, blue whiting, redfish	Herring and capelin stocks very variable and inside safe biological limits. Saithe inside safe biological limits. Other major stocks outside safe biological limits.
Northwest areas	Capelin, Icelandic cod, herring (Icelandic summer-spawning), Icelandic saithe, redfish	Offshore cod at Greenland, Icelandic saithe, halibut and open-sea redfish *(S. mentella)* outside safe biological limits. Icelandic summer-spawning herring and capelin inside safe biological limits. Icelandic cod stock well below its long-term average, but harvest control rules currently in operation are in accordance with the precautionary approach.
Faroe Islands	Saithe, cod (Faroe plateau), haddock	Some recovery since recent depletion, but saithe still outside safe biological limits.
North Sea and neighbouring waters	Sandeel, herring, mackerel, Norway pout, sprat, haddock, cod, plaice, saithe, whiting, horse mackerel, and blue whiting	**Inside safe biological limits:** saithe, North Sea herring, Irish Sea plaice & sole, Eastern Channel sole, Celtic Sea whiting. **Harvested outside safe biological limits:** Western mackerel, blue whiting, Celtic Sea sole, Eastern Channel plaice. **Outside safe biological limits:** Northern hake, North Sea cod & whiting, W. Scotland cod & whiting, Irish Sea cod, North Sea plaice & sole, Western Channel plaice & sole. Sandeel and Norway pout in the North Sea can sustain current exploitation.
Bay of Biscay and Portuguese waters	Sardine, horse mackerel, mackerel, anchovy, hake, Norway lobster	Status of sardine stock uncertain. Southern horse mackerel can sustain current exploitation. Anchovy inside safe biological limits. Southern hake outside safe biological limits. Norway lobster seriously overexploited.
Baltic Sea	Sprat, herring, cod	Cod and herring outside safe biological limits. Sprat inside safe biological limits.

The number of major stocks that are inside safe biological limits has declined from 27 in 1996 to 18 in 2001, as can be seen in Table 3.2.2, despite the efforts of scientists and managers to follow a precautionary approach. At the same time, Table 3.2.2. shows that there has been an increase in the number of stocks of which the status is unknown. This shows that fisheries are targeting new stocks without adequate monitoring of what is being caught, or without sufficient research on the biology and conservation requirements of the stocks.

It is also symptomatic of the fact that scientific resources allocated to core fisheries problems have declined internationally, while demands for scientific advice on fisheries have increased.

This discrepancy between the demands for scientific advice on fisheries, and the data and capacity to provide the advice, is a serious and growing problem.

	Stocks outside safe biological limits		Stocks harvested outside safe biological limits		Stocks inside safe biological limits		Stock status unknown		Total* number of stocks assessed by ICES
	No.	%	No.	%	No.	%	No.	%	
1996	28	27	14	13	27	26	35	34	104
1997	36	35	19	18	19	18	29	28	103
1998	30	31	18	19	22	23	27	28	97
1999	34	31	17	16	21	19	37	34	109
2000	30	29	17	16	23	22	35	33	105
2001	31	27	16	14	18	16	48	42	113

Table 3.2.2. Number of stocks inside and outside safe biological limits.

** Stocks excluded from comparison: salmon, sea trout, dab, brill, turbot, eel, and Norway lobster.*

Following the scientific advice

The fishing of many stocks is regulated using Total Allowable Catches (TACs) that are internationally agreed on an annual basis. Sometimes the TACs are identical to the levels of fishing recommended by ICES, but in many other cases they are not. On average, the chosen TACs have been about 30% above the scientifically advised levels. For a single year, 2000, the average deviation was about 50%, reflecting the inevitable compromise between scientific advice and political pressure.

Where the scientific advice has been followed, there have been some success stories. Two examples are the North Sea herring and the Norwegian spring-spawning herring. Both stocks were heavily overfished and plummeted to critical levels. But international management plans were then agreed on the basis of ICES scientific advice and, helped by some successful recruitment years, both stocks have now recovered. In both cases, the crucial aspect of the recovery was that the management plan gave the first promising year classes of fish a chance to spawn and reproduce.

In summary, overfishing continues to be a key problem in many areas and less than a quarter of all stocks assessed by ICES are in good shape (see Table 3.2.2.). About another 17% could be, if exploitation were reduced somewhat. Nearly one-third of the stocks are in poor condition and the status of over one-third is unknown.

OVERFISHING CONTINUES TO BE A KEY PROBLEM IN MANY AREAS AND LESS THAN A QUARTER OF ALL STOCKS ASSESSED BY ICES ARE IN GOOD SHAPE

A study undertaken by the European Commission in 1995 calculated that the EU fleet as a whole was 40% bigger than that required to fish the resources in a sustainable way. It is clear that the available catching capacity in many parts of the Northeast Atlantic, and not just in the EU zone, continues to be greater than the fish stocks can sustain.

IMPACT OF FISHING ON THE MARINE ECOSYSTEM

Fishing activities influence marine ecosystems in a number of ways. These include:

- Removal of the target species such as cod, haddock or herring, and resulting changes in the size structure of their populations;
- Mortality of non-target populations of fish, and of seabirds, marine mammals, and benthic marine life;
- Alterations to the seabed habitat; and
- Changes in the food web with impacts on the predators and prey of the species affected.

WHERE THE SCIENTIFIC ADVICE HAS BEEN FOLLOWED, THERE HAVE BEEN SOME SUCCESS STORIES

The most immediate effect of fishing is the reduced abundance of the target species (and species killed as by-catch), particularly the removal of the larger individuals. High fishing pressure on many fish stocks has created a situation where many stocks are outside safe biological limits (see above). This situation could be reversed if the fishing pressure on commercial species was reduced to a more sustainable level, as advised by ICES.

DISCARDS AND BY-CATCHES

A major effect of fishing on the marine ecosystem comes from the fact that fishing kills many more fish than are landed and registered. On deck, fishermen sort out the fish that can be sold, and the remaining fish are returned to the sea – most of which will already be dead or dying. This fraction that is thrown back into the sea is the "discards".

DISCARDS MAINLY CONSIST OF YOUNGER FISH AND IN THE NORTH SEA WHEN THEY ARE MEASURED IN INDIVIDUAL FISH, RATHER THAN IN TONNES, MORE FISH ARE DISCARDED THAN LANDED

The quantity and species composition of discards are very difficult to measure because observers are only present onboard on rare occasions and fishers rarely volunteer accurate information on the fish they discard. In Norwegian fisheries, however, discarding is banned and all commercial species of fish that are caught are supposed to be landed.

Discards increase the mortality caused by a fishery, but this loss from the fish stock is usually not recorded or taken from the quota. Some fish and other creatures are discarded because they are species for which there are no markets (or for which the quota has already been taken). Others are discarded because they are too small, or of too poor a quality to achieve top prices on the market (high-grading), or simply damaged in the process of being caught.

In addition to the 85 million t of fish harvested worldwide in 1991, the UN Food and Agriculture Organization estimated that global discards were around 27 million t. Shrimp/prawn fisheries tended to have the highest discard rates, with an average of 84% of the catch (by weight) being discarded, compared with an average of 26% for fisheries in general.

The total amount of fishery discards in the North Sea alone in 1990 was around 260,000 t of round-fish, 300,000 t of flatfish, 15,000 t of rays, skates and dogfish, and 150,000 t of bottomdwelling inver-tebrates per year. These fish discards corresponded to about 22% of the total North Sea landings.

Despite attempts to reduce discards, such as the introduction of square mesh panels in fishing nets by EU Member States in January 2000 (to make it easier for juvenile fish to escape), discards remain a problem. Available data on discards from North Sea fisheries indicate that around 40% of the plaice catch (by weight) was discarded in 2000 and 2001. For North Sea cod, the corresponding figure is 12%, and for haddock and whiting in ICES area VIa (West of Scotland), about 50%. Discards mainly consist of younger fish and in the North Sea when they are measured in individual fish, rather than in tonnes, more fish are discarded than landed.

In addition to the by-catch of non-target fish and invertebrates, fishing gear may also accidentally catch and drown air-breathing marine animals, such as seabirds, turtles, and marine mammals. There is no overall information on the numbers of animals in the by-catch, but detailed studies have been carried out in several fisheries. For example, estimates have been made of the by-catch of porpoises in Danish gillnet fisheries for cod, hake, plaice, sole, and turbot in the North Sea; by-catches in this fishery averaged over 5,000 harbour porpoises per year during the 1990's, declining towards the end of this period. Acoustic warning devices (pingers) are now required in parts of this fishery to scare the porpoises away from the fishing nets. Steps are also being considered to limit by-catches of harbour porpoises in the Baltic Sea, where they are severely depleted.

Another key point is that while some commercial species may be, by their nature, more resilient to high exploitation, some non-commercial species, such as sharks, skates, and rays, and cetaceans are only able to withstand much lower mortality rates. This means that the by-catch mortality could be unsustainable for some non-target species, even when the fishing effort is appropriate for the target species.

Many species of elasmobranchs (rays and sharks) have declined markedly in the Northeast Atlantic and some have totally collapsed, at least in some specific regions. For instance, the "common" skate might be better renamed as "rare" skate over much of its historic range of distribution. Fishing has been the primary cause of the population declines observed.

CHANGES TO SEABED HABITAT

The direct physical effects of fishing can alter the seabed habitat and change its ability to sustain the original fish and seabed communities. The combined action of factors such as mortality of non-target seabed organisms, changes in predation pressure, addition of offal and discards, and stirring up of sediments by bottom fishing gear can all contribute to changing nutrient fluxes between the sediment and the water, thus changing the availability of nutrients in the sea.

One of the more recent high profile physical effects of fishing has been damage reported on cold-water coral reefs in the Northeast Atlantic. Photographic and acoustic surveys have recently located trawl marks at 200–1400 m depth all along the edge of the Northeast Atlantic shelf slope area of Ireland, Scotland, and Norway. Any trawling over these reefs is likely to cause mechanical damage, which will kill the coral polyps and break up the reef structure. The breakdown of this structure will alter the water and sediment processes, as well as cause a loss of shelter around the reef, which will make the habitat much less suitable for the normally thriving marine life that depend on these features. Trawling may also have the effect of evening out the seabed by scraping off high points and infilling lows, as well as redistributing boulders. Since *Lophelia pertusa* seems to require some of the high points to grow initially, the seabed habitat following trawling may become unsuitable for *Lophelia pertusa* growth.

ONE OF THE MORE RECENT HIGH PROFILE PHYSICAL EFFECTS OF FISHING HAS BEEN DAMAGE REPORTED ON COLD-WATER CORAL REEFS IN THE NORTHEAST ATLANTIC

CHANGES TO MARINE FOODWEBS

It is estimated that the small creatures living on or in the seabed (worms, shellfish, etc.) can supply as much as two-thirds of the annual food requirements of bottom-feeding fish, so any increased mortality of these seabed animals as a result of fishing could alter the foodweb.

Trawling over Lophelia pertusa reefs kills coral polyps and breaks up the reef structure.

In addition to direct mortalities, fishing can also affect the predator-prey relationships and/or competitive balance among species within ecosystems. This might explain why some species respond positively—for example shrimps and Norway lobster have increased as cod have been depleted in the North Sea—while others respond negatively. For the time being, the intricate nature of species interactions in the fish community prevent firm conclusions from being drawn on the full effects of fishing.

While data limitations restrict the potential for detailed assessments of individual non-target species, changes in the entire fish community may be suitable for establishing the overall effects of fishing. There is increasing evidence that the overall level of exploitation is related to overall changes in size composition (declines in abundance of large individuals, increases in abundance of small individuals). It is also thought that trawling activities have been involved in shifting the seabed communities in the North Sea from long-lived to more opportunistic species.

DEVELOPING THE ECOSYSTEM APPROACH IN FISHERIES MANAGEMENT

A goal in fisheries management should be to avoid not only overfishing of the target fish stock, but also ecosystem overfishing (i.e., ecosystem changes that drastically alter food web structures, nutrient cycling, etc.). Part of the challenge is to define properties of the ecosystem that can be used as reference points to meet objectives in the formulation of management plans. Naturally, such definitions would not be restricted only to fish but would need to include other components of the fauna such as benthos, seabirds, and marine mammals. In addition, this would need to consider not only how fishing mortality affects individual species and their genetic make-up, but also how discarding and physical seabed disturbance affects the system.

The precautionary approach has been accepted as a guiding principle in fisheries management and reference points have already been set for commercial fish stocks. But we do not know whether conservation and sustainability of the ecosystem as a whole would be achieved if these reference points were met. What we do know is that, without question, fishing has changed the size composition of fish in some, possibly many, exploited systems, and in the North Sea in particular. Regardless of the trophic model considered, changing the size composition of predators in the ecosystem has very likely changed the way that predation pressure is distributed among lower trophic levels in the ecosystem. The uncertainty lies in the magnitude of the change and its consequences for the ecosystem.

WITHOUT QUESTION, FISHING HAS CHANGED THE SIZE COMPOSITION OF FISH IN SOME, POSSIBLY MANY, EXPLOITED SYSTEMS, AND IN THE NORTH SEA IN PARTICULAR

We also know that the cycling of nutrients within the system must also have changed, as the numbers and biomass in different trophic levels, as well as features of the benthos, have changed. Again, it is the magnitude and ecosystem consequences that are uncertain.

Regardless of the level of our present understanding, if fisheries management is to adopt a truly precautionary approach then changes that appear to be taking place in Northeast Atlantic marine ecosystems should be of serious concern.

3.3 Nutrients and eutrophication

As already noted, nutrients and light are essential for the growth of marine plants, including phytoplankton, which form the base of the food chain which leads up through fish to man. For all seas on

the western margin of Europe, the main source of nutrients is the North Atlantic. However, human activities contribute important additional sources of nutrients from:

- River runoff – including inputs from industry, municipal discharge, and agriculture;
- Direct inputs of municipal discharge and industrial waste;
- The atmosphere – emissions from agriculture, fuel combustion, including traffic; and
- Marine activities such as fish farming.

These sources lead to increased concentrations of nutrients in coastal waters and, in particular, partially enclosed sea areas. Excessive nutrient enrichment from human activities is termed eutrophication and can cause reduced water transparency, algal blooms (red tides, foam or green tides on beaches), fish and benthos kills owing to decreased amounts of oxygen in the bottom waters, bad smells (hydrogen sulphide), and changes in the communities and biodiversity of planktonic and bottom-living organisms.

The two most important nutrients that are needed for plant growth are nitrogen and phosphorus. Marine phytoplankton take up nitrogen and phosphorus in a ratio of about 16:1. Under normal conditions in the marine environment nitrogen is the limiting nutrient, but the recent major reductions in phosphorus inputs, due amongst other reasons to the introduction of phosphate-free detergents and municipal wastewater treatment, has led to a condition where phosphorus limitation of phytoplankton production now occurs in certain coastal areas. Nitrogen inputs, on the other hand, are much more difficult to control as there are many diffuse sources, including agriculture and fuel combustion.

This has led to an excess of nitrogen over phosphorus in the coastal waters of some European seas, which can result in an altered phytoplankton species composition and an enhanced growth of nuisance algae. Algal blooms that are toxic and detrimental to the environment or perceived as a nuisance, for example, by affecting tourism, are termed Harmful Algal Blooms (HABs).

NUTRIENT STATUS OF EUROPEAN SEAS

Budgets of nutrient inputs have not been produced for all European seas, but in the case of the North Sea more than 90% of both nitrogen and phosphorus are derived from inflows from the North Atlantic each year. In the semi-enclosed Baltic Sea, this source is less important and confined to sub-surface waters.

While the North Atlantic is the major source of nutrients for seas on the western margin of Europe, the highest concentrations of nutrients enter the sea via rivers. Nutrient concentrations in river water are often 50 times higher than those in Atlantic water, so exceptionally high concentrations of nutrients from man's activities are mainly found in coastal waters and semi-enclosed systems with limited water exchange.

Phosphorus inputs to the sea have decreased significantly in recent years, but inputs of nitrogen have not decreased to the same extent as the sources are more difficult to control.

Riverine discharges, as measured at the fresh/salt-water interface at the head of estuaries, contribute from 65% to 80% of the total nitrogen and 80% to 85% of the total phosphorus inputs from land-based sources to the North Sea, and 56% of total nitrogen to the Irish Sea.

For the Baltic Sea, riverine sources of nitrogen comprise 69% of total inputs, while riverine sources contribute 65% of the nitrogen input to the Black Sea. However, the seaward transport of nutrients from rivers through estuaries is strongly affected by processes such as denitrification, which releases nitrogen gas to the atmosphere, and the storage of phosphorus in sediments. Nutrients are also deposited into the sea from the atmosphere. In the North Sea, atmospheric sources as a proportion of the total inputs of nitrogen are considerable; they are as high as 23% in the Baltic and 31% in the Irish Sea.

Variations in total land-based nutrient inputs occur from year to year and closely reflect patterns of river runoff for nitrogen, with higher inputs in wet years. The inputs are also almost proportional to the amount of water discharged by the rivers, with, for example, 75% of the nitrogen that enters the coastal zone of the North Sea transported via the Rhine and Elbe, as the two largest sources. The five largest of the 200 rivers flowing into the Baltic Sea account for

50% of the total inputs. In the Black Sea, it is estimated that 70% of the riverine nutrient inputs derive from the Danube alone; this load comprises 50% from agriculture, 25% from industry, and the remainder from domestic sources.

Riverine runoff also has marked seasonality, and in the case of the Rhine and the Elbe, is highest in the winter and spring; variations in the timing of inputs from year to year are a major factor in the inter-annual variability of the composition and primary production of phytoplankton. In the Mediterranean Sea approximately 80 major rivers, the top four of which are the Nile, Rhone, Po and Ebro, contribute nutrient inputs, with very variable seasonality in their hydrological patterns depending on their geographical position around the basin. Concentrations of nutrients in Mediterranean rivers are generally at least four times lower than in equivalent rivers in northwest Europe, although there is evidence for an increasing trend in both nitrogen and phosphate concentrations.

Since the mid-1980's there has been a significant reduction (about 50% in the North Sea) in the total input of phosphorus from rivers to most European seas through improved sewage treatment, reduced industrial discharges, and a change to phosphate-free detergents. In the southern Baltic Sea, levels of phosphate have now stabilised at a lower level, while in the Black Sea phosphate is at lower levels previously seen in the 1960's. Although direct inputs of nutrients have also decreased, there has been no clear reduction in overall nitrogen inputs (in some seas, including the North Sea, agricultural sources have continued to increase) and atmospheric inputs of nitrogen have also remained static for the North Sea region, although they are reported to have decreased by 20% to 30% over the Baltic. Nitrogen levels in the Black Sea are four times higher than they were in the 1960's, although important reductions have occurred recently due to changes in the economies of former Soviet bloc countries.

EUTROPHICATION STATUS OF EUROPEAN SEAS

The OSPAR Commission is currently in the process of evaluating the eutrophication status of the whole of the Northeast Atlantic region. In the North Sea, eutrophication effects have been described from the Southern Bight, German Bight, Skagerrak, eastern Kattegat, areas on the French Channel coast, and in some estuaries of the UK. Some coastal embayments and estuaries are also affected in the Celtic Seas and along the Bay of Biscay and Iberian coasts.

In the recent assessment of the Baltic Sea by the Helsinki Commission, eutrophication symptoms were most evident in the brackish and nitrogen-limited southern Baltic; here water transparency has been halved and the extent of areas deficient in oxygen on the bottom has spread. There was no evidence of eutrophication in the phosphorus-deficient northern Baltic (Gulf of Bothnia), which has low productivity.

Open waters of the Mediterranean show no signs of eutrophication; effects are confined to nearshore areas and enclosed coastal bays, which are subject to inputs from rivers, increased urban and industrial discharges, as well as an expanding aquaculture industry in the eastern Mediterranean. The northern shores of the Mediterranean (particularly the Adriatic) are most seriously affected by eutrophication, although serious problems also exist on the southern shores of the sea where detailed information is lacking (Figure 3.3.1).

The Black Sea has been heavily impacted by eutrophication, with extensive loss of keystone species, mass mortality of fish and benthos, damage to habitats, pronounced changes to the composition of the phytoplankton, and major reductions in fish stocks. A major international recovery programme has been initiated to address these problems, entitled the Black Sea Ecosystem Recovery Project (BSERP).

IMPACTS OF EUTROPHICATION

Over the last fifty years there have been marked changes in the plankton populations of many European seas and increased production in some areas. While exact causes often cannot be established with certainty, many have been attributed to eutrophication. For example, plankton biomass increased fourfold between 1962 and 1985 in the German Bight at Helgoland and was initially considered as a response to eutrophication.

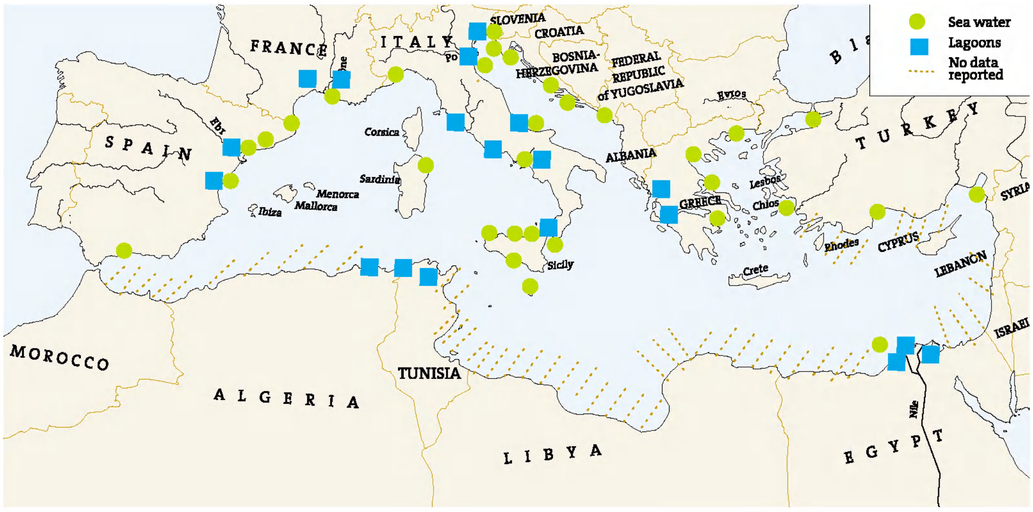


Figure 3.3.1. Mediterranean areas where eutrophication phenomena were reported. (Source: EEA. Environmental assessment series No. 5)

However, as additional years of information have accumulated, it is clear that much of the variability can be attributed to hydrographic change and variations in the flow of the adjacent River Elbe.

Distinguishing between the relative contributions of natural versus human sources of nutrients is a priority issue for research in Europe at this time.

Running low on oxygen?

Low concentrations of oxygen may occur in areas with a high load of nutrients and a limited water exchange. Increased nutrient concentrations lead to increased production of phytoplankton. When phytoplankton dies, it sinks and decomposes using up oxygen in the process.

If phytoplankton decomposes in a spatially restricted water body with little circulation, it will lead to the depletion of oxygen in the bottom water and possibly to the complete loss of oxygen (anoxia), resulting in the death of animals living near and in the seabed.

Parts of the Baltic Sea have naturally occurring oxygen depletion due to irregular inflows of more saline oxygenated water to the deep parts. The extent and frequency of these low oxygen events have increased due to human impact, primarily from the agricultural use of natural and mineral fertilizers as well as reduced inflow from the North Sea.

Several coastal areas of Europe have frequent oxygen depletions, and even large marine areas like the Kattegat and parts of the North Sea have been affected during the last two decades, resulting in the deaths of benthic invertebrates and fish.

3.4 Harmful algal blooms

Many species of phytoplankton are known to form mass concentrations, known as blooms.
Most of these events are entirely natural, generally representing the same natural process as the grass, plants, and flowers growing on land. However, a number of these planktonic species are known to produce potent toxins that can lead to poisoning of humans (who eat shellfish that have concentrated the biotoxins), as well as mortality of marine mammals, seabirds, and other animals, mass mortality of wild and farmed fish, and detrimental changes to the community structure of marine ecosystems. These events, which can have huge eco-

nomic consequences, are collectively termed "Harmful Algal Blooms" (HABs). The occurrence of such toxic events is not usually linked to direct nutrient enrichment or eutrophication, and sediment studies have shown that such blooms have occurred long before any significant man-made inputs of nutrients.

MANY SPECIES OF PHYTOPLANKTON ARE KNOWN TO FORM MASS CONCENTRATIONS, KNOWN AS BLOOMS. MOST OF THESE EVENTS ARE ENTIRELY NATURAL, GENERALLY REPRESENTING THE SAME NATURAL PROCESS AS THE GRASS, PLANTS, AND FLOWERS GROWING ON LAND

Nuisance plankton blooms (mass development of plankton) are of public concern, particularly during the summer holiday season and in recreational areas. Swimming in water where there is a bloom can cause skin irritations and there are known cases where pets or cattle were poisoned by drinking such water.

When toxic algae are ingested by filter-feeding species such as mussels and oysters they concentrate the algal toxins in their tissues to levels that can cause illness or be potentially lethal to humans. There are four types of shellfish poisoning known in European waters and they are classified according to their effect on human health:

Paralytic shellfish poisoning (PSP):
can be fatal, symptoms include tingling and numbness of the lips and fingertips. In severe cases causes respiratory paralysis.
Diarrhetic shellfish poisoning (DSP):
not fatal, causes gastrointestinal disorders.
Neurotoxic shellfish poisoning (NSP):
not fatal, symptoms include tingling and/or numbness of the lips, tongue, throat, hands and feet.
Amnesic shellfish poisoning (ASP):
causes decreased reaction to pain and short-term memory loss.

The first three are caused by biotoxins synthesised by species in the algal group dinoflagellates and the last by a diatom. A second category is made up of algae that release toxins and other compounds into the water or kill through side effects from damaged gills. Such effects can impact all compartments of marine ecosystems, but they have particular economic impacts on fish farming. A third category includes effects from the breakdown and decay of mass blooms or mass concentrations of seaweeds on beaches. These events can also be caused by non-toxic species and can lead to low oxygen conditions, foam on beaches, or smelly and unpleasant concentrations of algae on beaches that have an impact on tourism.

Monitoring of phytoplankton populations and of shellfish and fish along coasts is aimed at providing an early warning of potential problems and banning the harvesting of shellfish in areas affected by toxic algae. Ongoing research programmes aim at a better understanding of the population dynamics of the species concerned in order to establish predictive models. These models will be used for better management of shellfisheries in relation to toxic events.

HARMFUL ALGAL BLOOMS HAVE BEEN RECORDED INCREASINGLY ALONG THE COASTS OF EUROPE

HARMFUL ALGAL BLOOM EVENTS IN EUROPEAN SEAS

Harmful algal blooms (HABs) have been recorded increasingly along the coasts of Europe (Figure 3.4.1). It is not clear whether this is a real trend or it represents an increasing recognition of the problem and improved documentation. In the seas of northwest Europe, more than twenty algal species are known to produce toxins and there have been a great number of reports of blooms or toxic events caused by these algae. The pattern of occurrence of these events appears to be irregular, however, and to link with exceptional meteorological and hydrographic events.

In the North Sea, there has been no increasing trend in the occurrence of blooms over the past decade. The Skagerrak and adjacent coastal waters under the influence of the brackish Baltic outflow are particularly subject to HABs that have caused mass mortality in fish farms, such as the very extensive 1988 *Chrysochromulina* bloom.

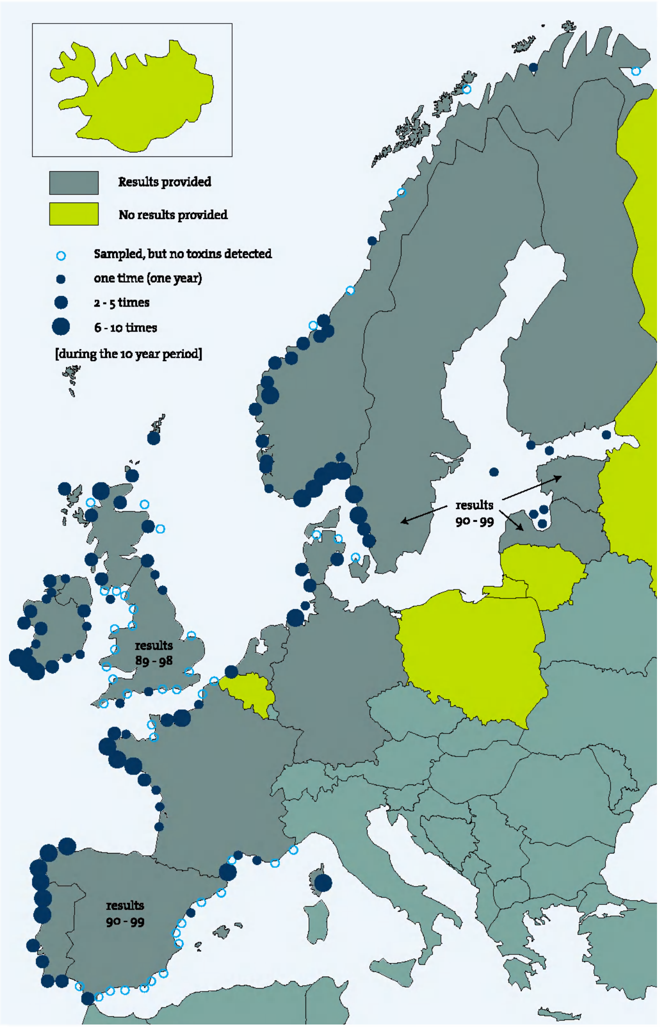


Figure 3.4.1. The occurrence and frequency of DSP poisoning events, 1991–2000. (Source: IFREMER).

In the coastal waters of The Netherlands and Belgium, blooms of the mucus-forming alga *Phaeocystis* have at times caused extensive nuisance banks of foam on beaches. Recurrent events of shellfish poisoning and algal blooms occur in the estuaries and rias on the west coast of France and Iberia, impacting on mariculture. In most areas of the Baltic, dense summer blooms of blue-green algae (cyanobacteria) occur on an annual basis.

There are several different species of blue-green algae, some of which produce toxins and most of which can cause skin and respiratory symptoms. Frequent algal blooms that are at times toxic, and mass development of seaweeds, have occurred in nearshore coastal areas.

The Black Sea has been heavily impacted by algal blooms and especially by an increase in the abundance of dinoflagellates. Algal blooms have been reported from a wide range of coastal locations around the Mediterranean and other events including toxic shellfish poisoning have been recorded from Spain, France, Italy, and Turkey. Proliferations of green algae, such as sea lettuce, in the spring are a major problem in some coastal regions such as the Venice Lagoon. These blooms lead to reduced levels of oxygen in bottom waters and bad smells; they also prevent the growth of other phytoplankton by limiting the light.

3.5 Contaminants and their effects

Contaminants are chemical substances that are detected in locations where they should not normally be found and can be either natural or man-made. Contaminants in the marine environment fall into four main groups:

- Trace metals: metals such as cadmium and mercury, which are generated in metallurgic industries such as the manufacture of batteries, and copper, which is widely used as an anti-foulant;
- Organic compounds: including pesticides and herbicides that occur in agricultural runoff;
- Oil: from energy extraction and marine transport;
- Radioactive elements: radioactive caesium is released from nuclear reprocessing operations.

Most types of contaminants have more than one source, and their relative importance will vary with location. The effects of contaminants on marine organisms (animals and plants) vary depending upon their behaviour and fate following release to the environment. Following release, substances can remain in the water (either in solution or attached to small particles), or be deposited in sediments, or be taken up by organisms. Some substances, depending on their physical properties, can also be transported long distances from their sources by ocean currents and through the atmosphere. Transport through the atmosphere is a particularly important mechanism in transferring certain persistent organic compounds from their sources in temperate latitudes (e.g., the USA and Europe) to the Arctic regions. The uptake of substances by organisms (their bioavailability) is an important feature in determining their effects.

There are many chemicals in common use. Around 100,000 chemicals are marketed in the European Union, and the chemicals industry markets 200 to 300 new chemicals each year. Although these are tested in some respects before they are introduced, it is impossible to carry out tests to give complete information on the likely environmental impact of so many chemicals. For this reason, a more precautionary approach has been recommended, to which North Sea countries agreed at the 4th North Sea Conference in 1995.

Compounds which remain in the environment for a long time (are persistent) and which accumulate within living tissues have the greatest opportunity to affect marine organisms, and so are of most concern. An example of this type of compound is PCBs (polychlorinated biphenyls). A number of the persistent organic compounds that have been produced in the past (including PCBs) are no longer produced and the use of others is severely restricted. However, because of the scale of use in the past and their persistent nature, these compounds can still be present at concentrations that can affect marine life.

INPUT OF CONTAMINANTS

The input of contaminants to marine areas follows three main routes: directly into the sea, via rivers, or via the atmosphere. The relative importance of these routes is different for different substances, and for different areas. In the oceans, far from sources on land, inputs from the atmosphere are the most important.

Direct inputs include discharges from sewage treatment works and industrial plants on the coast, and from offshore activities, release of oil, oil residues and chemical residues from shipping, and the disposal of dredged spoils removed in order to maintain access to ports and harbours. Following the European Union's Urban Waste Water Treatment Directive, improvements in sewage treatment are leading to reduced discharges from EU countries. National regulatory activities and more modern industrial processes have generally led to reduced inputs from this source also. In the offshore oil and gas industry, discharges of oil with drill cuttings have effectively ceased, and most oil is now discharged with produced water. As the fields in the North Sea grow older, the quantities of produced water increase. These matters are discussed in more detail below.

Antifoulants are used to prevent the growth of marine plants and animals on the hulls of ships, as this growth slows the vessels down and increases their use of fuel.
Drill cuttings are the fragments of rock removed when a well is being drilled, in association with the fluid circulating within the drilling system that aids removal of the cuttings from the hole and can be used to lubricate the drill itself.
Produced water is water from the underground formation that rises to the surface with the oil. This is cleaned on board the production platform and then either discharged overboard or returned to the formation (re-injected).
Chlor-alkali plants produce caustic soda and chlorine gas by the electrolysis of sodium chloride brine.
Dioxins are by-products of industrial processes and low-temperature incineration (particularly of plastics).

River inputs include runoff from land and discharges (e.g., from industries and sewage treatment plants) into the rivers and their tributaries. The size of these inputs can be difficult to estimate accurately, for two main reasons: firstly, the estimates are very dependent on river flow and this can change rapidly during rainy periods; secondly, processes occurring within estuaries can significantly alter the concentrations of substances which actually enter the sea.

TRACE METALS

Trace metals occur naturally in the earth's crust, from which they can be released by weathering processes. Their presence in the environment does not, therefore, automatically indicate pollution. However, human activities have effectively increased the rate of weathering, and thus the rate at which metals are released into the environment. Whilst many metals (such as copper and zinc) are essential to growth, and organisms are able to adapt to changing concentrations, at higher concentrations they may cause toxicity. Also other metals, such as cadmium, mercury, and lead, have no known vital function, and can cause effects when they accumulate in organisms, including humans.

TRACE METALS IN THE NORTHEAST ATLANTIC AND THE BALTIC SEA

There has been a general reduction in direct and riverine inputs of a number of contaminants in the Northeast Atlantic and the Baltic Sea over the past decade, mostly as a result of tighter controls on point source inputs such as industrial discharges. As a specific example, mercury inputs from two chlor-alkali plants in Portugal decreased from 284 kg to 45 kg per year between 1991 and 1996. Similar reductions were made in earlier years at chlor-alkali plants in northwest England, for example, and have led to significant (though slow) reductions in concentrations of mercury in fish in inshore areas of the Irish Sea (Figure 3.5.1). Even after some activities have ceased, however, there may be a legacy of contamination in their local areas, for example, lead inputs from historic mining activities in the Celtic Sea area.

THERE HAS BEEN A GENERAL REDUCTION IN DIRECT AND RIVERINE INPUTS OF A NUMBER OF CONTAMINANTS IN THE NORTHEAST ATLANTIC AND THE BALTIC SEA OVER THE PAST DECADE

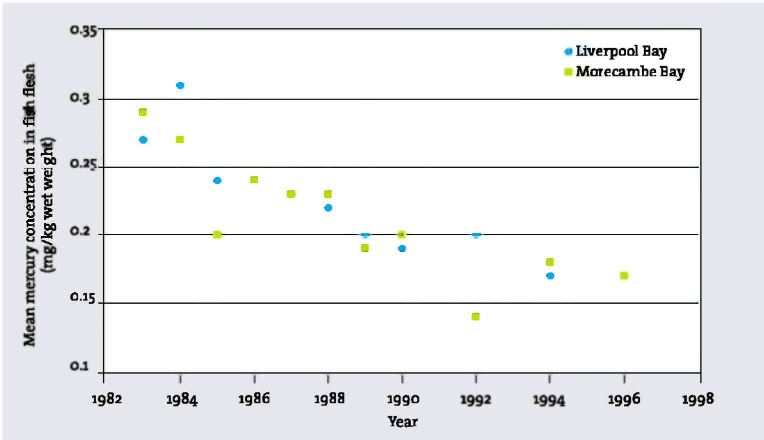


Figure 3.5.1. Time-series of average concentrations of mercury in fish flesh from Liverpool and Morecambe Bay (mg/kg wet weight). (Source: Matthiessen and Law, 2002. In Environmental Pollution)

Atmospheric inputs of lead to the North Sea have decreased by up to 65% from 1987 to 1995, primarily due to the removal of alkyl-lead anti-knock additives from petrol (Figure 3.5.2). Changes in the pattern of use of chemicals are also seen for other industries. Antifoulants based on TBT (tributyltin) were banned from use on small boats in the late 1980's when it was discovered that this compound had serious effects on the growth and survival of shellfish in estuaries and enclosed bays (see section on Organotin compounds, below). The return to the use of copper-based alternatives has resulted in increased inputs of copper, and the possible effects of this are currently being studied.

In general, trace metal concentrations in sediments in estuaries are higher than those from coastal and offshore areas, but differences in geology mean that the normal background levels vary from location to location. Data on concentrations of copper, cadmium, mercury, and lead in sediments in a number of areas in the Northeast Atlantic are shown in Figure 3.5.3.

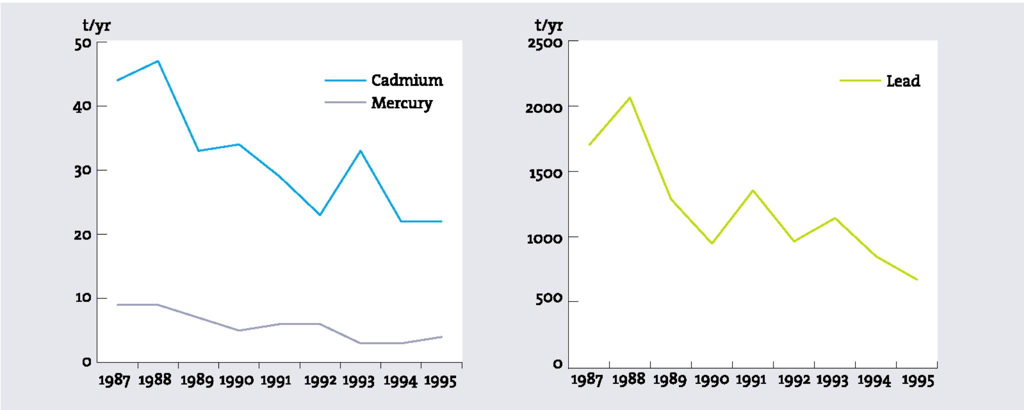
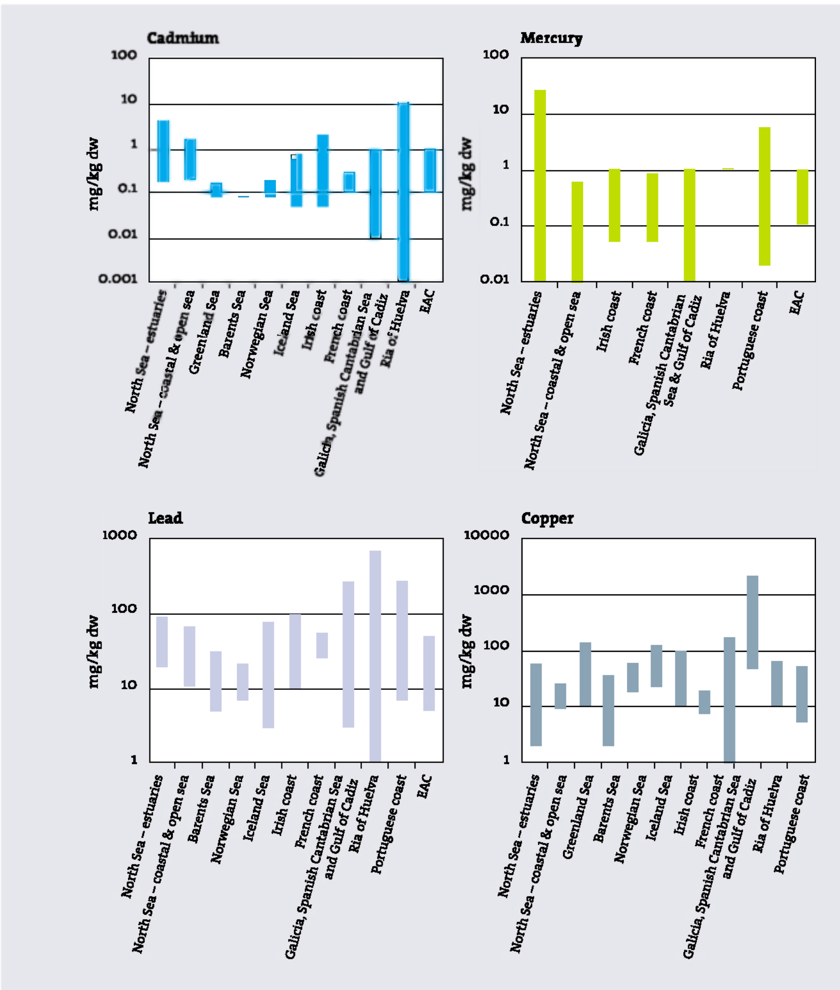


Figure 3.5.2. Atmospheric inputs of cadmium, mercury, and lead in the North Sea. (Source: OSPAR, QSR 2000).



In many areas there was a wide range in concentrations, as shown by the length of the bars, and the agreed OSPAR guideline ranges (termed Ecotoxicological Assessment Criteria or EACs) for these metals were all exceeded at some locations. The highest concentrations were found close to particular activities or industries, both contemporary and historical. Examples include dredged spoil disposal areas (e.g., for lead in the Rotterdam Harbour area), mercury from the chlor-alkali industry (e.g., Pontevedra ria in Spain, Aviero and Lisbon in Portugal), and cadmium from phosphoric acid manufacture (now ceased) in the northeastern Irish Sea. Decreasing trends over time have been reported: for mercury at disused disposal sites in the German Bight and off the coast of Belgium, for cadmium in the Dutch coastal zone and the Scheldt estuary, and for copper during the period 1981 to 1996 in the vicinity of the Rhine/Meuse estuary mouth, along the Belgian coast, and in the Wadden Sea. Discharges of these trace metals from various types of industrial sources have been reduced as a result of regulations by OSPAR countries over a number of years, based on OSPAR recommendations.

Figure 3.5.3. Concentrations of cadmium, mercury, lead, and copper in sediments from various locations in the Northeast Atlantic (EAC = OSPAR Ecotoxicological Assessment Criteria). (Source: OSPAR, QSR 2000).

Mussels – silent watchdogs

Mussels are widely used as indicator organisms for the comparison of contaminant concentrations because they are widespread, remain in one place once the young have settled, and readily take up a wide range of contaminants. The way in which the contaminants are taken up by these animals is also well understood.

The highest trace metal concentrations in mussels are closely related to their sources and inputs (often industrial), with high cadmium and lead concentrations near metal smelters in Norwegian fjords, and mercury close to chlor-alkali plants. Time trends are downwards in a number of areas: for cadmium in mussels from The Netherlands, Norway, and France; for lead in mussels from Germany, Norway, Spain, and on the Dogger Bank (central North Sea); for copper in mussels from Denmark, Germany, The Netherlands, Norway, and Spain. In contrast, copper concentrations in oysters from the Bay of Arcachon in France (a major shellfish-growing area) have doubled over the last 10 years, apparently because of the increased use of copper-based antifoulants following the ban on those containing TBT.

Concentrations of trace metals in the Baltic marine environment are generally stable or decreasing, although they still create local problems around significant past and present sources. On the other hand, cadmium concentrations in herring and other organisms in the central Baltic and the southern Gulf of Bothnia are increasing, for unknown reasons.

The presence of trace metals does not appear to be a major problem in the Mediterranean Sea, although mercury concentrations in organisms from the

TRANSPORT IN THE AIR IS THE MOST IMPORTANT PATHWAY BY WHICH MERCURY REACHES THE ARCTIC AND, ONCE THERE, IT IS TAKEN UP BY ORGANISMS

Mediterranean are generally higher than in organisms from the North Atlantic owing to the higher content of mercury in the geological base. The contribution from industry is small compared with the Northeast Atlantic; other man-made sources of heavy metals include agriculture and urban pollution.

Mercury pollution is an increasing concern in the Arctic. Although the reduced emissions of this metal in Europe and North America have been followed by reductions in environmental concentrations in those areas, the high levels observed in the Arctic are not falling. This may be because these reductions have been offset by increased emissions in Asia, where coal is burnt to provide electricity and heat. Mercury can occur as a vapour, and around 5,000 t are present in the world's atmosphere at any one time.

Transport in the air is the most important pathway by which mercury reaches the Arctic and, once there, it is taken up by organisms. Study of teeth from beluga whales from the Beaufort Sea has shown that mercury concentrations have increased substantially between the 16th century and the present day (Figure 3.5.4). Mercury from industrial sources is responsible for over 80% of the total mercury in this species of whale. Concentrations in soft tissues of some animals, particularly those at the top of Arctic food chains like seals and whales, are high enough to give concern for possible toxicity. This also includes humans, due to the fact that marine mammals are an important component of the traditional diet of indigenous people.

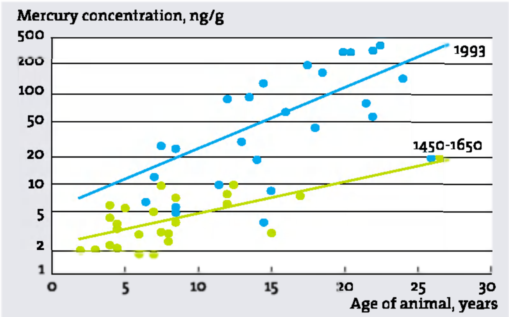


Figure 3.5.4. The teeth of Beaufort Sea beluga, harvested in the Mackenzie Delta in 1993 as part of the traditional Inuit hunt, contained significantly higher concentrations of mercury than archaeological samples dated 1450–1650 AD. (Source: AMAP, Arctic Pollution 2002).

In contrast, lead concentrations in the Arctic atmosphere have declined substantially since the introduction of unleaded petrol from the 1970's onwards. Levels in Arctic animals, as a consequence, are either stable or declining.

ORGANIC CONTAMINANTS

As consumers, we use a wide range of commercial products in our everyday lives. Following use, many will be released to the environment either directly, via disposal and landfill sites for rubbish, or through drains and sewage treatment works. Pesticides, for instance, are often introduced directly into the environment by spraying crops, and are subsequently transported by rivers and through the atmosphere to the sea. Incineration can generate dioxins, and all combustion processes (including power generation and vehicle traffic) produce polycyclic aromatic hydrocarbons (PAHs).

TBT IS ONE OF THE CLASSES OF COMPOUNDS KNOWN AS ENDOCRINE DISRUPTERS ("GENDER-BENDING" CHEMICALS), WHICH INTERFERE WITH THE HORMONE SYSTEMS OF ANIMALS

Many of these compounds will be broken down either during this transport or following their entry into the sea, and many are designed in such a way that this happens, but compounds which are persistent (not easily destroyed) may be found over large areas and can be taken up by organisms. There is, therefore, a long list of chemicals of concern in the marine environment. This situation is further complicated by the fact that, being industrial products, many are not pure single compounds but mixtures of (in some cases, hundreds or even thousands of) similar compounds. This makes their detection and the measurement of their concentrations, which are generally low but not necessarily harmless, very difficult.

In the following section, the impacts of three groups of compounds will be discussed:

- Organotin compounds;
- Organochlorines, in particular PCBs (polychlorinated biphenyls);
- Other persistent organic pollutants; and
- PAHs (polycyclic aromatic hydrocarbons).

ORGANOTIN COMPOUNDS

Although antifoulants based on tributyltin (TBT) have been banned from use on small vessels (less than 25 m overall length) for ten years, their widespread earlier use has left many areas contaminated. TBT is one of the most toxic compounds ever to have been deliberately introduced into the environment, and exhibits serious effects on shellfish at concentrations that are so low that they are very difficult to measure. As well as tributyltin itself, its breakdown products, dibutyltin and monobutyltin, are also found in the environment, although they are less toxic than the parent TBT compound. The highest concentrations are found in sediments from harbours, marinas and shipping channels, because TBT is broken down only very slowly in sediments with low oxygen content, as is often the case in muddy areas inshore. Its use on large vessels is currently the major source of input to the sea.

TBT is one of the classes of compounds known as endocrine disrupters ("gender-bending" chemicals), which interfere with the hormone systems of animals. In many species of marine snails (for example, whelks and dogwhelks) this causes sexual abnormalities, and females begin to develop a penis or other male genital features. This results from increased levels of the male hormone testosterone in the females' tissues, owing to altered steroid metabolism caused by TBT. In severe cases, the oviduct becomes blocked and this prevents the laying of eggs, which reduces the reproductive ability of some populations, so that dogwhelks have disappeared from areas badly contaminated with TBT. Since the ban on TBT on small boats, the occurrence of these sexual abnormalities in wild populations has decreased, but imposex (as the condition is known) is still widely used as a very sensitive indicator of the presence of low-level TBT contamination. Following international agreement, the use of TBT-based antifoulants on large ships is also to be phased out during 2003–2008.

ENDOCRINE-DISRUPTING CHEMICALS

In addition to the masculinisation of female marine snails caused by TBT, other forms of endocrine disruption have been receiving increasing recognition as a problem in the marine environment, and studies have been undertaken in a number of countries. Oestrogenic effects on fish due to the presence of natural and synthetic hormones, as well as some industrial chemicals, such as alkylphenols, that have been found to have similar, but unintended, effects, can be seen in many estuaries and even some offshore areas. The potential for effects on reproduction and at the population, rather than the individual, level has not been assessed yet. In comparison, androgenic effects—due to male hormones or their mimics—appear to be weak or non-existent. Other types of endocrine disruption include disruption of thyroid function and altered immune function in marine mammals and fish. Studies have shown that most of the endocrine-disrupting chemicals in the environment are unknown or unidentified, but their effects can be seen at very low environmental concentrations.

Oestrogenic hormones are naturally produced by women and regulate their reproductive cycles. A synthetic version is the active ingredient in the contraceptive pill. **Mimics** are compounds that can exert the same effects as natural hormones due to structural similarity, although usually much higher concentrations are required in order to produce the same level of effect.

ORGANOCHLORINES – POLYCHLORINATED BIPHENYLS (PCB'S)
PCBs are one class of compounds known as POPs (persistent organic pollutants) that are of significant concern in the environment. PCBs were initially manufactured during the 1930's, and were used in a variety of products until manufacture ceased about 1976. These compounds found widespread use because they were resistant to degradation, which also made them very persistent and unlikely to break down quickly when released to the environment. Their properties also make it possible for them to be transported long distances in the atmosphere so that, although they were mostly produced and used in the mid-latitudes (mainly in Europe, North America, and Japan), there is now concern over rising concentrations in animals from the Arctic, where they have never been used in any quantity.

PCB levels in marine mammals are particularly high as they have large blubber deposits in which these compounds accumulate.

The historical record of production, use, and release of PCBs can be seen in the sediments. Figure 3.5.5 shows the concentrations of PCBs over time in a sediment core from northwest England taken in 1992. This shows that PCB contamination first appeared in the late 1940's, and that its level increased rapidly though the 1960's to a peak in the 1970's, and has declined steadily since then. The fact that the concentrations have taken so long to decline reflects the resistance to breakdown of PCB compounds, and the fact that there are probably still some inputs as a result of leaching from landfill sites and leaking from old equipment, buildings, or other sources.

PCBs have very low water solubility, so concentrations in seawater are very low and difficult to measure. PCB concentrations in sediments are higher close to sources, so the highest concentrations are usually found in contaminated estuaries, with lower concentrations in coastal and offshore locations.

Many marine animals readily take up PCBs and their concentrations are highest in animals at the top of the food chain (i.e., top predators). They are particularly high in marine mammals, which have large blubber deposits in which these compounds accumulate.

IMPACTS OF PCB'S

High concentrations of PCBs in blubber have been linked with infertility in seals from the Wadden Sea and the Baltic Sea, and sterility in Baltic seals in the 1970's. This probably coincided with the peak inputs to the environment, which can be seen from Figure 3.5.5. The occurrence of these reproductive abnormalities has declined in subsequent years, although seals in the Baltic still experience reproductive problems.

HIGH CONCENTRATIONS OF PCBS IN BLUBBER HAVE BEEN LINKED WITH INFERTILITY IN SEALS FROM THE WADDEN SEA AND THE BALTIC SEA, AND STERILITY IN BALTIC SEALS IN THE 1970'S

PCBs also have more subtle effects, including endocrine disruption and immunosuppression. In the UK, recent data from the Marine Mammals Strandings Programme have suggested that animals with higher PCB concentrations in their blubber are more likely to die of infectious diseases than those with lower concentrations. Whilst this does not prove immunosuppression, it does provide supporting evidence for the suggestion that subtle impacts may still be occurring as a result of PCB releases to the environment, twenty-five years after their production and use in new applications ceased. Seals in the Baltic Sea are also suffering from illnesses, including severe intestinal ulcers, that appear to be related to immunosuppression. The PCB concentrations in seals from the Arctic are lower than those in Baltic seals.

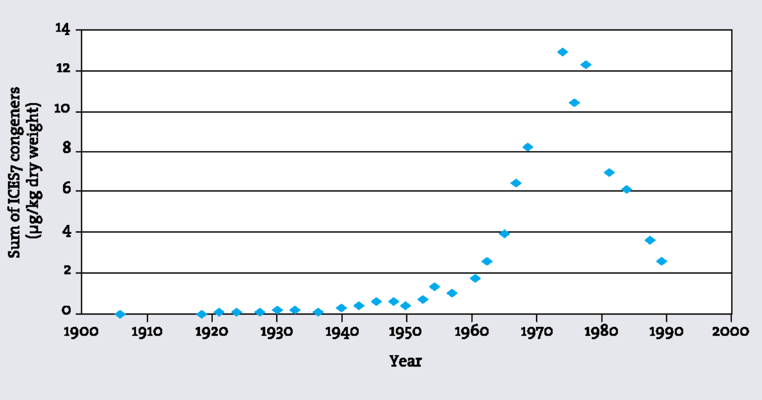


Figure 3.5.5. PCB concentrations in a dated saltmarsh core from Banks Marsh, Northwest England (µg/kg dry weight). (Source: Matthiessen and Law, 2002. In Environmental Pollution).

Immune system: an animal's immune system protects it from infection.
Immunosuppression means reducing the effectiveness of the immune system.

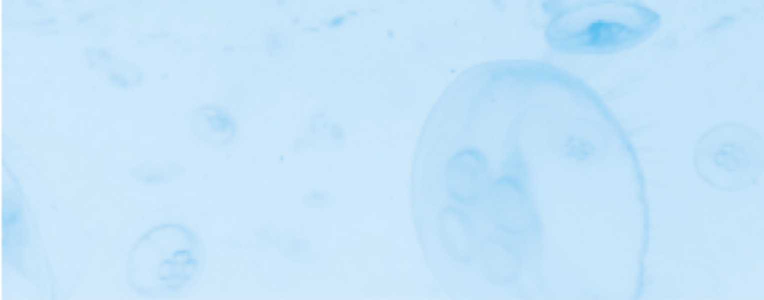
Seabirds have also been found with high levels of PCBs in their tissues. A particular case is seen in glaucous gulls on Bear Island, off the north coast of Norway, a "hotspot" of PCBs. High PCB levels in glaucous gulls from this island have been correlated with hormone effects in the glaucous gull population that affect the ability of the birds to reproduce successfully, as well as a higher proportion of non-viable eggs and a decreased survival of adult birds.

Although PCB concentrations have declined close to their historic sources, high concentrations are now being seen in the Arctic environment due to global atmospheric transport. On Svalbard, polar bears with high levels of PCBs have impaired defence against infection, and the survival of their cubs may also be reduced. This highlights the fact that declines in the concentrations of many POPs will occur later in the Arctic than in the temperate areas in which they were released.

PCBs are also of concern with regard to human health. The World Health Organization (WHO) has established permitted weekly intake levels of dioxins and compounds that have dioxin-like toxicity. In some EU countries, maximum weekly intakes from the diet for example from fatty foods, exceed the WHO guideline values.

OTHER PERSISTENT ORGANIC POLLUTANTS

Organochlorine pesticides such as DDT are linked with PCBs in their historic patterns, as they rose to their peak concentrations and controls on manufacture were implemented at a similar time. The effects of DDT on eggshell thinning and reducing the populations of birds of prey in the terrestrial environment are well known; these contaminants also caused problems in marine birds, but the effects are now abating as concentrations of DDT and its metabolites fall. The populations of white-tailed sea eagles in the Baltic area have increased, and



reproductive success is almost back to that seen during the 1940's. In common guillemots in the Baltic, eggshells were much thinner in the 1960's due to DDT pollution, but they began to increase in thickness in the mid-1970's and have now also returned to the thickness seen in the 1940's. Pollution by DDT deriving from Rhine discharges also led to population crashes in several species of birds nesting in the Wadden Sea in the 1960's and 1970's.

In addition to DDT, a number of organochlorine pesticides have been used in the past, including aldrin, chlordane, dieldrin, endrin, heptachlor, mirex, and toxaphene. The use of most of them has been banned, or will soon be banned, in most European countries, but owing to their persistence, they are likely to be found in the marine environment for a long time. Recent studies have shown high concentrations of toxaphene in the blubber of narwhal and walrus from northern and eastern Greenland, respectively. Chlorinated naphthalenes (PCNs) are chemicals similar to PCBs and have many similar industrial applications. Although their use has declined in the past few decades, few countries have actually prohibited their use. Some PCNs have toxic properties similar to those of the chlorinated dioxins, furans, and dioxin-like PCBs, and they should be taken into account when determining safe limits in seafood.

The use of brominated flame retardants has increased dramatically in the past decade, particularly in the industrial regions of the northern hemisphere. Although some of these brominated compounds, mainly certain polybrominated diphenylethers (PBDEs), are now being phased out in Europe, experience suggests that increasing concentrations in the Arctic environment will result in the future. Recent data show that peregrine falcons in northern Norway and Sweden and several other birds of prey in northern Norway are already contaminated with brominated flame retardants.

Some POPs are produced as unintentional by-products in industrial processes; these include dioxins and furans. Important sources include waste incineration without efficient temperature control, wood-burning stoves, and metallurgical industries. A UNEP review of global inventories for dioxin and furan emissions indicated that the United States and Japan are the most important global source regions. Given the atmospheric transport of these contaminants, it is likely that they will be deposited as far north as the Arctic.

The chemical contaminants mentioned here are those that have been studied in the marine environment and represent only a small fraction of those actually present. There are an increasing number of other man-made chemicals that are being detected, for which the ecological effects are unknown. Furthermore, there is little information on chronic and combined effects of contaminants, as well as about the ecological impacts of substances that affect the hormone system.

AN INCREASING NUMBER OF OTHER MAN-MADE CHEMICALS ARE BEING DETECTED, FOR WHICH THE ECOLOGICAL EFFECTS ARE UNKNOWN

Polycyclic aromatic hydrocarbons (PAH's)

PAHs are naturally produced compounds, formed, for instance, in forest fires and volcanoes. The natural input of these compounds is now a minor source though, and the major inputs are from man's activities, particularly combustion processes such as the burning of fossil fuels for heat and power. They are also found in crude and most refined oils, so oil spills are another source of these compounds, as well as produced water from offshore oil installations.

Impacts of PAH's

There are many thousands of individual PAH compounds, and they are of concern for two reasons. The smaller and more water-soluble of the PAH compounds are directly toxic to marine animals, whilst some of the larger compounds can become potent carcinogens (compounds which can initiate cancers) after ingestion both in fish and humans. As an example, PAHs include the same compounds that are present in cigarette smoke and cause cancer. PAHs may also affect reproduction in fish and other aquatic organisms.

PAHs enter the sea both from rivers and from the atmosphere, as many of the initial discharges (e.g., those from power station and factory chimneys) are made to the air. Like PCBs, most PAHs do not have a high water solubility and tend to accumulate in sediments. Again as for PCBs, higher concentrations are found in sediments from contaminated and industrialised estuaries than at coastal and offshore sites, for example, in the estuaries of the Seine, Humber, and Scheldt. High concentrations of PAHs in shellfish can result from both chronic industrial contamination and following major oil spills, like that from the "Sea Empress" tanker in Wales in 1996. Fishery closures are often implemented to protect human consumers from PAH intake and are underpinned by substantial monitoring programmes.

Recent studies have also shown that the direct toxic effects of PAHs are increased in the presence of ultraviolet light, causing concern for animals that live in the very top layer of the water column, such as the larvae of some fish species. These studies are continuing in order that the scale of the problem can be assessed.

RADIOACTIVITY

Radioactivity results both from natural sources and man's activities. Natural radiation comes from the decay of radioactive elements in the earth's crust, and from the action of cosmic rays entering the earth's atmosphere from space. Man-made inputs fall into three categories:

- Historic: from the testing of nuclear weapons;
- Accidents: the Chernobyl power station meltdown; and
- Industrial processes: for example, nuclear reprocessing and the production of phosphate fertilisers, which releases the natural radioactive elements in the rock used as a raw material.

All industrial discharges of radioactive substances are subject to authorisation and monitoring. Distinctions between radioactivity resulting from these three different categories are usually made on the basis of the mix of radioactive elements found in each case, and the radiation doses received by individuals both working in these industries and in the general population are well within internationally agreed limits.

3.6 Oil and gas industry

In terms of inputs to marine waters, the main sources are the offshore oil and gas industry in the North Sea, although oil and gas production occurs in several other areas (e.g., northern Norway, north coast of Spain) to a much smaller extent. In addition, there is considerable oil production in some countries bordering the Mediterranean Sea, but this occurs both on land and offshore. Refineries are distributed all around the Mediterranean coasts, often in association with petrochemical plants, and these will have discharges to sea. Shipping traffic, carrying both crude oil and its refined products, travels through all the seas of the North Atlantic and adjacent seas except for the high Arctic. During the past few decades spillages of crude oil have declined in both frequency and total volume, but those involving fuel oils have increased (see Shipping and Transport, below).

IMPACTS OF OIL AND GAS EXTRACTION

The impacts of offshore oil and gas exploration and production have been studied most within the North Sea, and especially in UK and Norwegian waters where most platforms are located. Drilling fluids are used when wells are being drilled, both to lubricate the drill itself and to carry the rock chippings removed by the drill bit to the surface. Historically, these fluids have been discharged directly from the platforms after some treatment; where tidal currents are slow, this has led to the formation of large cuttings piles below platforms.

These cuttings contain contaminants and, especially where oil-based fluids have been used, are potentially toxic to marine life. While the fields have been in operation, this has caused only localised disturbances close to the platforms, as shown by changes in benthos communities. However, many fields are now reaching the end of their productive life and most platforms will be removed once production ceases. Studies are now under way which will advise on the best way to treat the cuttings piles, whether to remove them or to leave them in place.

During the production phase, the major discharge is of produced water. This is water which has lain in the underground formation with the oil, and which comes to the surface when oil is produced. The volume of water produced and discharged increases with the age of the field, as the interface between water and oil rises closer to the well pipe. This water contains a number of substances of concern. The first of these is dissolved oil, and treatment facilities on-board the platforms reduce oil concentrations to below a defined limit (40 parts per million) before the water is discharged. A number of other organic chemicals are present in the formation and are discharged with the produced water, including organic acids, alkylphenols, PAHs, and water-soluble organic compounds. The alkylphenols are of concern because they belong to a class of chemicals known as endocrine disrupters (see earlier section on Organanotin Compounds).

Laboratory experiments in Norway have shown that alkylphenols can have endocrine-disrupting effects when fed to cod, but studies conducted around platforms have so far not shown such effects in the wild. Although the concentrations of these naturally produced compounds are quite high in produced water at the discharge point, there is considerable dilution of the discharged water in the sea immediately following its release, and ultimately the compounds will be degraded.
The third category is production chemicals, which are added to both the formation water and the oil stream on the platform to aid the production and separation process. Depending on their properties, these chemicals may then be carried by either the oil or the produced water. The use of chemicals is strictly controlled, and there is a continuous movement towards less toxic alternatives within the control scheme. The chemicals that may have endocrine-disrupting effects (such as other alkylphenol compounds used in the past) have been identified and removed from use.

3.7 Shipping and transport

The European seas are crisscrossed by some of the busiest shipping routes in the world – a good example being the Dover Strait through which more than 400 ships pass every day. In other areas such as the Baltic or further south, the Mediterranean, over 2,000 sizeable ships are normally at sea every day. Whilst they are an essential part of life, shipping activities have a number of impacts on the marine environment. These can range from impacts on the coastal zone—resulting from the development and daily activities of large-scale port facilities—to the stirring up of contaminated sediments by dredgers, working to keep the shipping channels open.

Whilst on route, ships can also have an effect on the marine environment if they suffer an accident and lose their cargo, although the scale of any impact obviously depends on the location, type and amount of substances released. There is also concern over the effect of marine organisms that ships can carry from one geographical area to another in their ballast water or attached to their hulls. If the non-native species are introduced to suitable conditions,

they can sometimes out-compete the local marine life, potentially altering entire marine ecosystems.

BALLAST WATER INTRODUCTIONS

Ever since ships began crossing oceans they have been accompanied by plants and animals, which have hitched a ride by attaching themselves to the hull. This form of transport was reduced with the development of effective antifouling paints, which make it more difficult for marine life to attach to boats. But another form of ship-travel for marine life has since arisen with the increasing use of seawater as ballast in ships.

BUT ANOTHER FORM OF SHIP-TRAVEL FOR MARINE LIFE HAS SINCE ARISEN WITH THE INCREASING USE OF SEA-WATER AS BALLAST IN SHIPS

Cargo vessels, when not fully laden with cargo, need to take on ballast. Originally ballast tended to be stones or sand, but since the advent of iron/steel ships there has been a shift to the use of water as the ballast. When ships load up with seawater ballast in one area, they also take in a sample of the local marine life. When the ballast water is discharged at the ship's destination, the marine life that has survived the journey is abruptly dumped into a new ecosystem.

Worryingly, translocations of marine life have become much more common in recent decades, as vessels have become larger and faster. Larger sizes mean that more ballast is needed, so greater volumes of water are carried. At the same time, increased ship speeds ensure that organisms taken on board have a better chance of surviving the voyage as they are in ships' holds for shorter periods, before being discharged.

IMPACTS OF BALLAST WATER INTRODUCTIONS

The International Maritime Organization (IMO) has identified the introduction of invasive marine species into new environments by ships' ballast water and attached to ships' hulls as one of the greatest threats to the world's oceans. Taking the UK as an example, it is estimated that at least 15 species of seaweeds, five species of diatoms, one species of flowering plant, and 30 invertebrate animals are non-native marine species that have become established in UK waters. Of these, 18% of introductions are definitely attributable to ballast water and a further 12% to either ballast water or via fouling on ships' hulls. Many other species will have been transported but were unable to become established.

The introduction of the American comb jellyfish *(Mnemiopsis leidyi)* via ballast water into the Black Sea and Sea of Azov in 1982 is one of the more infamous examples of ship-borne marine introductions. The jellyfish entered the Black Sea at a time when the combined effects of eutrophication and overfishing had removed the main plankton-eating fish, leaving an open niche for the jellyfish to exploit. By 1987–1989, the abundance of the American comb jellyfish had increased dramatically as they feed voraciously on large amounts of zooplankton, which included fish eggs and larvae and molluscan larvae. By eating the young of plankton-eating fish such as anchovies, the jellyfish were not only feeding themselves but also eating the future competition. Before 1989, the stock of small pelagic fish was estimated to be around 3 million t, but anchovy catches and stock size then dropped dramatically. By 1991 the stock size was estimated at 30,000 t and by 1994, the anchovy fishery, particularly in the Sea of Azov, had almost disappeared. Remarkably, in 1997 another comb jellyfish *(Beroe ovata)*, invaded the Black Sea, probably arriving from the Mediterranean Sea. *Beroe* is a predator of *Mnemiopsis* and already in 1999 the biomass and numbers of *Mnemiopsis* had decreased greatly, resulting in some improvement in the pelagic ecosystem of the Black Sea.

Another example of the effects of ballast water introductions includes the marine phytoplankton species *Chatonella verruculosa*. Normally this microscopic algal species is at home in Japanese waters, but in April–May 1998 and 2000 it suddenly started forming blooms in the Skagerrak, northern Kattegat, and adjacent parts of the North Sea. Although its toxicity is poorly understood, it has been responsible for deaths of wild and farmed fish in Scandinavian waters and, in one case, it was responsible for the death of 350 t of farmed salmon. Establishing whether a non-native species entered a new sea area via ballast water, aquaculture, or expansion is not always easy. This is particularly true in the Mediterranean. While most non-native species entering this sea have arrived via the Suez Canal—over 500 Indo-Pacific species—more than 53 species have invaded via the Straits of Gibraltar or as fouling, in ballast, or via aquaculture activities.

NORMALLY *CHATONELLA* IS AT HOME IN JAPANESE WATERS, BUT IN APRIL–MAY 1998 AND 2000 IT SUDDENLY STARTED FORMING BLOOMS IN THE SKAGERRAK, NORTHERN KATTEGAT, AND ADJACENT PARTS OF THE NORTH SEA

Action on ballast water introductions

The International Maritime Organization (IMO) has responded to the threat of ballast water introductions by adopting guidelines for the control and management of ships' ballast water to minimise the transfer of harmful aquatic organisms and pathogens.

Other actions include developing a new international legal instrument (Convention) on ballast water management to be considered for adoption by an IMO Diplomatic Conference in early 2004 and joining forces with the Global Environment Facility (GEF) and United Nations Development Programme (UNDP) to help developing countries implement the IMO Guidelines and prepare for the Ballast Water Convention, through the Global Ballast Water Management Programme.

CARRIAGE OF OIL

Oil and oily residue discharges from ships represent a significant threat to marine ecosystems. These discharges may occur during normal activities (operational) or may be accidental or illegal. Illegal discharges of oil from ships are often limited in size and scattered, but, surprisingly, their sum is higher than that from oil spills, and they may create a chronic impact of oil in certain areas. Accidental oil spills have historically been of crude oil rather than refined products—such as diesel or fuel oil—but in recent years this trend has reversed and spills of heavy fuel oil have become more common. There have been a number of large oil spills from tankers in the Northeast Atlantic area over the last few decades, examples include:

- The "Torrey Canyon" off England in 1967 (93,000 t);
- The "Amoco Cadiz" off Brittany in 1978 (260,000 t);
- The "Haven" off Genoa, Italy, in 1991 (114,000 t of crude oil, most of which burned);
- The "Aegean Sea" off Northwest Spain in 1992 (80,000 t);
- The "Braer" in Shetland in 1993 (85,000 t of crude oil);
- The "Sea Empress" in Wales in 1996 (72,000 t of crude oil);
- The "Erika" off Brittany in 1999 (of the 30,000 t of heavy fuel oil on board, more than 10,000 t got into the marine environment); and
- The "Prestige" off northwest Spain in late 2002 (more than 25,000 t of heavy fuel oil, with 50,000 t remaining in the wreck).

In recent years, a number of new oil terminals have been built in the Baltic Sea area, resulting in increased transport of oil by ships and, consequently, an increased risk of accidents.

Clearing oil from beaches after the "Prestige" oil spill.

IMPACTS OF OIL SPILLS

Coastal areas in the vicinity of busy ship traffic (e.g., the Channel, Brittany, Iberian coast, Mediterranean coast) are at particular risk from oil spills. The environmental impact of all these spills has been thoroughly studied (or is being studied, in the case of the "Prestige"), with monitoring studies ongoing for two or more years following most of the spills mentioned above. In all cases, the spills had both immediate and longer-term effects, including contamination of farmed fish and shellfish for human consumption.

Taking the "Erika" as an example, heavy fuel oil came ashore along over 400 km of the coast of western France, from south Finisterre to the Vendée. Initial mortalities of shellfish in coastal waters were accompanied by contamination of seawater, which persisted for several months. Oil, and heavy fuel oil in particular, stranded on rocky coasts and trapped in inshore sediments causes direct kills and habitat losses, but is also likely to remain there for long periods. This provides a long-term source of contamination, which impacts on coastal habitats and resources, e.g., preventing the re-opening of some coastal fisheries.

One of the most immediate and conspicuous casualties of any oil discharge at sea are seabirds. Spills have caused large kills of seabirds in recent decades although the size of the spill is not necessarily reflected in the scale of the kill, as seabirds are not distributed evenly in our seas. A spill in an area important for flocks of seabirds is much more lethal than in areas without such flocks. Catastrophic accidents seem to be difficult to avoid fully, but the numbers of small "operational" spills may be declining in the North Sea, based on the proportion of oiled (compared with unoiled) birds found dead on beaches.

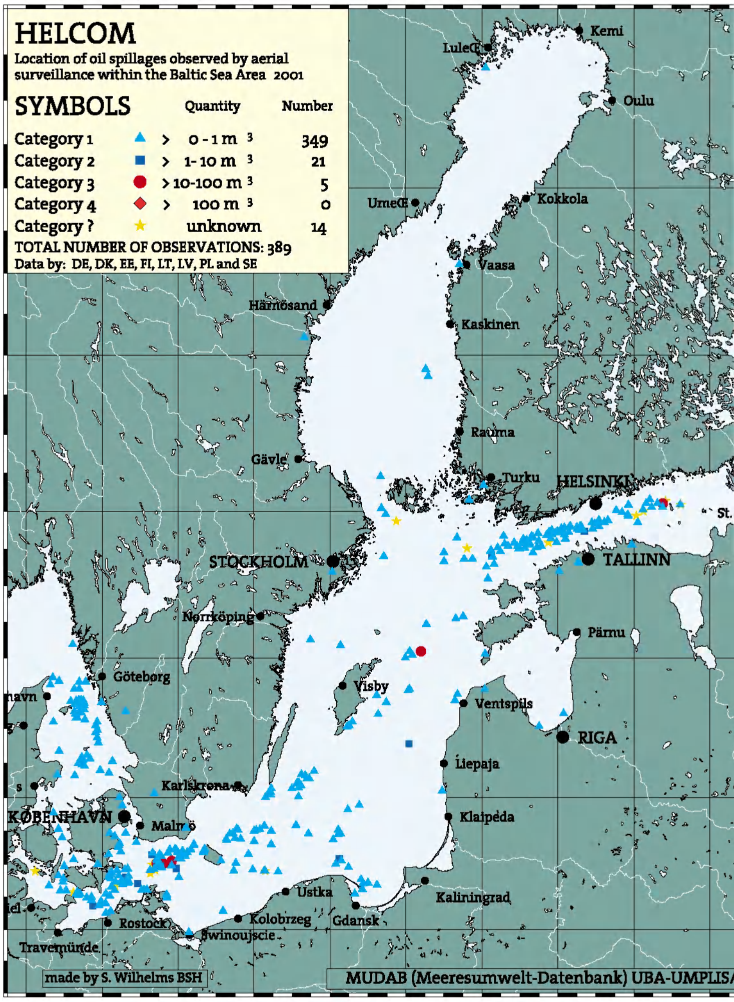


Figure 3.7.1. The location of oil spillages observed by aerial surveillance in the Baltic Sea during 2001. (Source: HELCOM).

Action on oil spills

The "Erika" and "Prestige" oil spills, in particular, have prompted calls for changes in the conduct and practice of the shipping industry, and changes to the laws controlling it. Both the "Erika" and the "Prestige" were old single-hulled tankers due to be phased out under international legislation. Tanker routes, which are often close to land, are under review in the UK, for example, with the development of MEHRAs (Marine Environmental High-Risk Areas), which are particularly vulnerable to oil spills and from which tankers should be excluded. The accidents have led to calls for rapid action on these developments, although the "Erika" was already 75 km offshore when it broke up and the "Prestige" 250 km.

However, these offshore wreckages result in wider impact along the coasts, as the surface currents may spread the oil over a wide area. Heavy fuel oils are particularly problematic. As they are heavy refined products, they do not disperse naturally, are not reduced in volume by evaporation, and cannot generally be dispersed using chemicals. For these reasons, the response options are much more limited than for crude oils, and heavy fuel oils are likely to cause more environmental damage than crude oils.

Under the IMO, the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) has been established to regulate operational discharges from ships. Owing to its status as a semi-enclosed sea, the Baltic Sea has been designated as a Special Area with regard to oil and waste; from 1 August 1999, the North Sea and the seas around Ireland and their approaches have also been designated as a Special Area with regard to oil. Stricter anti-pollution regulations apply in Special Areas.

CARRIAGE OF CHEMICALS

Chemicals are transported at sea in bulk by specialist tankers. These generally carry thousands of tonnes of one or a small number of chemicals. Many chemicals are also carried as packaged dangerous goods, in containers if solid or tanks if liquid, and these can be carried aboard any vessel including passenger ferries and container ships. Both types of transport can result in the release of chemicals to the sea if the vessel sinks, as with the "Perintis" in 1989 and the "Ievoli Sun" in 2000, both of which sank in the Channel. In the first case, 6 t of the insecticide lindane were lost in a container carried on deck; in the second, 1,000 t each of two solvents (isopropanol and methylethyl ketone) were released from the wreck of the vessel on the seabed. The most hazardous chemical aboard the "Ievoli Sun", 3,000 t of the synthetic chemical styrene, was recovered in a seabed salvage operation, along with the ship's fuel oil. Other incidents include the loss of containers by the "Lykes Liberator" off the coast of France in 2002, with one container holding tanks with chemical products classified as dangerous, and the "Balu", which sank in the Bay of Biscay in March 2001 with 8,000 t of sulphuric acid.

EMISSIONS OF SULPHUR DIOXIDE AND NITROGEN OXIDE

Another issue of concern is the emission of sulphur oxides and nitrogen oxides from ships. The contribution from international shipping in the North Sea to acidification in Europe increased during the 1990's, and shipping now contributes 10% of the deposition of sulphur oxides and nitrogen oxides over wide areas of Europe to over 15% in some coastal areas.

ANOTHER ISSUE OF CONCERN IS THE EMISSION OF SULPHUR OXIDES AND NITROGEN OXIDES FROM SHIPS

Figure 3.7.2 shows the atmospheric deposition of sulphur oxides to the European marine areas as contributed by ships (land-based sources, which are considerably larger, have been omitted in this diagram). In the Baltic Marine Area, emissions from international ship traffic is a major source of nitrogen oxides, exceeding the emissions from most countries around the Baltic except the Russian Federation, Poland, and Germany.

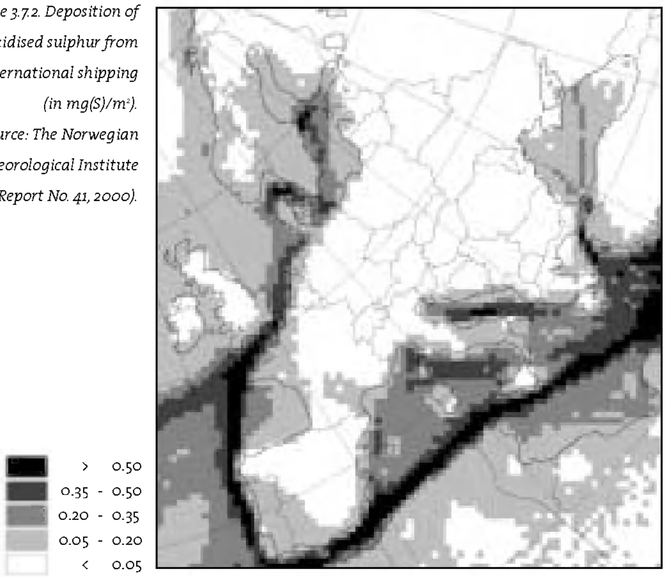


Figure 3.7.2. Deposition of oxidised sulphur from international shipping (in mg(S)/m²). (Source: The Norwegian Meteorological Institute Research Report No. 41, 2000).

BOOSTER BIOCIDES

Since the ban on the use of tributyltin (TBT)-based antifouling paints on vessels less than 25 m in length, the copper-based paints used before the introduction of TBT are now being used again. These paints are not as effective as TBT-based paints at controlling algal slimes, which form a surface on which other colonising organisms can grow. As a result, it has become common practice to add herbicides to copper-based paints to improve this aspect of their performance. These are commonly known as booster biocides. Around ten compounds are in widespread use, and two of them (diuron and irgarol) have now been controlled or prohibited due to their widespread distribution in the environment and concerns about wider impacts. The use of TBT-based paints on larger sea-going vessels will be phased out during the period 2003–2008, and it is important that the most effective and least environmentally damaging alternatives are identified in the next five years.

THE USE OF TBT-BASED PAINTS ON LARGER SEA-GOING VESSELS WILL BE PHASED OUT DURING THE PERIOD 2003–2008

3.8 Coastal zone issues

The sea coasts are popular areas for many human activities. From small holiday homes on the beach to large multi-activity resorts, coastal areas have always been popular sites for recreation and tourism. Coastal development is intense in many areas, with many large population centres located on or near the coast. Ports and harbours are also built on the coasts or in estuaries, and these facilities have been expanding in many countries located around the Northeast Atlantic, especially in the North Sea, as well as in the Baltic Sea and the Mediterranean. Many types of industries, as well as power plants, are located on coasts, often using the sea for the discharge of cooling water or wastewater. Fish and shellfish farming also occurs in coastal areas, particularly in sheltered bays or lagoons. In addition, in low-lying areas or areas where erosion by the sea takes place, coastal defence barriers are often set up. All of these activities impact the environment both inland and seaward, and particularly the plants and animals that grow on the coastal margin, including breeding areas for seabirds, marine mammals, and coastal fish.

In the European Union, about one-third of the population is concentrated near the coast. Urbanisation claims large expanses of coastline and, while stabilising in northern Europe, it continues to increase in the southern countries. In the Mediterranean in 1985, almost 90% of urbanised land was located in the coastal zones of Spain, France, Greece, Italy, and the former Yugoslavia. In southern Mediterranean countries, from Morocco to Syria, 55% of the total population is located in coastal areas, which account for 6% of the total area of these countries. Most of the coastal ecosystems that are potentially threatened by unsustainable development are located within northern temperate and northern equatorial zones, with Europe having 86% of its coasts at either high or moderate risk.

Human activities are often in competition for the use and control of the coastal resources. Examples include agriculture and urban areas in the North Sea, agriculture and forests in the Mediterranean and the Baltic Sea; and coastal wetlands threatened by other land uses in the Mediterranean, the North Sea, and the Atlantic coasts.

TOURISM AND RECREATION

Tourism is a rapidly growing source of pressure on natural resources and on the environment. European countries have long been a favourite destination for tourists, accounting for 60% of all international arrivals. France, Spain, Italy, and the UK are among the top ten world destinations, and 63% of holiday trips are to the sea.

A crowded beach on the Baltic Sea coast.

Coastal areas are popular places for recreation and leisure activities that attract both local people and tourists from inland and abroad. Swimming, sailing, surfing, recreational fishing, scuba diving, and camping are among the most popular activities. The number of tourists shows a distinctly seasonal pattern. For example, in the Wadden Sea area, 75% to 90% of all overnight stays occur in the period April to October.

As in other northern areas, tourism in the Baltic Sea coastal areas peaks in the summer months. The establishment of bird and seal sanctuaries constitute important parts of the regulatory measures needed to protect the wildlife from disturbance during the sensitive breeding period.

The Mediterranean is the largest tourism region in the world, accounting for 30% of international tourist arrivals. The French, Spanish, and Italian coasts account for 90% of the tourists travelling to the Mediterranean. The number of tourists in Mediterranean countries is expected to increase from 260 million in 1990 (with 135 million in the coastal region) to 440–655 million in 2025 (with 235–355 million in the coastal region). Tourism in coastal regions is estimated at around half of the total tourism to these countries, with the highest concentration in coastal resorts.

Signs of negative impacts of tourism are visible, for example, through problems related to waste disposal, deterioration of water quality, physical alteration of coastlines, disturbance of coastal biota (e.g., seabirds, turtles), loss of habitat, and damage to fragile ecosystems.

MARICULTURE OPERATIONS

Mariculture, the farming of finfish, shellfish, or seaweeds in coastal areas, occurs in various coastal and inshore areas throughout the Northeast Atlantic and the Baltic Sea areas, but mainly in the former. Total mariculture production has increased 2 1/2 times over the past two decades to 1.2 million t (Figure 3.8.1), divided almost equally between fish and molluscs. Atlantic salmon currently dominates fish mariculture; the 614,000 t produced in 2000 accounted for 99% of the total mariculture fish production. Turbot cultivation commenced in the mid-1980's and now produces almost 5,000 t.

TOTAL MARICULTURE PRODUCTION HAS INCREASED 2 1/2 TIMES OVER THE PAST TWO DECADES TO 1.2 MILLION T, DIVIDED ALMOST EQUALLY BETWEEN FISH AND MOLLUSCS

Halibut mariculture started on a commercial scale in the late 1990's, but total production has not yet

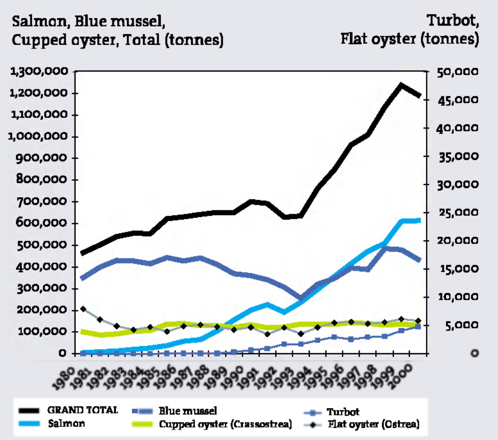


Figure 3.8.1. *Aquaculture in the Northeast Atlantic and the Baltic Sea. (Source: FAO Fishstat+ Database).*

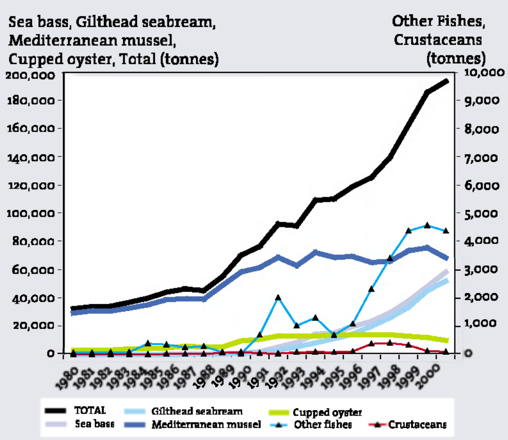


Figure 3.8.2. *Aquaculture in the Mediterranean and Black Seas. (Source: FAO Fishstat+ Database).*

reached 100 t. More recently, cod mariculture has been established and it is anticipated that this will certainly increase in the near future, particularly in Norway.

Blue mussel *(Mytilus edulis)* is the main product from shellfish mariculture, followed by cupped oyster *(Crassostrea gigas,* also known as Pacific oyster). The major blue mussel producing countries are Spain, The Netherlands, and France.

In the Baltic Sea, the main species produced in marine waters is rainbow trout, mainly in Finland, Denmark, and Sweden. There is no current marine production of fish or shellfish in the southeastern Baltic areas (Poland, Lithuania, Latvia, or Estonia). However, larger quantities of fish are cultivated in freshwater facilities within the catchment area of the Baltic Sea in Denmark, Germany, and Poland.

A large variety of fish and shellfish species are cultivated in the Mediterranean Sea. In the last two decades, total mariculture production in the Mediterranean and the Black Sea has increased by a factor of six, to 193,000 t (Figure 3.8.2). The available statistics make no separation between the two areas, but the breakdown by countries makes it clear that most of the production takes place in the Mediterranean. The major fish species cultivated are sea bass *(Dicentrarchus labrax)* and gilthead seabream *(Sparus aurata)*, of which 58,000 t and 52,000 t, respectively, were produced in 2000 (96% of total cultivated fish production). Mariculture of molluscs consists almost entirely of the Mediterranean mussel *(Mytilus galloprovincialis)* and the cupped oyster – respectively, 68,000 t and 10,000 t were produced in 2000.

IMPACTS OF MARICULTURE

Environmental impacts from finfish mariculture operations can include the discharge of organic matter and the nutrients nitrogen and phosphorus in organic waste (faecal material and uneaten feed), and the release of chemicals including medicines used on the fish. Most countries have established authorisation schemes for mariculture operations, which require monitoring the impacts of waste from mariculture facilities and regulating production accordingly. Nonetheless, in embayments and areas with restricted circulation, the release of excess nutrients and other waste products can have a local impact, particularly on the seabed.

Other potential impacts include the transfer of diseases and parasites between wild and cultured animals, and genetic effects arising from interbreeding between wild and cultured fish. Interbreeding may occur with salmon either when hatchery-reared salmon are released into the wild to enhance the fishery, such as in the Baltic Sea, or when salmon accidentally escape coast-based facilities into the wild. Such escapes are known to occur from salmon rearing facilities in Norway, Scotland, and Ireland, but total numbers and their impact are unknown.

Mariculture may also cause the introduction of non-native species to a sea area, either deliberately for mariculture purposes or accidentally. Some species are imported from other sea areas specifically for cultivation and occasionally they escape into the wild and establish themselves. In other cases, common species are imported from other sea areas, but unwittingly bring other organisms with them, either disease organisms or small larval forms of invertebrates. This can have serious consequences on the native organisms, for example by competing with them for food or space.

One example of a non-native species that was purposely introduced into a new sea area, in what could loosely be termed mariculture, is the introduction by Russia of the red king crab into the Barents Sea in the 1960's. The crab normally lives in the North Pacific but was introduced into the Barents Sea to create a new fishery. The crab, which grows to a large size (weighing up to 10 kg), has become well established in the Barents Sea and is now extending its range westwards along the Norwegian coast.

OTHER POTENTIAL IMPACTS OF MARICULTURE INCLUDE THE TRANSFER OF DISEASES AND PARASITES BETWEEN WILD AND CULTURED ANIMALS, AND GENETIC EFFECTS ARISING FROM INTERBREEDING BETWEEN WILD AND CULTURED FISH

Although some biological aspects of this species have been studied, relatively little is known about the ecological impact of the crab on native bottom communities in Norwegian waters. The concern is that it may have caused a reduction in scallop *(Chlamys islandica)* and flatfish populations in the areas where it has become established.

Environmental impacts affecting mariculture include diseases, which affect the species being cultivated, and blooms of harmful algae, which may affect the cultured organisms and influence their harvesting and use for human consumption. There are around twenty species of phytoplankton in the Northeast Atlantic that produce toxins. Some of these toxins affect fish directly, while others are concentrated in molluscan shellfish and may cause poisoning in human consumers. The poisoning is classified according to the symptoms caused by the chemically very different toxins (see Section 3.4). Monitoring for the main marine biotoxins produced by harmful algae is conducted in shellfish-growing areas and the results of this monitoring determine when a shellfish-growing area must be closed to harvesting.

Red king crabs can weigh up to 10 kg and reach a length of 1.5 m between the tips of the legs.

MOVING TO RENEWABLE ENERGY – OFFSHORE WIND FARMS

There is a need to develop renewable energy resources as part of a strategy to reduce CO_2 emissions and the impact of global warming. This can involve wind, wave, and tidal energy schemes, although wind power is likely to be more widespread, as suitable locations for the extraction of energy from waves and tides are fewer. The development of offshore wind farms is a new activity, so we do not have full knowledge of the potential impacts and the scale of such impacts. Current developments are small, but plans for the use of wind energy currently include the proposed building of large wind farms (up to 500 turbines) in shallow coastal waters. Negative impacts include loss of habitat, the potential for bird collisions, a change in current and sediment dynamics, and an increased risk of ship collisions. The benefits include the use of a sustainable, pollution-free energy source.

MARINE AGGREGATE EXTRACTION

Sand and gravel deposits in nearshore areas are valuable resources for use in construction (mainly for making concrete), land reclamation (e.g., infilling of docks, road base), and coastal protection, for example, beach replenishment. The extraction of marine sand and gravel causes changes to the seabed surface and the nature of surface sediments, and affects the bottom-living organisms in the surrounding area. These deposits are also important habitats for some species of organisms; for example, herring spawn on gravel-covered seabeds.

Clean sand and gravel deposits suitable for commercial extraction occur only in certain areas in the Northeast Atlantic, mainly in shallow, near-shore areas in the North Sea, with a few deposits in the Baltic Sea. The countries with the greatest extraction activity include The Netherlands, which uses about one-third of the amount extracted for coastal protection, the UK, and Denmark. France, Belgium, and Germany extract smaller amounts of marine aggregates.

IMPACTS OF AGGREGATE EXTRACTION

Dredging for marine aggregates causes physical disturbance that may have an impact on marine life in the vicinity of the extraction area. The most obvious biological effect of sand and gravel extraction is the removal and destruction of marine life in the area of extraction. Also marine life living in the vicinity, particularly downstream, of the extraction area may be impacted by the fine sediment particles that are suspended by the action of the dredger. Close to the extraction area, bottom-living organisms may be blanketed by stirred up or spilled sediments. Further away, the increase in fine particles in suspension may harm filter-feeding organisms, such as mussels, owing to the abrasive effects of sediment passing over their feeding and respiratory structures. These effects may cause a change in the types of organisms living in areas subject to commercial sand and gravel extraction, favouring opportunistic organisms that can re-establish themselves more quickly after such physical disturbance and changes to the seabed.

COASTAL REALIGNMENT

Around the North Sea there are many inhabited areas that are protected by seawalls, especially in the reclaimed areas of land in Germany, the UK, and The Netherlands. With the likely increase in sea levels that are expected to accompany global warming, there is concern over the practicality and cost of building these walls ever higher to keep out the sea, especially where they are protecting agricultural land rather than homes.

The southeast of England is also slowly sinking. The resulting rise in sea level is already putting pressure on both salt marshes (nature's defences against waves) and the seawalls currently in place. As one of the first areas threatened by rising sea levels, innovative approaches such as coastal realignment are being tested. Where seawalls are currently protecting agricultural land, a number of the sea-walls, especially around the county of Essex, have been deliberately breached. The intention is to allow the sea to flood the fields immediately behind the seawalls and aid the regeneration of natural salt marsh. This will then protect the coast, and the funds for the maintenance of seawalls can be targeted towards those of major importance, and which protect major domestic and industrial locations. The results of the trials will be known within the next five years when the wider application of this technique can be considered.

MARINE LITTER

Sources of marine litter are mainly related to wastes generated by shipping, fisheries, and tourist and recreational activities, as well as unsafe deposits on land near rivers or the coast. Floating and sunken litter have been found in large quantities in many sea areas. Impacts on marine life include the drowning of birds entangled in plastic sheeting and netting, and the death of birds, turtles, and crustaceans caused by ingested plastic objects. Economically, the recreational and commercial fishing sectors are likely to be the most affected by litter. As tourism, urban development, and industrial pressure for development in the coastal zone increase, the problem of litter may become more severe.

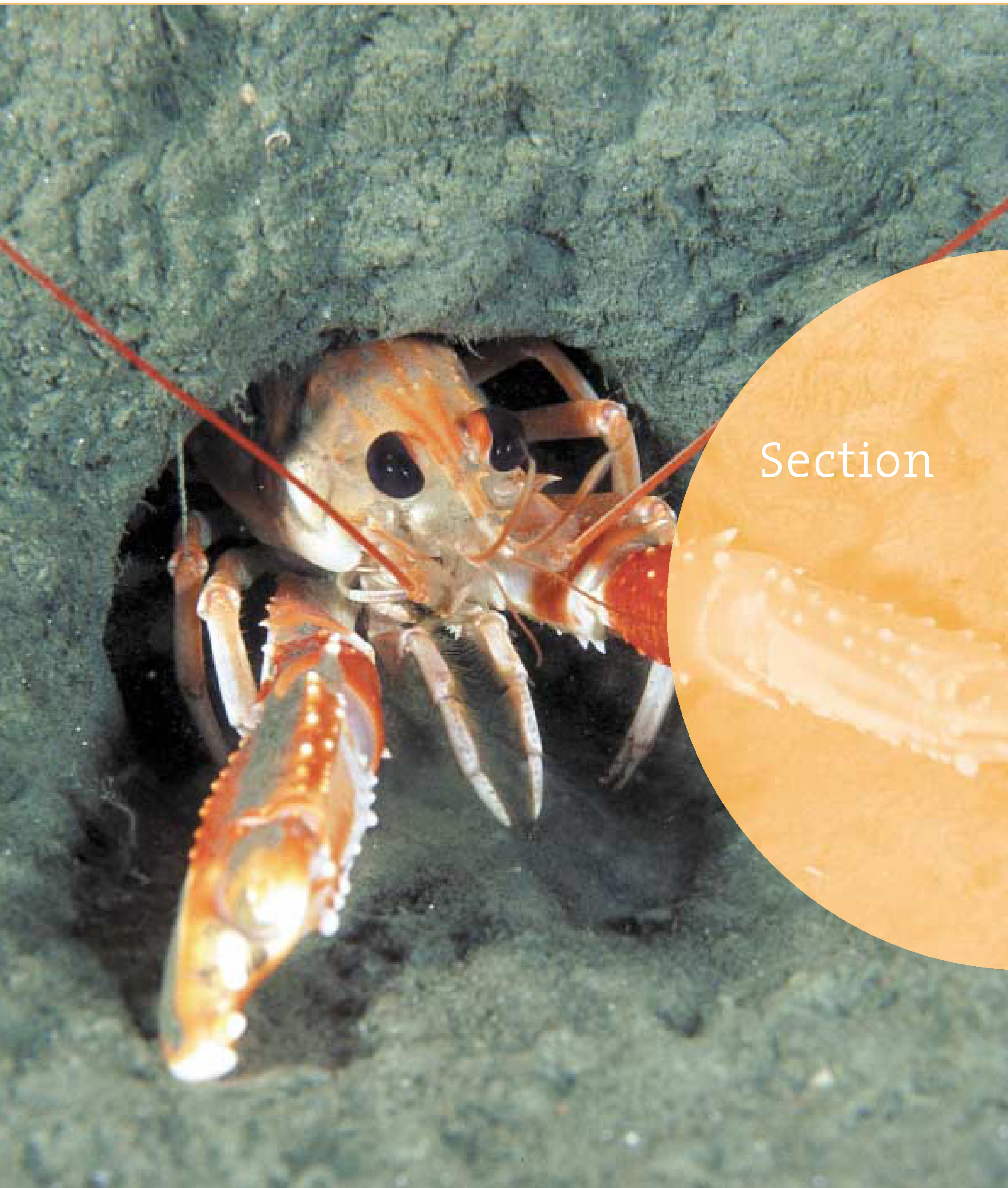
Action on marine litter

As noted previously, the North Sea and the Baltic Sea have been designated as MARPOL Special Areas and thus the dumping of all garbage and litter from ships into these sea areas is prohibited. However, there seems to have been no subsequent improvement in the situation with regard to marine litter.

3.9 Concluding remarks

All of the human activities mentioned in this section have impacts on marine biological diversity. Each activity should not, however, be evaluated and treated separately, but rather in conjunction with other activities that may have an effect, so that an overall view of priorities for action can be obtained. The conservation of biological diversity is not an easy task, however, owing to the lack of understanding of what determines marine biological diversity and how it affects ecosystem function, and the shortage of baseline descriptions of biological diversity. Furthermore, natural fluctuations in marine populations and ecosystems can be quite large and there is little knowledge about the normal levels of such variability. This makes it difficult to set clear limits on tolerable changes in biodiversity, which are needed in relation to management measures.

Despite these problems, there is a clear commitment to develop management actions to restore and preserve biological diversity in European seas. Among others, the OSPAR and Helsinki Commissions, as well as the European Commission, are each in the process of developing specific measures to preserve marine biodiversity.


Section

Key messages

It is difficult to rank the relative severity of the various human impacts on the European seas, partly because they affect different aspects of the marine ecosystem and partly because this involves value judgements as to what is considered important. In this section, we will provide a summary of the main human impacts on marine ecosystems and biodiversity, and indicate success stories where previous environmental problems are being dealt with, point to remaining problems and potential new problems, and indicate areas that require attention or action.

CLIMATE CHANGE

- Studies by the Intergovernmental Panel on Climate Change predict that, by 2100, global warming will have led to an increase in the surface air temperature of the Northeast Atlantic by 1.5°C and a rise in sea level by 25 cm to 95 cm.

- Sea ice over the Arctic is slowly receding farther north and becoming thinner. This will have a major impact on plants and animals, particularly those in the far north. For example, marine mammals (seals and bears) that depend on the ice platform will have less available habitat and may have to migrate to other areas.

- Other likely impacts in the wider Northeast Atlantic include more rain, which will increase flooding in low-lying areas and raise the amount of nutrients entering the sea via rivers. Coastal erosion is expected to increase due to increased storminess. And the predicted rise in sea level may inundate some intertidal areas and salt marshes, and alter the shape of estuaries.

FISHERIES

- Many fish stocks in the Northeast Atlantic have declined during the past decade. In 2001, out of 113 stocks assessed by ICES, only 18% were inside safe biological limits.

- One major reason for the decline in fish stocks is overfishing. A study undertaken by the European Commission in 1995 calculated that the EU fleet as a whole was 40% bigger than that required to fish the resources in a sustainable way. It is clear that the available catching capacity in many parts of the Northeast Atlantic, and not just in the EU zone, continues to be greater than the fish stocks can sustain.

- Generally, the demersal stocks like cod, haddock, and plaice have declined during the past two decades, the pelagic stocks like herring and blue whiting have increased and so have the smaller but economically important stocks of shrimps and Norway lobster.

- Cod stocks in the North Sea, Irish Sea, and West of Scotland are now so low that ICES has recommended a total ban on fishing to give these stocks a chance to recover. Even if stringent recovery measures are implemented, these stocks are not expected to recover within a decade or more.

- For several years ICES has recommended a total ban or revised recovery plan for Baltic cod. But this has not been followed and instead an existing recovery plan, which was first implemented in 2001, has continued. This recovery plan allows some fishing on Baltic cod (76,000 t in 2002). At such an exploitation rate, recovery of the stock in the medium term is unlikely, particularly if discarding and under-reporting of catches continue.

- Deep-sea fish are slow-growing, slow-reproducing species and catches of most of these stocks have been declining. The degree of this decline is a warning signal and ICES has advised, for many years, that deep-sea fisheries should not be allowed to expand until more knowledge is available about the biology of the stocks.

- The news on fish stocks is not all bad, however, and the recovery of the North Sea herring and Norwegian spring-spawning herring stocks after their collapse in the 1970's and 1960's, respectively, shows what can be achieved if scientific advice is followed and international management plans are agreed.

- Fishing also has an impact on the seabed, killing bottom-living organisms and altering seabed habitats. This is a particular issue in the southern North Sea, which is subject to frequent passage of heavy bottom-trawling gear. ICES has provided advice on measures to minimise such effects, but they have not yet been implemented. ICES has also, frequently, recommended an overall reduction in fishing effort.

- Fishing also has an impact on the marine ecosystem through the by-catch of marine mammals, seabirds, and turtles. There is a particular concern over harbour porpoise by-catches in bottom-set nets in the Baltic Sea, North Sea, and Celtic Sea. ICES has recommended the adoption of measures such as putting more observers onboard fishing boats to monitor by-catches and the use of pingers (acoustic alarms) on fishing gear in certain fisheries, to help porpoises and other cetaceans avoid fishing nets.

- Scientific resources allocated to core fisheries problems have declined internationally, while demands for scientific advice on fisheries have increased. This discrepancy between the demands for scientific advice on fisheries, and the data and capacity to provide the advice, is a serious and growing problem.

NUTRIENT ENRICHMENT

- Inputs of phosphorus have decreased considerably in the North Sea and the Baltic Sea owing to measures implemented by countries bordering these areas.

- Unfortunately, eutrophication due to excessive inputs of nutrients is still a problem in several coastal areas in the Northeast Atlantic, the southeastern part of the North Sea, the eastern Skagerrak, the Kattegat, the southeastern and central Baltic Sea, and the Black Sea.

- Measures to decrease problems caused by eutrophication are, in principle, in place, for example in the form of the Urban Waste Water and the Nitrate Directives of the European Union and measures and programmes of the Helsinki and OSPAR Commissions.

- However, the present degree of implementation is not sufficient to efficiently address, in particular, nitrogen inputs resulting from agriculture. In addition, these measures cannot compensate for wrong incentives (such as provided by the Common Agriculture Policy).

CONTAMINANTS

- There has been a general reduction in direct and riverine inputs of several trace metals and organochlorine contaminants in the Northeast Atlantic and the Baltic Sea over the past one to two decades, mostly as a result of tighter controls on point source inputs such as industrial discharges.

- Atmospheric inputs of lead to the North Sea have decreased by up to 65% from 1987 to 1995, primarily due to the removal of alkyl-lead anti-knock additives from petrol.

- Although reduced mercury emissions in Europe and North America have been followed by reductions in environmental concentrations, mercury pollution is on the increase in the Arctic. This may be due to increased emissions in Asia, where coal is burnt to provide electricity and heat.

- Antifoulants based on tributyltin (TBT) are known to interfere with the hormone systems of marine animals, particularly invertebrates such as dogwhelks. They have now been banned from use on small vessels (less than 25 m overall length) for the past ten years and thus the occurrence of sexual abnormalities in dogwhelks has decreased in many areas.

- However, TBT is still used on large ships and remains a problem in the vicinity of busy shipping routes. But an international agreement has been reached and the use of TBT on large ships is now due to be phased out during 2003–2008. The return to the use of copper-based antifoulants has resulted in increased inputs of copper into the sea and the possible effects of this are being studied.

- Many chemical contaminants are readily taken up by animals and concentrate at the top of the food chain in marine mammals and fish. This is particularly the case for the persistent organic contaminants, including PCBs, dioxins and furans, and brominated flame retardants. These contaminants can cause reproductive disturbances, decreased survival, and suppression of the immune system.

- The concentrations of some of these substances, such as DDT, have decreased markedly in the marine environment since controls were placed on their use in the 1970's and thereafter. However, owing to their persistence and often inadequate disposal, even substances like PCBs, which have not been manufactured for more than two decades, remain in the marine environment. This is the case in the Arctic, where these compounds build up in the blubber of marine mammals, and in the Baltic Sea, owing to the restricted water exchange.

- Measures against a number of these organic contaminants, or their major sources, are being taken by the European Commission, OSPAR, and HELCOM. Nonetheless, with the large number of chemicals in industrial and agricultural use, there are many new contaminants that could reach the marine environment and affect marine life. Of particular concern is the growing range of chemicals that can cause disturbances to the hormone systems of marine animals.

SHIPPING

- The transfer of non-native species to other sea areas in ships' ballast water is a major threat to marine ecosystems, as was illustrated by the impact of the American comb jellyfish on the Black Sea. The International Maritime Organization is now tackling this problem by developing measures to reduce ballast water introductions.

- Ships often use fuel oil with high sulphur content and rarely purify their combustion gases, leading to air pollution with sulphur dioxide and nitrogen oxides. This contributes to acid rain and also to a substantial input of nitrogen to the sea.

- Oil discharges from ships represent a significant threat to marine ecosystems whether they are accidental or deliberate. Accidental oil spills are difficult to avoid. Action is being taken in the field of shipping safety, *inter alia*, to keep tanker routes away from sensitive marine areas, and the International Maritime Organization has set out a timetable to phase out single-hulled tankers by 2015.

- Furthermore, the MARPOL 73/78 Convention has already been established to regulate operational discharges from ships; under this Convention, the Baltic Sea and, more recently, the North Sea and the seas around Ireland have been designated a Special Area, where stricter anti-pollution regulations apply.

COASTAL ZONE

- The coastal zone is under increasing pressure from many human activities. Coastal development, in particular, can reduce or disturb marine habitats such as intertidal areas and salt marshes. Loss of habitat affects not only marine species but also the many birds that rely on coastal habitats for feeding and breeding. Attempts are being made to stem the piecemeal loss of these coastal habitats and species by setting up protected areas, developing action plans to preserve biodiversity, and strengthening European environmental legislation.

- While mariculture is increasingly becoming an important source of fish protein it can have adverse effects on the marine ecosystem. These range from localised nutrient enrichment, to impacts on wild fish stocks that are used as fish feed. Attempts are being made to reduce the environmental footprint of mariculture by reducing discharges into the marine environment and culturing other sources of fish feed such as marine worms.

MARINE BIODIVERSITY

- All of the human activities mentioned in this section have impacts on marine biological diversity. Each activity should not, however, be evaluated and treated separately, but rather in conjunction with other activities that may have an effect, so that an overall view of priorities for action can be obtained. The conservation of marine biological diversity is not an easy task, however, because of the shortage of baseline descriptions and lack of understanding of what determines diversity and how it affects ecosystem function. Furthermore, natural fluctuations in marine populations and ecosystems can be quite large and there is little knowledge about the normal levels of such variability. This makes it difficult to set clear limits on tolerable changes in biodiversity, which are needed in relation to management measures.

- Measures are, however, being taken to protect species and habitats in European seas. In the Baltic Sea area, the Helsinki Commission has prepared a "Red List" of marine and coastal biotopes and biotope complexes, and 62 marine and coastal areas have been designated as Baltic Sea Protected Areas (BSPAs). Many BSPAs that are in EU countries have also been designated for the EC NATURA 2000 Network. NATURA 2000 is a network of protected areas across the whole of the European Union and provides a framework for the protection of coastal and marine habitats.

- In the OSPAR Convention Area, the OSPAR Commission is in the process of adopting a Priority List of Threatened and Declining Species, developing a habitat classification system, and preparing proposals for the establishment of a network of Marine Protected Areas. Another measure under the OSPAR Commission is the development of Ecological Quality Objectives (EcoQOs) for the North Sea, based on scientific advice by ICES, and aimed at restoring and preserving marine biodiversity.

From the above, it is clear that there are many challenges to attaining a sustainable and responsible use of the marine environment and its living resources, both in preserving biodiversity as well as providing for human needs. ICES is committed to actively studying and providing advice on these issues, in order to facilitate and enhance further action by management authorities in governments and regional regulatory commissions.