chapter 5

# Biology

## 5.1 Introduction

The organisms living in the OSPAR maritime area belong to a wide range of taxonomic and ecological groups, including viruses, bacteria, plankton, benthos, fish, squid, birds, mammals and turtles. A general description of these groups of organisms is given in Section 5.2, while the impact of various human activities on the organisms is presented in Section 5.3. This chapter forms a basis for the overall assessment of the impacts of human activities in Chapter 6.

The various groups of organisms are interlinked in more or less tightly coupled food webs which together with the abiotic environment, make up the marine ecosystems. In terms of principles, the organisation of marine ecosystems is similar in all OSPAR Regions. Microscopic phytoplankton constitute the ‘grass’ of the sea and the basis for production at higher tropic levels. Phytoplankton is grazed by zooplankton, which again forms the food for plankton-feeding fish (e.g. anchovies, herring, mackerel) and whales. Benthic animals living in or on the seabed feed on plankton and dead organic material sinking out from the upper layer. Fish, squid, sea mammals and seabirds feed on smaller fish or benthic animals. Kelp and other macroalgae grow as plants in the lighted zone in shallow waters. Microorganisms contribute to decomposition of organic material and recycling of nutrients.

Many species of plants and animals have restricted distributions, and the biogeographical regions give distinct characteristics in terms of biodiversity to various parts of the OSPAR area.

Annex V to the OSPAR Convention, adopted in 1998, aims at protecting species and habitats in the OSPAR area. The Annex V strategy is to identify species and habitats for which protection measures will be considered. This work is ongoing and criteria for identifying species and habitats have been developed, including criteria for species and habitats under threat or subject to rapid decline.

## 5.2 General description of the biology of the OSPAR area

### 5.2.1 Microorganisms

Microorganisms, principally bacteria (but also yeasts, fungi and viruses), are constituents of the plankton as well as of the benthos. Planktonic bacterial production in the open sea is related to primary production and the abundance of bacteria increases following phytoplankton blooms. One of the main functions of bacteria in marine ecosystems is to remineralise organic matter (including oil) to inorganic components. In doing so, benthic bacteria show great metabolic diversity, utilising oxygen, nitrate or sulphate as their reduction substrate. Their respiratory activity creates a chemical gradient within the sediment with oxygen-utilising forms closest to the sediment/water interface and sulphate-utilising forms at greater depths.

### 5.2.2 Phytoplankton

Phytoplankton biomass shows considerable spatial variability in the OSPAR area *(Figure 5.1)*. The seasonal cycle is typical of temperate latitudes with a spring increase, summer decline and a second, generally less high, autumn increase. The spring bloom is generated mainly by diatoms which decline as concentrations of the winter accumulated nutrients (e.g. silica and nitrate) are utilised and as grazing pressure from zooplankton increases. In ice covered waters in the Arctic the seasonal cycle has a pronounced peak as the developing bloom moves north with the retreating ice edge. South of 40° N, in the wider Atlantic, the upper water column stays stratified throughout the year so the biomass is lower and less variable throughout the seasons.

The timing of the spring bloom is closely linked with the developing water stratification, which allows phytoplankton cells to remain in the higher light levels of the upper water column. During summer months recycling of nutrients occurs and other algal groups such as the dinoflagellates dominate the phytoplankton. Diatoms may return again in the late autumn as stratification breaks down and nutrients are again mixed into surface waters.

There is marked interannual variability in the timing and intensity of phytoplankton growth, and long-term trends (both up and down) have been described for different parts of the OSPAR area. These trends appear to be linked to changes in coupled ocean-atmosphere circulation.

A wide diversity of different phytoplankton species is found in the North Atlantic. Named species range from ~ 300 in the Arctic to ~ 1000 in Region IV, although many species have not yet been described. Traditionally diatoms were seen to be the most important group, it is now recognised that many very small flagellates and other algal classes may dominate at times. When temperatures increase in the summer flagellates dominate; most toxic species belong to this group (see Section 5.3.2 and *Table 5.5*).

Total annual production of phytoplankton varies from region to region. The lowest rates (*c*. 45 g C/m$^2$/yr) are found in the Wider Atlantic south of 40º N, the highest (> 400 g C/m$^2$/yr) on the Galician shelf and in the Cantabrian sea. In the North Sea the rate in the coastal areas (*c*. 400 g C/m$^2$/yr at a station 6 km off the Dutch south-west coast) is nearly an order of magnitude higher than in its central part. The rates also vary considerably within each region.

### 5.2.3 Zooplankton

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

Zooplankton are the main source of food for pelagic fish and the early life stages of all fish. Variations in zooplankton composition and in the timing and location of occurrence can thus have important effects on fish recruitment and growth.

The growth of zooplankton is governed by temperature and food availability so that their seasonal cycle is linked to that of the phytoplankton. For example, some species such as *Calanus finmarchicus* hibernate during winter in deep water timing their arrival in near surface waters to exploit the phytoplankton spring bloom. The herbivorous copepods of the genus *Calanus* play a key role in ecosystems of the OSPAR area. They are the most abundant form of zooplankton and may account for over 90% dry weight of the total zooplankton biomass in the northern and eastern part of the area.

There are strong year to year variations in zooplankton abundance. For example, *C. finmarchicus* and *C. helgolandicus* abundance in the Irish Sea can vary by an order of magnitude between years. The zooplankton biomass and composition in the central and northern Barents Sea have also shown several fold variations between years, which in part appears to be caused by fish predation. Elsewhere, as for phytoplankton, longer-term changes for many species appear to be related to variability in ocean-atmosphere circulation.

### 5.2.4 Benthos

The biota living near, on or in the seabed are collectively called the benthos. A distinction is made between plants (phytobenthos) and animals (zoobenthos). The phytobenthos may be composed of microalgae or macroalgae, the latter being colonised by epiphytic plant and animal species. The zoobenthos either lives as infauna within the sediments or as epifauna on the seabed.

Diversity and biomass of the benthos are dependent on a number of factors including substrate (e.g. sediment, rock), water depth, salinity and hydrodynamics. Depending on the characterisation of habitats by such factors, certain communities can be expected.

### Phytobenthos

Since it is light dependent, the micro- and macrophytobenthos is restricted to shallow waters. Whilst the microphytobenthos may thrive on any substrate, thus for example contributing to the stabilisation of loose sediments, perennial red and brown macroalgae (e.g. *Lithothamnion, Fucus*) require a hard substrate (e.g. rock, stones) whilst green algae (e.g. *Ulva*) may thrive on mussel beds or even (solid) sediments. Higher plants such as eelgrass (e.g. *Zostera*) may be found on sandy sediments.

The total number of macroalgal species decreases from south to north within the Arctic and northern temperate areas. The dominating macrophytes of these areas are large, brown algae (Laminarians or 'kelp'). The main depth to which macroalgae grow is in general lower at high latitudes than in temperate regions.

In the southern part of the OSPAR area the coastal

Figure 5.1 **SeaWiFS satellite images of chlorophyll concentrations in the North-east Atlantic. Source: CCMS.**

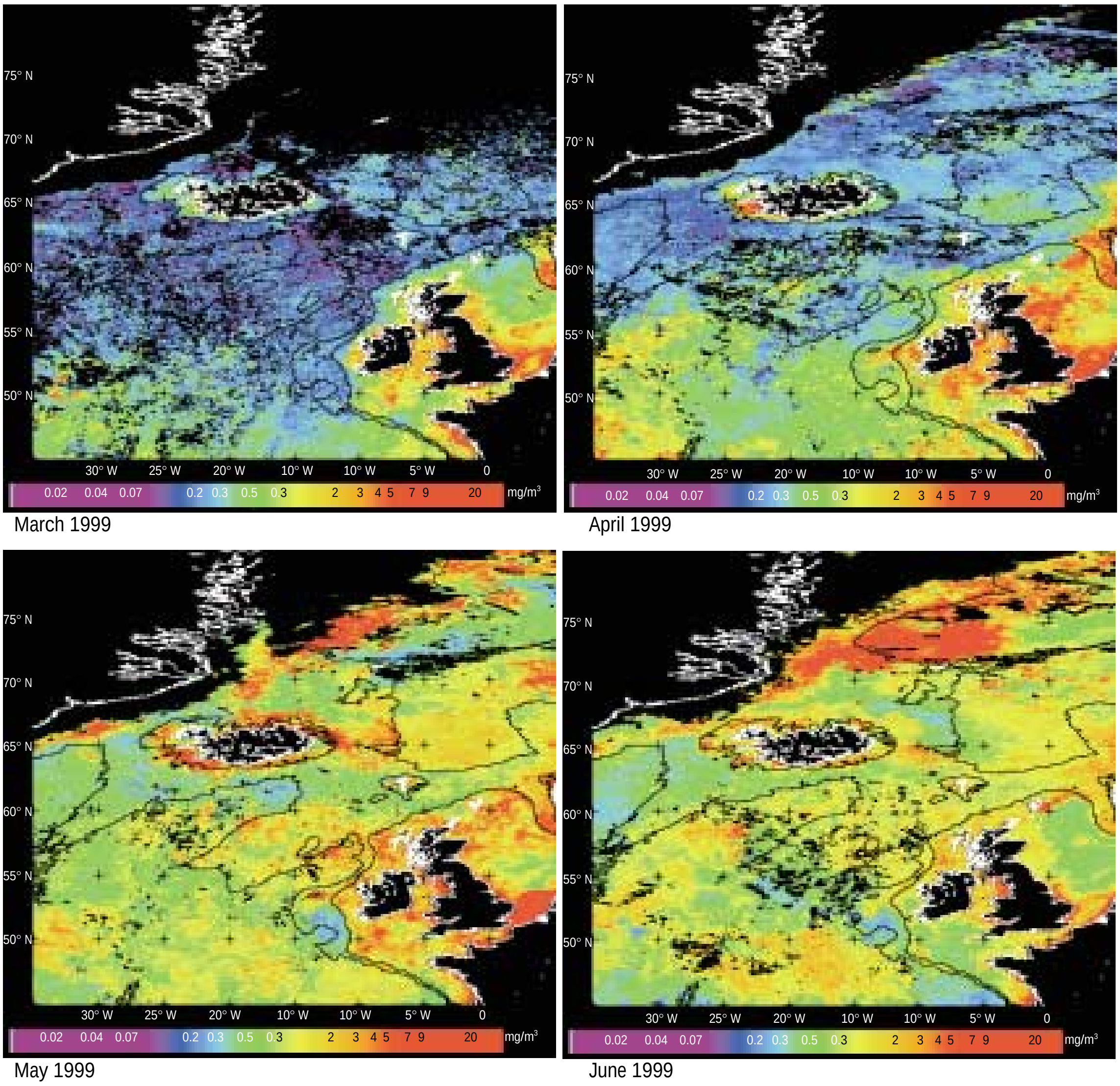


**Table 5.1 Landings and spawning stock biomass of the commercially important fish species in the OSPAR area, and status of the stock according to whether it is within 'safe biological limits'. Source: ICES (1999).**

| ICES division or stock description | Landings (t) 1997 | Spawning stock biomass (t) 1998 | Status* |
|---|---|---|---|
| Region I | | | |
| Cod | | | |
| North-east Arctic | 755 000 | 419 000 | outside SBL |
| Norwegian coastal | 36 000 | uncertain | uncertain |
| Iceland | 204 000 | 529 000 | within SBL |
| Faroe plateau | 34 000 | 68 000† | close to or within SBL |
| Herring | | | |
| Norwegian (spring spawning) | 1 427 000 | 9 800 000 | within SBL |
| Icelandic (summer spawning) | 64 000 | 486 000 | within SBL |
| Capelin | | | |
| Barents Sea | closed in 1997 | 254 000 | within SBL from 1998 |
| Greenland / Iceland | 1 245 000 | 490 000 | within SBL |
| Saithe | | | |
| North-east Arctic | 143 000 | 211 000 | outside SBL |
| Iceland | 37 000 | 90 000 | outside SBL |
| Faeroes | 22 000 | 50 000 | outside SBL |
| Haddock | | | |
| North-east Arctic | 146 000 | 219 000 | outside SBL |
| Iceland† | 44 000 | 67 000 | harvested outside SBL |
| Faeroes | 18 000 | 50 000 | close to SBL |
| Region II | | | |
| Cod | | | |
| North Sea | 124 000 | 136 000 | outside SBL |
| Whiting | | | |
| North Sea | 59 000 | 172 000 | outside SBL |
| Haddock | | | |
| North Sea | 142 000 | 213 000 | close to SBL |
| Saithe | | | |
| North Sea | 103 000 | 132 000 | outside SBL |
| Plaice | | | |
| North Sea | 83 000 | 274 000 | outside SBL |
| Sole | | | |
| North Sea | 15 000 | 26 000 | outside SBL |
| Herring | | | |
| North Sea | 248 000 | 1 145 000 | outside SBL |
| Mackerel | | | |
| North Sea | 228 000 | see combined stock below | see combined stock below |
| Horse mackerel | | | |
| North Sea (excluding IVa) | 20 000 | see combined stock below | see combined stock below |
| Region III | | | |
| Herring | | | |
| VIa | 60 000 | na | uncertain |
| Irish Sea (VIIa) | 6 600 | 10 300 | harvested outside SBL |
| Celtic Sea and VIIj | 18 800 | 70 000 | harvested outside SBL |
| VIa, VIIb-c | 27 000 | 57 000 | harvested outside SBL |
| Mackerel | | | |
| VIa, VIIa, VIIb, VIIf, VIIg-k | 196 000 | see combined stock below | see combined stock below |
| Horse mackerel | | | |
| VIa, VIIa, VIIb, VIIf, VIIg-k | ~ 358 000 | see combined stock below | see combined stock below |
| Cod | | | |
| VIa | 7 000 | 15 100 | outside SBL |
| Irish Sea (VIIa) | 5 700 | 8 750 | outside SBL |
| VIIe-k | 11 800 | 12 800 | outside SBL |
| Haddock | | | |
| VIa | 19 500 | 44 300 | outside SBL |
| VIb (Rockall) | 5 200 | 8 400 | outside SBL |
| Irish Sea (VIIa) | 3 500 | na | unknown |
| Whiting | | | |
| VIa | 10 900 | 17 200 | outside SBL |
| Irish Sea (VIIa) | 4 200 | 8 100 | outside SBL |
| VIIe-k | 18 100 | 31 800 | within SBL |
| Saithe | | | |
| VI | 9 400 | 11 900 | outside SBL |

| | | | |
|---|---|---|---|
| Plaice | | | |
| Irish Sea (VIIa) | 1 900 | 5 600 | within SBL |
| Celtic Sea (VIIf and g) | 1 200 | 1 540 | outside SBL |
| Sole | | | |
| Irish Sea (VIIa) | 1 000 | 3 000 | outside SBL |
| Celtic Sea (VIIf and g) | 900 | 2 000 | outside SBL |
| Megrim | | | |
| VI | 3 600 | na | within SBL |
| Anglerfish | | | |
| VI | 12 800 | na | outside SBL |
| Elasmobranchs (sharks, skates, rays)[‡] | | | |
| VIa, VIIa, VIIb, VIIf, VIIg-k | 32 300 | na | na |
| | | | |
| Region III – IV | | | |
| Megrim | | | |
| VII and VIIIa,b,d,e | 17 300 | 65 000 | within SBL |
| Anglerfish | | | |
| VIIb-k and VIIIa,b | 28 900 | 73 700 | within SBL |
| | | | |
| Region IV | | | |
| Sardine | | | |
| VIIIc & IXa | 115 000 | 253 000 | outside SBL |
| Anchovy | | | |
| VIII & IXa | 27 500 | na | within SBL |
| Mackerel | | | |
| VIIIc & IXa | 41 000 | see combined stock below | see combined stock below |
| Horse mackerel | | | |
| VIIIc & IXa | 57 000 | 256 000 | close to SBL |
| Hake | | | |
| VIIIc & IXa | 7 600 | 13 200 | outside SBL |
| Sole | | | |
| Bay of Biscay (VIIIa,b) | 6 900 | 13 600 | outside SBL |
| Megrim (*L. boscii*) | | | |
| VIIIc & IXa | 900 | 5 300 | outside SBL |
| Megrim (*L. whiffiagonis*) | | | |
| VIIIc & IXa | 360 | 1400 | outside SBL |
| Anglerfish (*L. budegassa*) | | | |
| VIIIc & IXa | 1 800 | na | outside SBL |
| Anglerfish (*L. piscatorius*) | | | |
| VIIIc & IXa | 3 700 | na | outside SBL |
| | | | |
| Region V | | | |
| Greenland Halibut | | | |
| Tuna | | | |
| Marlin | | | |
| | | | |
| Region I, II, III, IV, V | | | |
| Mackerel (highly migratory) | | | |
| North Sea component | ~ 10 000, closed in southern and central North Sea | | outside SBL |
| combined stock | 570 000 | 2 650 000 | outside SBL |
| Blue whiting (highly migratory) | | | |
| Norwegian Sea | 63 000 | | |
| Region I | | | |
| Region II, III and V | 541 000 | | |
| Region IV | 30 000 | | |
| combined stock | 634 000 | 2 718 000 | within SBL |
| Western horse mackerel (highly migratory) | 3 000 | | |
| Region I | | | |
| Region II | | | |
| IVa only | 64 000 | | |
| Region III | ~ 358 000 | | |
| Region IV | | | |
| VIIIc and IXa only | ~ 12 000 | | |
| combined stock | 443 000 | 1 000 000 | outside SBL |
| Northern hake (highly migratory) | | | |
| IIIa, IV, VI, VII and VIIIa,b | 44 200 | 127 000 | outside SBL |

* A stock is considered to be outside or harvested outside ‘safe biological limits’ (SBL) when the spawning stock biomass is below $B_{pa}$, which is the lowest biomass where there is a high probability that the production of offsprings/recruits is not impaired, or when the fishing mortality is higher than $F_{pa}$, which is a fishing mortality that with high probability is sustainable; † taken from ICES (1999b); ‡ Statlant data.

environment is highly heterogeneous in terms of habitats. For this reason, the algal diversity is high. For example, approximately 700 macroalgal species are found in the Channel area. The sediments of intertidal flats are colonised by hundreds of species of microscopic benthic algae. Most of them are diatoms, whose populations are also accompanied by blue-green algae and interstitial flagellates. In addition to the microalgae populations shallow areas are to some extent covered by beds of higher plants such as *Zostera* and *Ruppia* species.

Besides providing habitat for epiphytic species, macroalgae and eelgrass provide food for numerous grazers and deposit feeders. As with excessive algal blooms, mass development of macroalgae due to excess nutrients may entail oxygen depletion in the bottom water following microbial breakdown of the excess biomass.

#### Zoobenthos

The bathymetry of the OSPAR area ranges from shallow continental shelf to abyssal plains (around 5000 m depth). Deep-ocean benthos tends to be much smaller than its shallow-water counterparts and it is generally accepted that species diversity increases with depth in the continental shelf regions to a maximum just seaward of the continental rise, and then decreases with increasing distance towards the abyssal plain (Levinton, 1995).

The Greenland–Scotland Ridge is a major biogeographical boundary for benthos within the OSPAR area. This ridge forms a barrier between warm- and cold-water species.

Large areas of coral banks of *Lophelia* occur in the Atlantic Ocean near the continental shelf break off Ireland, Scotland, the Faroe Islands, Norway, and off the south coast of Iceland. High diversity of biota is associated with these coral banks.

In shallow shelf areas such as the North Sea, benthic and pelagic processes are often strongly coupled and work in concert to make the region highly productive. Highly productive benthic communities can be found in tidal areas, for example in the Wadden Sea along the south-eastern border of the North Sea, and in several estuaries along the western European coast.

On the shores of northern and north-western Spain and on the Portuguese shore hard substrata are dominated by sessile and slow moving macrofauna in the upper levels. Intertidal and subtidal soft bottoms on the shores of northern and north-western Spain have a rich infauna related mainly to grain size and organic matter content. Along the Portuguese coast, intertidal sands have a low faunal density, whereas fauna in the subtidal soft substrata is more abundant due to the increase in sediment organic matter.

Frontal regions, where different ocean currents meet, normally have a high primary production resulting in highly productive benthic communities. Such frontal regions occur throughout the OSPAR area: in the Denmark Strait, between Iceland and the Faroe Islands, in the western part of the Barents Sea, in the Norwegian Sea, in the North Sea, in the Kattegat/Skagerrak area and the Irish shelf front, to the west of Ireland.

### 5.2.5 Fish and squid

Over a thousand species of fish have been recorded in the OSPAR area. Of these, about 5% can be commercially exploited and about 2% of species make up 95% of the total fish biomass. The major commercially exploited fish stocks in each part of the OSPAR area are given in *Table 5.1*. The larvae of many commercially important fish species disperse into the open ocean from their spawning grounds at the continental shelf and in estuarine areas. Some fish species perform long annual migrations between the feeding, spawning, and overwintering areas. Variability in stock recruitment is related to both the size of the parental stock and to a number of factors, including environmental variability and predation, which affect egg and larval survival.

Approximately 160 species of fish have been recorded in the Barents Sea, with the total number of species in Region I unlikely to exceed 200. Much of the total fish biomass is concentrated in a few species, which are exploited commercially. The number of fish species is comparatively low in the shallow southern North Sea and eastern Channel and increases towards the Celtic Sea and Bay of Biscay. Overall, around 250 species have been found in Region II, with more species occurring commonly than in Region I. In the Bay of Biscay and Region III the number of species reaches 700, since many northern species reach their southern limit of distribution and many southern species reach their northern limit of distribution along the boundary for cold temperate species in the vicinity of 47° N. Along the Iberian coast in Region IV, the number of species remains high, as more demersal species of southern or Mediterranean distribution occur. The biodiversity of Region V is less well quantified, particularly in deeper waters, but fewer species are likely to occur than on the continental shelf.

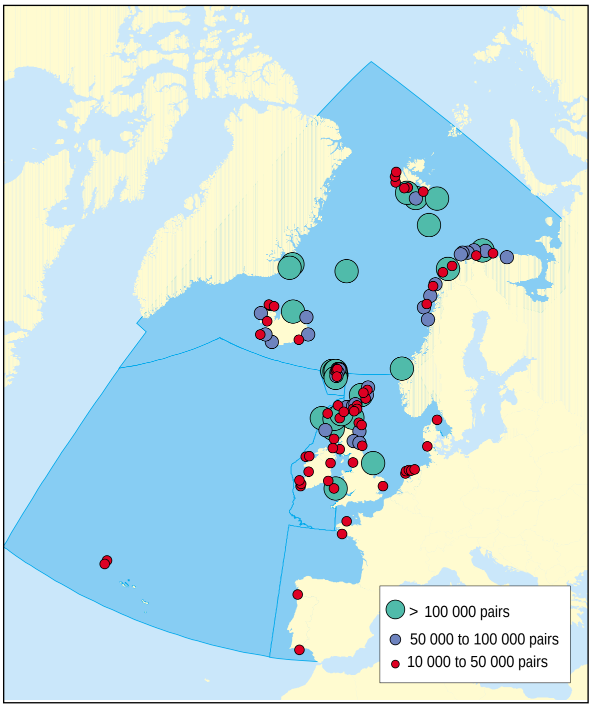
Many deep-water species have an extensive geographical distribution owing to the small environmental variations of their habitat. In the Wider Atlantic, top predators such as sharks probably play an important role in maintaining the structure and diversity of fish assemblages. Large pelagic predators (tuna and marlin) are highly migratory, ranging far beyond the boundaries of the OSPAR region.

The biology of squid is poorly known despite being very abundant especially in the Wider Atlantic. Only a few species are exploited commercially but squid are of considerable ecological importance as predators and as the food of some whales, fish and seabirds.

### 5.2.6 Birds

Almost all parts of the OSPAR area support breeding and migratory birds dependent on the sea. Proportionately, the greatest numbers of breeding seabirds nest on the coasts of Arctic waters and the North Sea. Total numbers of individuals in these northern areas are several orders of magnitude greater than those in the southern regions of the OSPAR area *(Figure 5.2)*. The total numbers of species, and two most common species in each Region are shown in *Table 5.2*. Only the great skua (*Catharacta skua*) is endemic to the OSPAR area, although some species are near-endemic (e.g. Manx shearwater (*Puffinus puffinus*)) or have endemic sub-species (e.g. shag (*Phalacrocorax aristotelis*)). Surveys of distribution at sea have not been carried out in all parts of the OSPAR area, but in those that have been studied surveys show shelf seas to hold substantially higher densities than oceanic waters. Large intertidal flats, such as in estuaries and in the Wadden Sea are particularly important for wading birds. Some 6 – 12 million birds of more than 50 different species may be present in the Wadden Sea at some times of the year.

Figure 5.2 **Location of large seabird breeding colonies in the OSPAR area. Source of data: Grimmett and Jones (1989).**




### 5.2.7 Marine mammals and turtles

#### Cetaceans

Whales are divided into two groups: baleen whales (primarily feeding on small fish and plankton) and toothed whales (preying on fish, squid and marine mammals). Over 30 species of cetaceans occur throughout the OSPAR area, ranging in size from the small harbour porpoise at < 2 m (*Phocoena phocoena*) to the giant blue whale (*Balaenoptera musculus*) at about 33 m *(Table 5.3)*. Following the moratorium on commercial whaling for most species, numbers of most species of large whale are showing signs of recovery. There has been an increase in recorded strandings of cetaceans in the North Sea and the Celtic Sea over the past few decades, but the reasons for this are not known.

#### Seals and bears

Some seal species live in coastal areas; others are adapted to the sea ice and never come ashore. All seals are carnivorous, feeding on fish, krill, pelagic amphipods or benthic animals. The vast majority of the seal population is found in Region I *(Table 5.3)*. Individual seals of all species have occurred well away from their normal range in the OSPAR area. Approximately 40% of the world's population of grey seals breed in the waters around Europe. The number of pups has increased steadily (by a factor of three or more) over the past 30 years.

Apart from the effects of commercial sealing, the only major change in the population of seals resulted from the

**Table 5.2 Number of species of seabirds breeding on coasts of the OSPAR Regions, with approximate population sizes for the two most common species in each Region. Note that even for the most common species, population sizes are not all well known.**

| | No. species | Most common two species | Population size (pairs) |
|---|---|---|---|
| Region I | 33 | little auk | 4 600 000 |
| | | puffin | 3 900 000 |
| Region II | 31 | common guillemot | 480 000 |
| | | kittiwake | 420 000 |
| Region III | 26 | common guillemot | 110 000 |
| | | storm petrel | 50 000 – 100 000 |
| Region IV | 21 | gannet | 150 000 |
| | | yellow-legged gull | 74 000 |
| Region V | 13 | Cory's shearwater | 50 000 – 100 000 |
| | | Madeiran petrel | 1 200 |

1988 phocine distemper virus outbreak. This fatal disease, which took on epidemic proportions, had the greatest impact on the eastern side of the North Sea where the population of harbour seals in the Wadden Sea was reduced from 10 000 to 4000 between 1988 and 1989. Since then the population has recovered and in 1998 consisted of more than 14 000 individuals.

Polar bears have a circumpolar distribution and are confined to ice covered areas of the Arctic *(Table 5.3)*. The distribution of bears between Eastern Greenland and Franz Josef Land is largely determined by the extension of the pack ice.

### Turtles

The range of most sea turtles is in tropical or subtropical waters but some species undertake long migrations using the warm current of the Gulf Stream. For this reason, a few species visit the Bay of Biscay, the Iberian coast and the wider Atlantic every year. The one species that is frequently recorded in the OSPAR area is the loggerhead turtle (*Caretta caretta*).

## 5.3 Impact of human activities

Owing to large natural variability and limited knowledge of cause-effect relationships, human influences on the biology of the OSPAR area are difficult to establish in the majority of cases. A direct link to human activities is clear for some contaminants (e.g. TBT), the exploitation of marine mammals, and for fishery effects on benthic invertebrates and seabirds. The need for an improved knowledge of anthropogenic effects on biota is recognised and is being developed within OSPAR and other bodies.

### 5.3.1 Impact of non-indigenous species

Non-indigenous species may arrive as a result of both natural (e.g. water currents) and human-mediated processes (e.g. ships' ballast water, hull fouling and commercial transport of fish and shellfish). To date, over one hundred non-indigenous species representing a large spectrum of taxonomic and ecological groups of organisms (plankton, macroalgae and benthos) have been recorded in the OSPAR area, mainly in the North Sea, the Celtic Sea, the Bay of Biscay and along the Iberian coast. A few non-indigenous species were deliberately introduced to the area mainly for mariculture purposes. The most significant ecological effects of these introductions are competition (for food, space or light) or predatory interactions with indigenous species, and pathogenic or other harmful effects. A list of some of the non-indigenous species that have had impacts in the OSPAR area is shown in *Table 5.4*.

**Table 5.3 Marine mammals of the OSPAR area.**

| | I | II | III | IV | V |
|---|---|---|---|---|---|
| bowhead whale* | X | | | | |
| northern right whale* | | | X | X | X |
| minke whale | X | X | X | X | X |
| sei whale† | X | (X) | (X) | X | X |
| Bryde's whale | | | | (X) | (X) |
| blue whale‡ | X | (X) | (X) | X | X |
| fin whale | X‡ | X | X | X | X‡ |
| humpback whale | X‡ | X | X | X | X‡ |
| pygmy sperm whale† | | | | X | X |
| dwarf sperm whale† | | | | (X) | (X) |
| sperm whale | X | (X) | (X) | X | X |
| white whale / beluga | X | | | | |
| narwal† | X | | | | |
| northern bottlenose whale | X | (X) | (X) | X | X |
| Sowerby's beaked whale† | X | (X) | (X) | X | X |
| Blainville's beaked whale† | | | | (X) | (X) |
| Gervais' beaked whale† | | | | | (X) |
| True's beaked whale† | | | (X) | (X) | (X) |
| Cuvier's beaked whale† | (X) | (X) | | X | |
| pygmy killer whale† | | | | | X |
| short-finned pilot whale | | | | X | X |
| long-finned pilot whale | X | X | X | X | X |
| killer whale | X | X | X | X | X |
| melon-headed whale | | | | | X |
| false killer whale | | | | (X) | X |
| common dolphin | X | X | X | X | X |
| striped dolphin | | | X | X | X |
| Atlantic spotted dolphin | | | | (X) | X |
| rough-toothed dolphin | | | | X | X |
| bottle-nosed dolphin | | X | X | X | X |
| Risso's dolphin | | X | X | X | X |
| Atlantic white-sided dolphin | X | X | X | X | X |
| white-beaked dolphin | X | X | X | X | (X) |
| harbour porpoise | X | X | X | X | X |
| walrus | X | | | | |
| harbour seal | X | X | X | (X) | |
| ringed seal | X | | | | |
| harp seal | X | | | | |
| bearded seal | X | | | | |
| hooded seal | X | X | X | X | X |
| grey seal | X | X | X | (X) | |
| polar bear | X | | | | |

X indicates that a species is present. Bracketed records indicate vagrant animals, these are mostly species that normally occur in deep water, or are tropical species; * numbers substantially below 'natural' levels due to past hunting; † the status of most of the beaked whales and some other whales is poorly known; ‡ numbers below or substantially below 'natural' levels.

### 5.3.2 Harmful algae

The vast majority of algal phytoplankton are harmless and form the basis for marine food webs. At times, however, they may occur in large concentrations and colour the water red or brown. At these concentrations the algae may be harmful to other marine life by reducing levels of oxygen or clogging gills of fish. Some algal species are toxic to marine life and to humans and some species may through their breakdown cause large masses of foam to develop on beaches that are aesthetically undesirable and can affect tourism (see *Table 5.5*). Fish farmers can suffer serious financial losses if harmful algal blooms pass through fish cages. In the period up to the early 1990s, the occurrence of harmful algal blooms increased both in space and time (Hallegraeff, 1995). Several mechanisms related to human activities may have driven this trend:

- introduced species via e.g. ballast water, mariculture;
- coastal installations intensifying stratification e.g. Bay of Vilaine;
- anthropogenic inputs and fluxes of nitrogen into areas susceptible to eutrophication;
- unbalanced nutrient ratios, e.g. N : P and N : Si;
- hydroelectric power plants – exceptional discharges; and
- increasing inputs of humic substances from rivers due to acid rain.

Algal toxins can accumulate in the edible tissue of bivalve molluscs (e.g. mussels) to levels that can be dangerous to the human consumer. Many countries in the OSPAR area have established biotoxin-monitoring programmes that provide early warning of the composition and numbers of toxic plankton species and levels of toxins in bivalve tissue. Warning and closure notices can be issued if permissible standards of toxins in shellfish are exceeded. The principal toxins monitored in the OSPAR area are those that cause Paralytic Shellfish Poisoning (PSP), Diarrhetic Shellfish Poisoning (DSP) and Amnesic Shellfish Poisoning (ASP). ICES provides decadal maps which give information on the regional occurrence of shellfish poisoning (ICES, 1999c and 2000).

### 5.3.3 Impact of microbiological pollution

Microbiological pollution may affect all marine biota, including invertebrates, fish, and seals. In the OSPAR area, the most important concerns are molluscs and bathing water quality. Discharges of sewage (treated and untreated) to the sea takes place throughout the coastal regions of the OSPAR area. The bacteria and viruses associated with sewage and other sources such as agricultural run-off, mainly attached to fine particulate matter, can affect bathing water quality and can accumulate in filter feeding shellfish such as mussels. The EC Directives for shellfish water quality (79/923/EEC) and shellfish hygiene (91/492/EEC) lay down permissible limits for levels of bacteria in water and shellfish respectively (the latter also applies to Iceland, and both apply to Norway). The country to which the relevant directive applies is obliged to establish appropriate monitoring programmes and to classify shellfish growing waters. Existing standards for the microbiological quality of bathing water (EC Directive on the quality of bathing water 76/160/EEC) and shellfish, although important in the protection of public health, may not protect all individuals against the entire range of human pathogens to which they might be exposed either through bathing or seafood consumption.

#### Bathing water quality

Since monitoring work began there has been a marked improvement in quality of bathing water, owing to the use

**Table 5.4 Some of the non-indigenous species in the OSPAR area including their mode of introduction and potential impact in each Region.**

| | Mode of introduction* | First observation† | Potential impact | Region‡ |
|---|---|---|---|---|
| bay barnacle | fouling (A) | 1844 (Sweden) | habitat altered<br>competition | I, II |
| soft-shelled clam | aquaculture (A) | 1200s (Denmark) | competition | I, II, III |
| Japanese seaweed | aquaculture (A) | 1971 (UK) | interference with water exchange<br>competition | II, III, IV |
| Pacific oyster | aquaculture (D) | 1926 (UK) | competition | II, III, IV |
| Atlantic razor clam | ballast water / sediment (A) | 1968 (Germany) | competition | II |
| *Marenzelleria viridis* (polychaete worm) | ballast water (A) | 1982 (Germany/UK) | competition | II |
| slipper limpet | aquaculture (A) | 1926 (Netherlands) | habitat altered<br>competition | II, III, IV |
| common cord grass | aquaculture (A) | | decreased habitat availability<br>competition | II, III, IV |
| *Bonamia ostrea* (protozoan) | aquaculture (A) | | oyster mortality | III, IV |
| *Elminius modestus* (barnacle) | fouling (A) | 1940 (UK) | competition | II, III, IV |

* D: deliberate introduction; A: accidental introduction; † first recorded observation by a Contracting Party in the OSPAR Convention area;
‡ OSPAR Region where the species is established or probably established.

**Table 5.5 Harmful algal bloom species in the OSPAR area.**

| Effect | Probable organisms | Mode of action | Region |
|---|---|---|---|
| Toxic to humans (via the food chain) | | | |
| PSP | *Alexandrium* spp. (e.g. *Alexandrium tamarense*) | chemical | I, III, IV |
| | *Gymnodinium catenatum* | chemical | IV |
| DSP | *Dinophysis* spp. | chemical | III, IV |
| ASP | *Pseudo-nitzchia australis* | chemical | III, IV |
| Non-toxic to humans, harmful to fish and/or invertebrates | | | |
| fish mortality (Ichthyotoxin) | *Chrysochromulina* spp. | chemical | I, II |
| | *Heterosigma akashiwo* | chemical | I, II |
| | *Gyrodinium aureolum* | chemical | II, III |
| | *Prymnesium parvum* | chemical | II |
| | *Chattonella antiqua* | chemical | II |
| | *Chattonella marina* | chemical | II |
| fish mortality (neurotoxin) | *Chattonella verruculosa* | chemical | II |
| | *Fibrocapsa japonica* | chemical | II |
| Non-toxic | | | |
| clogs / damages fish gills | *Phaeocystis* spp. | physical | II |
| | *Coscinodiscus* spp. | physical | II |
| fish mortality | *Dictyocha speculum* | physical | I, II |
| foam production on beaches | *Phaeocystis pouchetti* | physical | III |
| water discolouration | *Noctiluca* spp. | physical | III |

of wastewater treatment plants. For example in the UK, the percentage of bathing areas meeting the standards has increased from 66% in 1988 to 90% in 1996. The vast majority of bathing waters in the OSPAR area now conform to the standard under the EC Directive. Where standards are not met, action is taken by the responsible authority within each country to improve bacterial quality of the bathing water.

#### Shellfish hygiene directive

All molluscan shellfish harvesting areas are required by EC Directive 91/492/EEC to be classified according to the extent to which shellfish samples from each area are contaminated with *Escherichia coli*. The classification of areas ranges from clean areas where molluscs can be sold for direct human consumption, to those from which molluscs need to be treated before consumption and those where molluscs are prohibited for human consumption. In some OSPAR Regions, the contamination of shellfish with *E. coli* has led to restrictions on marketing shellfish and has increased processing costs, which have caused concern within the shellfish industry. These concerns have focused attention on water quality within shellfish harvesting areas and in some cases have prompted water quality improvements through improved sewage treatment systems.

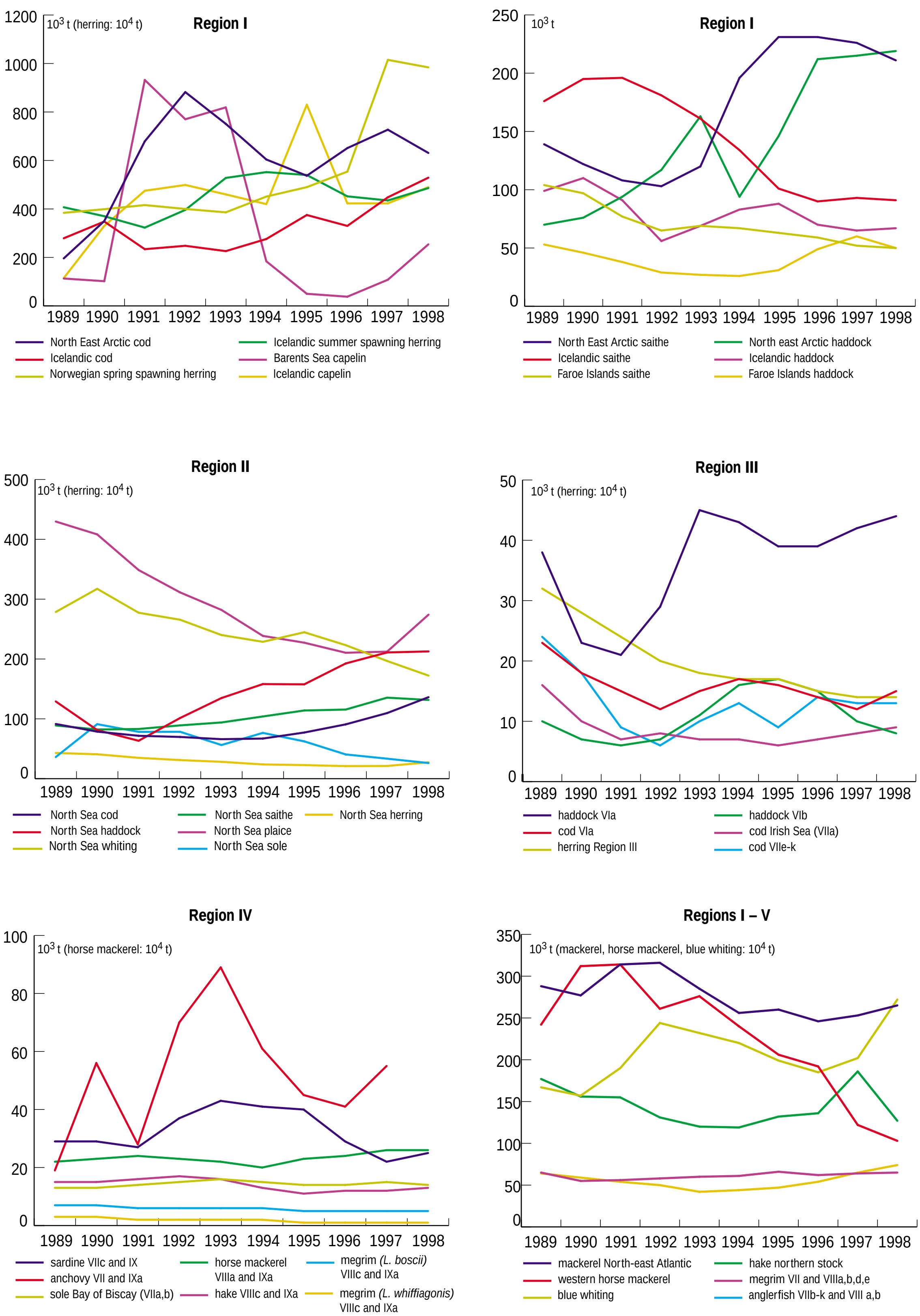
### 5.3.4 Impact of fisheries on ecosystems

Commercial fishing has direct and indirect effects on the marine ecosystem. These can be summarised as follows:

- removal of target species;
- mortality of non-target species (fish and invertebrates), birds and marine mammals, through their incidental catch in fishing gear;
- physical disturbance of the sea bottom through some demersal fishing gear and therefore an adverse impact on benthic habitats and communities;
- shifts in community structure; and
- indirect effects on the food web.

The fish stock biomass of the exploited species in the main fishing areas has fluctuated considerably over the past 50 years. Ten-year trends in the biomass of a number of the spawning stocks in the OSPAR area are shown in *Figure 5.3*. Two main factors are responsible for these fluctuations, namely commercial fishing pressure and the recruitment of young fish to the spawning stock. In some cases, intensive fishing combined with poor recruitment depleted stocks to the point where they could no longer support a commercially viable fishery. Examples of this are a number of herring stocks such as the Norwegian spring spawning and North Sea stocks that collapsed in the 1960s and 1970s. As a result, bans on fishing were imposed to allow the stock to recover. In 1999, ICES reported that 40 of the 60 major stocks for which OSPAR requested information were outside ‘safe biological limits’ (see definition in footnote to *Table 5.1*). The results of this assessment are summarised in *Table 5.1*.

Figure 5.3 **Ten-year trends in spawning stock biomass for stocks in each of the four main OSPAR Regions together with migratory stocks that extend into more than one Region.**



In regions where commercial stocks have been over-exploited, fishing pressure is often switched to stocks in other areas, including deep-sea populations. The slow growth rates and low fecundity of many deep-sea fish makes them especially vulnerable to overexploitation. Evidence is beginning to emerge that deep-sea trawling inflicts damage upon some of the deeper ecosystems. These impacts may already be quite extensive and recovery can be relatively slow.

Non-target catch can include juveniles of target species and juveniles and adults of non-target species as well as large benthos, mammals and seabirds. Juvenile fish are sometimes unable to escape from trawl nets. This occurs mainly where small mesh nets are used such as in fisheries for shrimp and *Nephrops*, and in mixed roundfish and flatfish fisheries. High rates of capture of juvenile whiting in the Irish Sea led in 1992 to the mandatory use of square mesh panels in UK trawl nets. Ireland followed in 1994. Other technical measures introduced to reduce discarding include sorting panels or grids in fisheries for shrimp and deep water *Pandalus*. During the 1990s, about half of the total catch in numbers of whiting and haddock taken by trawlers off the west coast of Scotland were discarded. In *Nephrops* fisheries in the Irish Sea, just under half a tonne of whiting is discarded for every tonne of *Nephrops* landed. In certain flatfish fisheries in the North Sea more than half of the weight of the fish caught may be discarded. The discarded fish represent an additional mortality to the stocks since they do not normally survive to become adults. The discards also alter the competitive relationships within the communities by favouring the scavenging species.

Harbour porpoises, dolphins and seals are the most common mammals entangled in fishing gear. Harbour porpoises are particularly vulnerable to bottom-set gillnets. Some dolphins are vulnerable to drift nets. A Danish action plan for reducing incidental by-catches of harbour porpoises includes measures such as the use of acoustic alarms, modifications to fishing equipment and regulation of certain types of fisheries. In order to assess the significance of any by-catch, it is important to know both the rate of annual by-catch, and the size of the population from which that by-catch was taken. Biological considerations indicate that by-catch rates above 1% of abundance may not be sustainable, and rates above 2% have an unacceptably high risk of unsustainability (ASCOBANS 1997). There have been few studies in the OSPAR area that have acquired the necessary data. Estimates for the central North Sea (extrapolated from Danish set-net fisheries) suggest that there was an average annual by-catch of approximately 7000 harbour porpoises over the period 1994 to 1998 (Vinther, 1999). This estimate exceeds 2% of the relevant porpoise population, which is considered non-sustainable. The proportion of the harbour porpoise population by-caught on the Celtic shelf may have exceeded 6% in the mid-1990s (Tregenza *et al*., 1997), but there has been some reduction in fishing effort since the studies were carried out. In the Bay of Biscay and along the Iberian coast, during 1992 and 1993, observers on French Albacore drift netters recorded a by-catch of 204 common dolphins (*Delphinus delphis*) and 573 striped dolphins during 1420 hauls. As a result of this and other observations, EU Fisheries Ministers voted in June 1998 to introduce a ban on drift net fishing for tuna. This will come into effect after 31 December 2001.

Increases in seabird populations over the past decades have been attributed to a number of factors, for example better protection, increases in small prey fish and an increase in fish discards and offal from commercial fishing boats. Periodically, some species have experienced a sharp fall in numbers. Some changes are directly related to a decrease in fish prey for example the decline in the common guillemot (*Uria aalge*) and puffin (*Fratercula arctica*) populations in some parts of the Arctic area following the decrease in stocks of capelin (*Mallotus villosus*) and herring respectively. In the North Sea, it is estimated that seabirds annually consume approximately 50% of all discards (109 000 t) and offal (71 000 t).

Bottom fishing gear can cause death or severe damage to benthos and physical disturbance to sediments. The degree of the impact is related to towing speed, gear size and weight, substrate type and local hydrodynamic factors. It should be stressed, however, that trawling is very patchy and that the impact of trawling is less severe in areas naturally impacted by storms and wave disturbance. The effects of gear type, in terms of seabed disturbance and species affected, in the North and Celtic Seas are given in ***Table 5.6***. Otter trawl boards may penetrate into soft sediment seabeds by 6 – 20 cm. The tickler chains from beam trawls plough sediments to a depth of 4 – 8 cm. Deep-water benthic habitats tend to be very susceptible to the impact of trawling, due to their slow regeneration rate. A 1994 survey indicated that up to 25% of the Irish Sea seabed is disturbed by otter trawling. The Irish otter trawl fleet alone trawls the Irish Sea *Nephrops* grounds up to five times per year. Data from the Dutch beam trawl fleet, which represents approximately 80% of the total beam trawl effort in the North Sea, indicate that about 171 000 $km^2$ of the North Sea between the Shetland Islands and the Hardangerfjord, and the Strait of Dover (i.e. approximately 429 000 $km^2$) is fished by trawlers (Rijnsdorp *et al*., 1997). Within the fished area, 70% is trawled less than once a year and, in total, about 10% of the North Sea region specified above is fished more than once per year. In the Dutch Wadden Sea, fishing for cockles in years of low abundance of this species has caused a food shortage for wader birds, for example oystercatchers (*Haematopus ostralegus*). However, since 1993, strict regulations have prevented

**Table 5.6 Effects of different types of fishing gear in terms of seabed disturbance, some of the species affected and estimated area trawled in the OSPAR region. Source: Region II (5NSC, 1997); Region III (Kaiser *et al*., 1996).**

| Gear type | Penetration depth | Species affected | Estimated area trawled |
|---|---|---|---|
| Otter trawl (pair and twin) | ground rope, bobbins chains: < 5 cm (soft bottom) < 2 cm (hard bottom) trawl door: 6 – 20 cm (soft bottom) | epifauna Region II: Crustacea (*Corystes, Eupagurus*), Mollusca (*Abra alba, Arctica islandica, Donax vittatus, Spisula subtruncata, Placopecten*), Echinodermata (*Echinocardium, Psammechinus miliaris*), Cnidaria (*Alcyonium digitatum*) Region III: Mollusca (*Arctica islandica*), Polychaeta (*Lanice conchilega, Spiophanes bombyx*), Echinodermata (*Echinocardium cordatum, Asterias rubens*) | Region II: 99 000 km$^2$ (entire North Sea) Region III: 25% of Irish Sea |
| Beam trawl | chains: 4 – 8 cm (soft bottom) 3 – 6 cm (hard bottom) trawl heads: 7 – 10 cm combined effect of beam trawling in other areas: < 10 – 20 cm deep tracks noted | epifauna Region II: same as otter trawl, plus *Pectinaria* spp. *Aphrodite aculeata*, sipunculida & tunicates, molluscs (*Tellimya ferruginosa, Turritella communis, Chamelea gallina, Dosinia lupinus, Mactra corallina*) Region III: same as otter trawl, plus *Nephthys hombergii, Corbula gibba* and Tanaid copepods | Region II: 171 000 km$^2$* (area between Shetland Islands and Hardangerfjord, and the Strait of Dover) Region III: 22% of Irish Sea |
| Demersal pair trawl | ground rope: 1 – 2 cm | same as for otter trawl | Region II: 108 000 km$^2$ (entire North Sea) |
| Twin trawl | same as for otter trawl but without door | same as for otter trawl | |
| Seines and ring nets | zero | minimal effect on benthos | Region II: 245 km$^2$ (entire North Sea) |
| Pair seine | zero | minimal effect on benthos | |
| Dredges | mussel dredge: 5 – 25 cm cockle dredge: 5 cm scallop dredge: 3 – 10 cm | same as for beam trawl | Region II: estuarine and coastal areas of North Sea Region III: 8% of Irish Sea |
| Shrimp beam trawl | bobbins: 2 cm | benthos and juvenile fish | Region II: estuarine and coastal areas of North Sea |
| Prawn trawl | bobbins: 2 cm | benthos and juvenile fish | Region II: northern North Sea |
| Industrial trawls | same as for otter trawl | same as for otter trawl | Region II: 11 000 km$^2$ pair trawl (central North Sea), 127 000 km$^2$ single trawl (entire North Sea) |

* Source: Rijnsdorp *et al*. (1997).

this from occurring.

Disturbance of the seabed by fishing gear can also change the species and size composition of benthos. For example, in areas of the North Sea, where fishing disturbance has occurred over a long period of time, there has been a shift in benthic diversity and composition from larger more long-lived benthic species to smaller more opportunistic species. In the Dutch Wadden Sea, there is discussion about the effects of cockle fisheries on possible changes in macrozoobenthos and sediment composition. Research has been commissioned to identify the precise nature of these effects. Recent investigations along the Norwegian coast show the damage caused to the coral reefs by trawling to be quite extensive. Legislation for the protection of reef areas in Norway has been implemented.

### 5.3.5 Impact of mariculture

In the OSPAR region, mariculture activity consists of salmon farming in large cages moored in sheltered waters and intensive and extensive cultivation of bivalve molluscs.

All types of mariculture are faced with the problem of producing an excess of nutrients and deposition of organic material in the vicinity of the mariculture facilities, especially in areas with poor flushing characteristics. This can result in increased organic content of sediments, decreased faunal diversity and the prominence of opportunistic polychaetes.

Shellfish cultivation involves less intensive manipulation of the environment than finfish cultivation. Mussel cultivation in the Wadden Sea involves the removal of young specimens from natural mussel beds; this has contributed to a decline in the area covered by wild mussel beds over the last two decades. Where imported bivalve molluscs are to be cultivated, there is always the possibility of introducing pests and diseases to the area that may affect indigenous species. In recognition of this possibility, ICES issued a Code of Practice on the Introductions and Transfer of Marine Organisms (ICES, 1994), to help minimise problems resulting from shellfish and other introductions. To avoid the introduction of non-indigenous species to Dutch coastal waters, a new policy for the import of shellfish and crustaceans was developed in 1996. Until 2003, specific restrictive regulations exist regarding the introduction of indigenous species into the Wadden Sea and eastern Scheldt area.

The effects of salmon farming are usually confined to inshore waters. What is still not clear, owing to a lack of data, is what effect escaped reared salmon will have on the genetic structure of the wild salmon populations in the OSPAR area.

Sea lice are copepod ectoparasites of fish that are common to both wild and farmed fish. Infestation in most marine salmon farms is initially from local wild salmon. Heavy infection on farmed salmon may result in tissue damage and heavy financial losses. Once caged fish become heavily infected this can lead to them infecting the nearby wild populations. There is also the potential for other parasites and diseases to be transferred from farmed to wild fish and vice versa. Improved husbandry and farm management, combined with the use of chemical treatments and vaccination, are being used to reduce infections and the outbreak of diseases among farmed stocks. In the UK, a recent joint Government–Industry Working Group has identified a range of husbandry and management measures to contribute to the control of Infectious Salmon Anaemia (ISA).

Chemicals are used for different purposes in mariculture, for instance to prevent diseases (antibiotics), to get rid of parasites (pesticides) and to prevent ‘growth’ on cages/nets (antifoulants). There are general concerns over the use of such chemicals but their impact is probably limited to the immediate vicinity of the fish farm area.

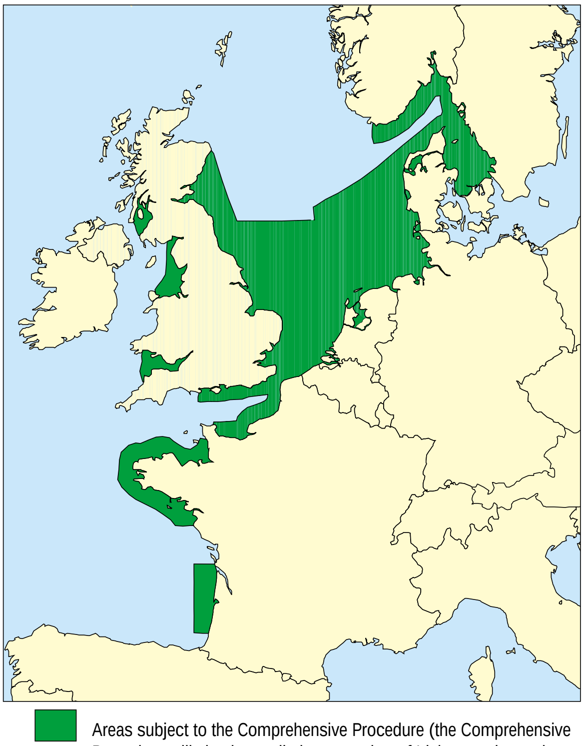
### 5.3.6 Impact of eutrophication

Eutrophication, as defined by OSPAR, refers to the undesirable effects resulting from anthropogenic enrichment by nutrients as described in its Common Procedure for the Identification of the Eutrophication Status of the Maritime Area adopted in 1997. The impacts of eutrophication include: increased phytoplankton and macroalgae production and biomass; changes in species composition (including the occurrence of harmful algae and short-lived benthic algae in shallow waters as well as changes in the animal communities); and increased oxygen consumption in water and sediments, in some cases leading to detrimental effects on benthic fauna. Eutrophication is non-existent in the open shelf and deep areas of the OSPAR region. However, within the coastal zone, embayments and estuarine areas of some parts of the maritime area, particularly the south-eastern part of Region II, there is clear evidence of eutrophication. The disturbance caused by increased nutrient loads in coastal areas may also have an effect on marine ecosystems outside the immediate area. The first step in the Common Procedure is a Screening Procedure to identify the more obvious non-problem areas. The results of the Screening Procedure are illustrated in *Figure 5.4*. Classification of the eutrophication status of the remaining areas into problem areas, potential problem areas or non-problem areas will be made by applying the Comprehensive Procedure, the second part of the Common Procedure (see *Figure 5.4*). However, several of these areas are already being considered as problem areas by the coastal states.

Some of the earlier eutrophication-linked events in the North Sea have been documented in the 1993 North Sea QSR (NSTF, 1993). These include increased production of phytoplankton in the coastal areas of the eastern part of the North Sea, the linking of inputs of nutrients to the extended duration of blooms in the Wadden Sea and changes in phytoplankton and zooplankton structure in the German Bight. In the Celtic Seas, there are indications that the Mersey Estuary / Liverpool Bay area and Belfast Lough may be showing signs of eutrophication and, as a result, reductions in nutrient inputs are probably required. Concern has been expressed over the occurrence of areas of anoxic sediment (‘black spots’) and accompanying mortality of benthos in the Wadden Sea in 1996, which was the result of an exceptional coincidence of meteorological and biological developments (de Jong *et al*., 1999).

Temporarily increased concentrations of nutrients in for example the Ria of Huelva (Spain) may be associated with eutrophication. A further example is the Bay of Vilaine, where oxygen depletion of bottom waters takes place each summer following the phytoplankton blooms. Depending on the level of spring rainfall and the extent of nitrate input through key small rivers, a few hydrodynamically confined areas on the north coast of Brittany can sometimes be affected by ‘green tides’, which deposit thousands of tonnes of the macroalga *Ulva lactuca* onto the beaches. Under certain conditions, algal foams can develop after spring blooms along the Belgian and Dutch coasts.

Figure 5.4 **Parts of the OSPAR maritime area to which the Comprehensive Procedure will be applied to determine their status with regard to eutrophication.**



Areas subject to the Comprehensive Procedure (the Comprehensive Procedure will also be applied to a number of Irish estuaries and to some local areas of possible concern). Areas to which the Comprehensive Procedure will not be applied have been classified as non-problem areas with regard to eutrophication as a result of applying the Screening Procedure. However, located within these non-problem areas may be some local areas of possible concern to which the Comprehensive Procedure will also be applied.

## 5.3.7 Impact of recreation and tourism

Pedestrian traffic and the use of motorised vehicles have increased pressure on some coastal dune systems, disturbing the natural vegetation and seabird habitats. Coastal habitats are being reduced or disturbed through the construction of recreational housing, caravan parks and golf courses. On some recreational beaches close to population centres the amounts of litter, particularly plastics and drink containers, are a continuing cause for concern. The growing popularity of yachting and boating is increasing demand for new marinas as well as potential for the introduction of non-indigenous species and pollution from antifouling paints.

In the North Sea, bird-breeding areas on sandy beaches have been almost completely lost because of recreational activities. Little tern (*Sterna albifrons*) and Kentish plover (*Charadrius alexandrinus*) are most strongly affected as their breeding success is reduced by human activities. In contrast, cessation of hunting in parts of the Wadden Sea has had a positive effect on the numbers of Brent geese (*Branta bernicla*), barnacle geese (*B. leucopsis*), and curlews (*Numenius arquata*). In Bannow Bay in south-east Ireland, which is designated as a Special Protection Area for birds, motorbike scrambling has weakened the dune systems and shooting has disturbed roosting birds. At other Irish sites, excessive human activity has excluded seabirds from parts of their natural habitat and denied them feeding opportunities. This has led to the initiation of protection schemes, especially along the east coast. Finally, disturbance of small cetaceans occurs as a result of interaction with high-speed boats (e.g. jet skis).

## 5.3.8 Impact of sand and gravel extraction

Sand and gravel extraction takes place in the inshore areas of the North Sea, particularly the southern part, the Celtic Sea and the French Atlantic coast. Not all of the extracted material is retained on board the vessel. The loss of material produces a temporary increase in turbidity in the water column and benthic organisms outside the dredged area may be impacted by settlement of both this residue and any resuspended material arising from this operation. In the short-term, the main impact on the ecosystem is the disturbance and removal of benthic organisms from the extraction site. There can be damage to sites that act as spawning areas for fish that lay their eggs directly on gravel, for example herring. In the longer-term, the rate of recovery of a site depends on the modifications made to the substrate and the potential of the benthos to re-colonise the area. For example, studies in the Wadden Sea showed that at extraction sites on sheltered intertidal flats, recovery of sediment composition and benthic fauna took more than fifteen years, whereas at sites with greater hydrodynamic activity, recovery was much faster. Studies carried out off the east coast of England, where extraction caused a reduction of approximately 40% and 80% respectively in the number and abundance of benthic species, revealed that a limited re-colonisation had occurred within a year (Kenny and Rees, 1994).

## 5.3.9 Impact of dredging and dumping of dredged materials

Most dredging serves navigational purposes in coastal approaches to and inside seaports. In some cases, for example near Rotterdam, dredged spoil from ports that is contaminated above certain limits is being deposited in specially built deposits. Slightly or non-contaminated dredged spoil is disposed of at dumpsites in estuaries and coastal waters. The effects of dredging activities are threefold. Increases in suspended matter in the water column can directly affect primary production and the growth of filter-feeding organisms such as bivalve molluscs. Enhanced sedimentation at dumpsites can lead to burial of the resident benthos. Finally, contaminants can be resuspended and remobilised from sediments and taken up into the food chain. However, dredging in the outer parts of estuaries may lead to larger-scale effects on the sediment dynamics, benthic communities and suspended matter regime.

### 5.3.10 Impact of coastal protection and land reclamation

Coastal protection, land reclamation and development of ports and harbours can affect coastal habitats. In many cases, habitats and associated ecological processes change permanently or even disappear. Examples of the latter are natural transition zones between freshwater habitats and coastal waters along the Dutch coast. At present for much of the OSPAR coastline there is insufficient information on recent rates of habitat loss in relation to habitat types and areas.

### 5.3.11 Impact of offshore activities and ship-generated oil spills

All oil-related activity in European waters is done under strict licence conditions, with the aim of minimising the effects on marine ecosystems. It should be noted however that this activity and the number of platforms have increased since 1993. Impacts on the benthic community are usually confined to a few kilometres around the platforms. These impacts are largely caused by the disposal of drill cuttings in the immediate vicinity of the platform. There is a reduction in species diversity near to the platform with polychaete worms dominating the biomass. Biological changes are not usually detectable beyond 3 km from platforms, but there are a few cases where effects have been detected out to 5 km. Changes in the regulatory regime governing the use of drilling fluids are expected to contribute to reducing the impact on the benthic communities. There is, however, uncertainty about the possible environmental effects of removing cuttings piles. Some alternatives to oil-based muds also possess properties which could result in adverse impacts on benthic communities.

There is uncertainty about the environmental effects of discharges of produced water. In addition to oil, produced water also contains a range of other natural organic compounds including monocyclic aromatic hydrocarbons (i.e. BTEX), 2- and 3-ring PAHs, phenols and organic acids. This includes added production chemicals, and may also include organic compounds not yet identified. Increased levels of PAHs in caged mussels and passive samplers have been found up to 10 km from produced water discharge sites.

Accidental and illegal oil spills result in the oiling of seabirds, shellfish, other organisms and the coastline, with ecological and often economic consequences. Measured in oiled seabirds, this type of contamination remained at high levels throughout the years in some parts of the North Sea, in others it declined for some time whilst it has again increased in recent years. Even minor accidents with ships can end in disaster as long as heavy fuel oil or its residues are involved. When the 'Pallas' grounded in the Wadden Sea in 1998, it lost about 250 $m^3$ of heavy fuel oil which killed about 16 000 birds overwintering in the area. The 10 000 – 15 000 t of heavy fuel oil spilt when the 'Erika' broke apart off the French Atlantic coast in December 1999, killed at least the 80 000 birds collected on the beaches, with estimates running as high as 200 000 – 300 000 birds killed. Slight contamination of fish has been found in the vicinity of platforms. The overall impact on fish stocks by low levels of hydrocarbons is considered to be small, although long-term effects of operational discharges of production water cannot be ruled out. Future increases in shipping traffic may increase the risk of pollution.

### 5.3.12 Impact of contaminants

The presence of high concentrations of metals and man-made substances in marine seafood could pose a problem for the human consumer, as has been demonstrated for indigenous people in Greenland who have been exposed to high levels of mercury and PCBs in seafood. In view of this, most countries in the OSPAR area have established monitoring programmes for contaminants in seafood to ensure that it is safe for consumption. For example, due to high concentrations of different contaminants in fish and shellfish there is advice against human consumption of seafood from several fjords along the Norwegian coast. Major wastewater discharges to rivers or coastal areas are subject to environment impact assessment and, as appropriate, the control requirements of the EC Directives on urban wastewater treatment and integrated pollution prevention and control.

The situation concerning impacts on marine life is somewhat different. Only in some cases has the impact of contaminants on populations or communities been measured directly in the OSPAR area, although there is much information about effects on individuals (referred to as 'biological effects'). BRCs and EACs were established to be used as the best available assessment criteria for contaminant levels and their effects, but the caution expressed as to their limited usefulness must be recognised. With respect to EACs it should be noted that they refer primarily to acute toxicity. The derivation of EACs does not include for example the bioavailability of a contaminant under field conditions, the degree of bioaccumulation, carcinogenicity, genotoxicity and hormone balance disturbances (endocrine disruption). In addition, the presence of other hazardous substances in the sea may cause enhanced or combined adverse effects in organisms or even on populations. Therefore, concentrations of a contaminant in the marine environment below the EAC for that contaminant do not guarantee a safe situation. On the other hand, it is not compelling that biological effects occur where an EAC is exceeded. This can only be established through biological investigations in the field.

The biological effects studies run to date within the OSPAR area have identified a number of places where impacts have been observed at the cellular and individual level. Biological effects essentially indicate the presence of contaminants, which are taken up by organisms. Some examples are given in the following paragraphs. An important sub-lethal effect is endocrine disruption, the impact of which may extend to the population level.

Tributyltin is one of the rare examples in the marine environment where effects can be attributed to a single substance. Exposure to TBT, originating for example from antifouling paints, produces distinctive responses in a number of organisms. These include shell thickening in Pacific oysters and imposex/intersex (the imposition of male characteristics in female gastropods). TBT is also found in seabirds, marine mammals, fish and plankton. Effects on hormone, reproductive, immune and certain enzyme systems of fish are reported. An impact to humans via the consumption of seafood might be possible.

Surveys of imposex in British waters during 1997 indicate that biological effects are still evident at all but the most remote coastal sites ten years after enforcement of TBT restrictions. Some estuarine and coastal areas in north-west Spain and northern Portugal have exhibited significant levels of imposex in dogwhelks (*Nucella lapillus*). Although in the former case this has led to female sterilisation, the dogwhelk population in north-west Spain is not considered to be at risk of extinction. Imposex has been documented in dogwhelks and common whelks in harbours in Iceland, Norway and Svalbard and in the North Sea region including the Kattegat. Over a ten-year period of monitoring at twenty sites on the Irish coast those with salmon farming operations and small craft demonstrated a recovery from TBT contamination; as indicated by a reduction in an index of imposex (Relative Penis Size Index).

Imposex still occurs near shipping lanes all over the world, and also in offshore areas, where it correlates positively with shipping intensity and TBT levels in biota and sediments. This is due to the present lack of regulations on the application of TBT to ships larger than 25 m.

The toxicological significance of the elevated concentrations of PCBs in marine organisms is unknown. However, prior to death some of the otters with high PCB body burdens have been reported to have behaved in a manner suggestive of organochlorine poisoning. The previously abundant Swedish otter population has for a long time suffered from PCB pollution. Along the Swedish Skagerrak coast concentrations of PCBs in fish are still too high and no otters are currently found in the Swedish coastal environment (Brunström *et al*., 1998; Roos *et al*., in press). PCBs can disturb reproductive, enzyme and endocrine systems in marine mammals, for example in harbour seals fed experimentally on fish from the Wadden Sea. Such effects are found in certain populations outside the OSPAR area, for example in Baltic grey seal and ringed seal populations (Olsson *et al*., 1992; Roos *et al*., 1998). High levels can affect the immune system of the polar bear (Bernhoft *et al*., in press) and it is possible that similar effects may be occurring in other marine vertebrates.

Various organic contaminants may induce higher activity of the enzyme 7-ethoxyresorufin-*O*-deethylase (EROD) in fish liver. The extent of this activity is used as an indicator of the degree of exposure to a range of compounds, including PCBs and PAHs. Elevated EROD activity has been measured in the livers of flatfish. In UK marine waters, the greatest activity was found in plaice in the area of the Firth of Clyde sewage sludge disposal ground at Garroch Head and near to industrial centres at Hunterston and Irvine Bay.

There is clear evidence that a diverse range of natural and man-made substances including PCBs, dioxins, TBT and various other organometallic compounds, pesticides, pharmaceuticals and industrial chemicals, have the potential to impair reproduction in aquatic organisms through interference with their endocrine (i.e. hormonal) systems. Studies in freshwater environments have shown that for some substances these endocrine-disrupting effects can occur even at very low ambient concentrations, considerably less than concentrations that are either mutagenic or acutely toxic. To date, it remains unclear which substances or combinations of substances are responsible for the observed effects (e.g. feminisation in male fish) but ethynylestradiol (a contraceptive agent), PCBs and alkylphenols (derived from some industrial detergents) have been positively implicated, as well as natural hormones. Furthermore, it is important to note that many different man-made and natural substances are able to act additively at hormone receptors to produce some of these effects. Although TBT-induced imposex in gastropod molluscs is one of the few confirmed instances of endocrine disruption in marine life at present, many other endocrine-disrupting substances are known to be present in effluents and river water discharged to the OSPAR area. Furthermore, studies in the UK have shown that a number of estuarine waters receiving effluents from sewage treatment plants and industrial sources induce œstrogenic effects (a form of endocrine disruption) in fish. Effects observed in male flounder include production of the yolk protein precursor vitellogenin and induction of intersex, although, to date, no effects at the population level have been demonstrated. Intersex, among other effects, involves the appearance of egg cells in the testis, and it is probable that it is associated with impairment of reproductive output. It is important that effects like these should receive further study, both to uncover the full range of impacts in different species, and to decide whether populations and communities are at long-term risk (as is the case with TBT).

Potential for harm to North Sea organisms from metals includes the effects of dissolved copper on lower trophic levels such as phytoplankton, and the accumulation of cadmium and mercury in top predators and lead in shellfish. These effects are due in large part to the tendency of these metals to bioaccumulate in organisms through trophic interactions. However, these effects are often local and occur most frequently in estuaries and in the coastal zone. Although potential for biological effects due to metals undoubtedly exists at some of the more contaminated sites, particularly those subject to continuing metal inputs, the regional QSRs provide no recent reports of specific effects due to elevated metal concentrations in sea water, sediments or biota.

Certain brominated flame retardants are known to bioaccumulate and are suspected to have developmental or behavioural effects on mammals.

Phthalates are known to persist under marine conditions and to bioaccumulate at lower levels of the food chain, in particular in sediment communities.

Nonylphenols degrade slowly, are known to bioconcentrate in salt-water fish and mussels and have been reported to induce changes in the endocrine system in the course of *in vivo* tests. They are also toxic to marine algae but not at levels usually found in the marine environment.

Short-chained chlorinated paraffins are known to persist in the environment and to bioaccumulate in marine mammals (seals, beluga, and walrus). The levels recently found in different Arctic regions were in the range of 200 to 800 µg/kg ww.

Copepods have been shown to be sensitive to a wide variety of organic contaminants, such as insecticides, organometals and oil. Field studies and mesocosm experiments as well as model simulations have shown that effects on zooplankton may cause increased phytoplankton densities due to reduction of grazing pressure.

Some decreases in numbers of seabirds have been attributed to the effects of organochlorine compounds. In the early 1980s concentrations of DDT in shags in one area of Region III may have resulted in eggshell thinning. More recent data suggest that this is unlikely to still be a problem. In addition, bacterial poisoning associated with feeding on municipal refuse sites in Region III has been highlighted as a possible cause of a reduction in numbers of birds.

Alkylphenols, alkyl-substituted naphthalenes, alkyl-substituted fluorenes and dimethyl benzoquinone were identified as possible causes of toxic effects in UK estuaries. (Thomas *et al*., 1999a,b). This information has been generated by Toxicity Identification Evaluation (TIE) procedures using a variety of bioassays. It is noteworthy, however, that no single contaminant was responsible for observed biological effects in estuaries – effects generally appear to result from the action of complex mixtures.

From mesocosm studies, there is evidence of a correlation between the occurrence of pre-stages of liver tumours in North Sea flatfish and contaminants, particularly PAHs and possibly chlorinated hydrocarbons (Vethaak *et al*., 1996).

Adverse biological effects caused by mixtures of unknown pollutants, tested using oyster embryo water bioassays and whole sediment bioassays with amphipods and annelids, including acute toxicity, have been measured in some UK estuaries, for example the River Tyne and River Tees (Jones and Franklin, 1998). The full ecological significance of these observations is not known, although invertebrate communities in some industrialised estuaries are known to be impoverished.

A further effect of mixtures of pollutants can be to decrease 'Scope for Growth' in the mussel *Mytilus edulis*. This is a well established biological effects technique and when combined with the measurement of chemical contaminants in the tissues of mussels provides a tool for assessing spatial changes in environmental water quality. Depression of Scope for Growth was demonstrated in the North Sea UK east coast survey in the early 1990s (Widdows *et al*., 1995). In 1996 and 1997 a further survey was carried out at 37 locations in the Irish Sea, including some sites on the east coast of Ireland. The results indicated reduced Scope for Growth in the Mersey/Liverpool Bay region and in Dublin Bay. High Scope for Growth was recorded along the west coasts of Scotland and Wales. These results indicate that contaminants are interfering with the ability of shellfish to grow normally in southern coastal areas of the North Sea, and also in some coastal areas of the central Irish Sea.

### 5.3.13 Impact of radioactive disposals

Interest in the behaviour of radionuclides in the marine environment has, until now, been driven by the objective of protecting human health from ionising radiation through the food chain. Whilst the system of human radiological protection has been developed through the adoption of internationally recognised guidelines and standards, there are currently no internationally accepted radiological criteria for the protection of marine flora and fauna. The assumption has been that man is the most radiosensitive organism and that if man is adequately protected, then other living things are also likely to be sufficiently protected. The International Commission on Radiological

Protection states that: ‘the standard of environmental control needed to protect man to the degree currently thought desirable will ensure that other species are not put at risk. Occasionally, individual members of non-human species might be harmed, but not to the extent of endangering whole species or creating imbalance between species’ (ICRP, 1991).

In 1994 OSPAR agreed that more emphasis should be put on assessing biological and ecological effects in the marine environment (including the vulnerability of marine organisms and communities) arising from existing and foreseen future discharges of radioactive substances (PARCOM Decision 94/8). There is now a growing recognition that protection of the environment merits attention in its own right. The International Atomic Energy Agency acknowledges that ‘there is a growing need to examine methods to explicitly address the protection of the environment from radiation. The concept of sustainable development places environmental protection on an equal footing with human protection, on the basis that it is necessary first to protect the environment in order to protect human populations.’ (IAEA, 1999). The OSPAR Strategy with Regard to Radioactive Substances is primarily concerned with reducing concentrations of radionuclides in the marine environment, with dose to man as a supporting consideration. The Strategy requires the OSPAR Commission to undertake the development of environmental quality criteria for protection of the marine environment from adverse effects of radioactive substances and to report on progress by 2003.

### 5.3.14 Impact of marine litter

Marine litter is derived from both land-based and marine sources and its impact on marine life has been observed. Most victims have been birds and the main culprit has been plastics. The mechanism of damage has either been by entanglement in plastic sheeting, which can lead to the birds being drowned or by ingesting small plastic objects, which can lead to blockages in the stomach or intestines. Autopsies carried out on dead mammals and turtles have also revealed that death in some cases has been linked to the ingestion of plastic waste. Studies have been conducted over ten years (1988 to 1998) on leatherback turtles (*Dermochelys coriacea*) and loggerhead turtles, the two species occurring most frequently in Region IV. Autopsies showed that respectively 58% and 11% of the individuals had ingested plastic waste. Cetaceans can also be significantly affected, and in the few observed cases from several hundred autopsies, the species affected seemed to be those that feed on cephalopods and which might have mistaken plastic bags for their prey. Floating litter also has the potential to act as a vector for the spread of epiphytic organisms beyond their normal ranges.