OSPAR Commission

for the Protection of the Marine Environment

of the North-East Atlantic

Quality Status Report 2000

Region III Celtic Seas

Quality Status Report 2000
Region III – Celtic Seas

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FOREWORD

The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention 1992) requires that Contracting Parties shall ‘take all possible steps to prevent and eliminate pollution and shall take the necessary measures to protect the maritime area against the adverse effects of human activities so as to safeguard human health and to conserve marine ecosystems and, when practicable, restore marine areas which have been adversely affected’.

To provide a basis for such measures, the Contracting Parties are required to undertake and publish at regular intervals joint assessments of the quality status of the marine environment and of its development. These assessments should also evaluate the effectiveness of measures taken and planned for the protection of the marine environment and should identify priorities for action.

The Ministerial Meeting at which the OSPAR Convention was signed also issued an action plan for the OSPAR Commission, with a commitment to prepare a quality assessment of the whole maritime area by the year 2000. A comprehensive quality status report on this scale has not previously been produced.

To implement these commitments the OSPAR Commission decided, in 1994, to subdivide the maritime area into five regions and to prepare, coordinated by the Environmental Assessment and Monitoring Committee, five detailed quality status reports. As a result, five regional task teams were set up to produce reports for the following areas (see inset in ***Figure 1.1***): Region I (Arctic Waters), Region II (Greater North Sea), Region III (The Celtic Seas), Region IV (Bay of Biscay and Iberian Coast) and Region V (Wider Atlantic). It was agreed that these reports should be developed in a scientifically sound manner and should be based upon an assessment plan and a scientific programme (covering monitoring, research and the use of assessment tools). It was also agreed that the information contained in the reports should reflect the outcome of the appropriate quality assurance procedures.

In 1995 the OSPAR Commission adopted a Joint Assessment and Monitoring Programme, to take over and build upon experience gained through its former Joint Monitoring Programme and the Monitoring Master Plan of the North Sea Task Force.

The findings of the five regional quality status reports (‘the regional QSRs’) form the basis of a holistic quality status report for the entire maritime area (the ‘QSR 2000’). This regional report is thus part of an overall quality status assessment for the North-east Atlantic in the year 2000. The QSR 2000 will represent an integrated summary of the quality status of the entire OSPAR maritime area and will both fulfil the commitment made by the parties to the 1992 Convention and provide a basis upon which the future work programmes of the Commission can be decided. In the Sintra Statement, which concluded the 1998 Ministerial Meeting of the OSPAR Commission, importance was attached to the outcome of the QSR 2000 as a basis for identifying and prioritising future tasks at the Ministerial Meeting of the OSPAR Commission to be held in 2003.

The term ‘OSPAR Commission’ is used in this report to refer to both the OSPAR Commission and the former Oslo and Paris Commissions. The 1972 Oslo Convention and the 1974 Paris Convention were superseded by the 1992 OSPAR Convention when it entered into force on 25 March 1998.

The conclusions and recommendations contained in this report draw attention to problems and identify priorities for consideration within appropriate fora as a basis for further work. Within its sphere of competence, the OSPAR Commission will decide what follow up should be given to these conclusions, recommendations and priorities for action. The rights and obligations of the Contracting Parties are not therefore affected by this report.

THE PARTICIPANTS

Framework

The Environmental Monitoring and Assessment Committee (ASMO) has overall responsibility for the preparation of periodic quality status reports, assisted by a working group, the Assessment Coordination Group (ACG). ASMO outlined the basic arrangements for the quality status reports in the Joint Assessment and Monitoring Programme (JAMP). Further scientific and technical arrangements were prepared by ACG. Regional Task Teams (RTTs) were set-up for each of the regions of the maritime area. The lead countries for the respective RTTs were responsible for providing logistical support to the RTT.

Information relating to the entire maritime area was prepared in 1996 – 1998 by the following OSPAR working groups: the Working Group on Inputs to the Marine Environment (INPUT), the Working Group on Impacts on the Marine Environment (IMPACT), the Working Group on Concentrations, Trends and Effects of Substances in the Marine Environment (SIME) and its Ad Hoc Working Group on Monitoring (MON). This information constituted the basis of the five regional quality status reports, and was supplemented by relevant national information as appropriate.

Regional Task Team for the Celtic Seas

The RTT for the Celtic Seas had primary responsibility for drafting this report.

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OSPAR COMMISSION FOR THE PROTECTION OF THE MARINE ENVIRONMENT OF THE NORTH-EAST ATLANTIC

QUALITY STATUS REPORT 2000: REGION III – CELTIC SEAS

EXECUTIVE SUMMARY

Introduction

This report is one of five regional quality status reports prepared by the OSPAR Commission as part of its commitment to produce the first quality status report of the North-east Atlantic by the year 2000.

Region III, the Celtic Seas, extends between 60° N and 48° N and between 5° W and the west coast of Great Britain to the 200 m depth contour to the west of 6° W.

The report is based upon the most recent information available from national and international sources. The work was supervised throughout by a Regional Task Team, with members drawn from public authorities in Ireland and the United Kingdom.

Geography, hydrography and climate

The region contains wide variations in coastal topography, including fjordic sea lochs, rocky headlands, cliff formations, salt marshes, sand dunes, bays, estuaries and numerous sandy beaches. Region III also contains a number of internationally important ports and harbours.

Generally, water movement is from south to north, with oceanic water from the North Atlantic entering from the south and west of the region and moving north towards either the Arctic or North Sea. However, there are also complex intermediate water movements, particularly within the Irish Sea.

The sand transport pattern is complex, with a zone of divergence across the Irish Sea west of Anglesey and in the North Channel and a dominant westward trend out of the Bristol Channel and across the Celtic and Malin Seas.

The strongest winds in Region III come from the west and south, with a tendency for the strongest winds to be experienced in the north and west of the region. There are indications of an increase in the frequency and severity of storms.

It is estimated that if global warming continues, sea level in Region III could rise by between 15 and 95 cm within the twenty-first century, increasing the risk of flooding and coastal erosion in low-lying coastal areas.

Winter sea surface temperatures to the west and south of Ireland are several degrees warmer than those experienced in the comparatively shallow Irish Sea, because of its greater heat loss compared to the deeper Atlantic waters influenced by the North Atlantic Drift. However, in summer, shallower parts of the Irish Sea warm more quickly in response to the warmer summer air temperatures.

It is possible that decadal variability in climate over the North Atlantic might affect the region’s hydrography.

Some estuaries and areas with restricted water circulation are under pressure as a result of high population density and industrial and/or port-related activities, for example the Severn Estuary, Belfast Lough and the inner parts of Dublin Bay.

Human activities

The general pattern of population change in the coastal areas of Region III is one of declining numbers in the largest city centres, growing populations in the suburbs of major towns, steady increases in many industrialised counties and stable or declining populations in more rural and remote regions. There are seasonal variations in the population of many coastal resort towns. Two areas have shown particularly marked increases in population since the mid-1980s; the coastal counties of south-west England and the area to the north of Dublin City.

Region III has a large number and variety of habitats, many of which are listed for protection under international and national designations.

The current trend in tourism and recreation towards a diverse range of more individual pursuits (such as angling and surfing) on less developed parts of the coast can result in new pressures on natural habitats and water quality.

For 1990–5 the total average landings (excluding industrial fisheries) reported from Region III (all fleets) were 926 000 tonnes. Industrial fishery landings for fishmeal comprise only a small percentage of total landings.

Other human activities in the region which may impact on the marine environment include:

- mariculture (which has increased throughout the region in the last twenty years);
- sand and gravel extraction;
- dredging and dumping;
- oil and gas exploration and production (particularly in the area to the west of Shetland);
- shipping;
- coastal industry;
- military activities; and
- agriculture.

Chemistry

Inputs of contaminants to Region III can be broadly categorised as:

- direct (mainly discharges to coastal waters from industrial and municipal outfalls) and riverine inputs;
- dumping of wastes at sea (which includes munitions disposal, but excludes industrial waste which is no longer disposed of at sea in Region III and sewage sludge for which sea disposal has recently discontinued);
- atmospheric inputs (although with prevailing westerly winds, levels are relatively low compared with continental Europe);
- inputs from mariculture (faeces, excess food, chemotherapeutic agents and antifoulants); and

- inputs of oil (from shipping, oil and gas installations and discharges from rivers, industries and municipal wastewater facilities).

In general, loads of heavy metals from rivers and outfalls have been fairly stable during the 1990s, although there are indications that gross inputs of cadmium, mercury and zinc are slowly decreasing in some parts of the region. However, data show elevated concentrations of cadmium, mercury, lead and copper in sediments close to coastal sources. Concentrations in fish do not exceed national food safety standards. Mercury is the only element for which observed concentrations in Region III give cause for concern, primarily in Liverpool Bay and Morecambe Bay on the eastern side of the Irish Sea.

The report summarises information on the distribution of persistent organic contaminants in Region III, including various pesticides, industrial chemicals and by-products of combustion. Low, but detectable, concentrations of tributyltin (TBT) were found in livers of marine mammals. The main repositories of polychlorinated biphenyls (PCBs) in the marine environment are fine-textured sediments, but highest concentrations are found in fatty tissues of seabirds and marine mammals. Concentrations of polycyclic aromatic hydrocarbons (PAHs) varied throughout the region, although very high concentrations were found at some sites.

Discharges from Sellafield are the main source of artificial radionuclides to the region. For many radionuclides, current discharges are much lower than in the 1970s. Discharges of technetium-99 rose to a peak in 1995, although they have since declined. Small amounts of radioactivity are also released by other industrial, military and manufacturing installations on the west coast of Great Britain. All are subject to regular monitoring. The available data indicate that the incremental risks to human health from consumption of fish and shellfish from the Irish Sea are extremely small.

Concentrations of dissolved nutrients from sewage plants, some industries and the atmosphere exhibit a pronounced seasonal cycle in Region III. Although some areas become deoxygenated when algal blooms collapse and decompose in the summer, there is no consistent pattern which might be regarded as symptomatic of eutrophication in the open sea.

Biology

The large range of habitats in the region support a diverse fish fauna, including many commercially important species. Many of these species have relatively short migration routes between feeding and spawning areas. For some species there is evidence of recent changes in migration.

The region has a large number of areas attractive to seabirds and waterfowl. However, human activities can affect seabird numbers (e.g. by the loss or disturbance of habitats and by the ingestion of litter).

Some species of marine mammals (e.g. harbour porpoises) are believed to be at risk, as a result of the numbers caught accidentally by fishing. The common or harbour seal and the grey seal are widely distributed throughout the region. The waters around Ireland and to the west of Scotland support a variety of cetaceans, but apart from the population of bottle-nose dolphins in Cardigan Bay, they are only occasionally seen in the Irish Sea.

In a number of shellfish harvesting areas, the implementation of the EC Bathing Water Directive has led to reductions in levels of microbiological contamination.

The introduction of non-indigenous species (either introduced intentionally or otherwise for mariculture, or through shipping) has caused some problems in the past.

Studies of imposex in dogwhelks around Ireland and the west coast of Great Britain show that ten years after the introduction of TBT restrictions, biological effects are still evident, although reducing.

Of 35 fish stocks assessed within Region III, the spawning stocks of thirteen are comparatively low. Of these, five stocks show a downward trend. The impact of fishing disturbance on benthic communities varies across the region.

Highest mortalities of maturing and adult fish occur in cod and whiting in all areas of Region III and in haddock in the Malin Sea. Celtic Sea herring is currently the most exploited pelagic stock, yet mortality among herring stocks appeared to stabilise at a relatively low level in the 1990s. Discards remain an issue and more sampling work is needed.

Past studies have linked fish diseases and environmental contamination. However, there are no indications of changing spatial or temporal trends in disease prevalence in fish populations in the Irish Sea.

Overall assessment

The assessment shows that Region III is generally in a good state of health. Ecosystem effects due to pollution are generally confined to urbanised estuaries. Measures taken to reduce risks include the ongoing provision and upgrading of sewage treatment plants for major coastal cities and towns, which is likely to produce a significant improvement in waters receiving such outfalls. Environmental levels of most contaminants routinely monitored appear either stable or decreasing. Apart from TBT, there is little evidence that present concentrations of these contaminants have been harmful to populations of marine biota.

However, several issues are highlighted as being of particular concern. These are fishing, endocrine disruption, coastal development and climate change.

- Stocks of several species, i.e. cod, hake, saithe, whiting, plaice and sole, are considered to be outside safe biological limits in parts of Region III. For several other species, e.g. skates and rays, the data do not allow an appropriate assessment. Monitoring of commercial species shows that seafood is of good quality and safe to eat.
- Endocrine disruption caused by TBT is a well established phenomenon in Region III. Although prohibition measures have been effective, TBT effects can still be seen where illegal use persists and around large ports (because TBT use is still permitted on hulls of large vessels).
- There is considerable pressure for more intensive use of coastal land.

- There is evidence of an increased frequency and severity of storms and an increase in temperature. If these increases continue, there will be implications for coastal defence and development.

Other issues which impact upon the region as a whole include:
- sewage;
- litter;
- microbiological contamination;
- mariculture;
- biotoxins;
- metallic contaminants;
- PAHs;
- oil spills;
- ballast waters; and
- ships on passage.

Other issues considered in the regional quality status report are:
- organochlorine pesticides;
- PCBs;
- eutrophication;
- deoxygenation;
- radioactivity;
- munitions;
- military activities;
- dredged materials;
- sand, gravel and maërl extraction; and
- offshore developments.

A number of gaps in current knowledge have been identified, these include:
- the effects of fishing on benthic species and marine mammals;
- the factors causing the development of toxin-producing species of algae;
- the risks of introducing non-indigenous species via ballast waters;
- data on fishing discards and landings;
- endocrine disruption in marine species; and
- data on the passage of ships carrying hazardous cargo.

chapter

1

Introduction

1.1 Aim and scope

Assessments of the quality of the marine environment provide a basis for protecting marine and coastal areas. They provide an opportunity to gather together and assess the results of scientific research and monitoring as well as information on the many human activities that can, directly or indirectly, change or damage the natural attributes of the marine environment. In combination, this information can be used to evaluate the causes and implications of change and to identify impacts that require early attention by policy-makers and environmental managers. Assessments are also used to review the effectiveness of existing measures to prevent degradation of the marine environment, to protect valued species and communities and to restore previously damaged habitats and ecosystems.

The value of environmental assessments depends to a large extent on the availability of reliable and up-to-date information. Thus it is essential that monitoring and other systems of recording marine environmental information are both ongoing and designed to yield high-quality data amenable to interpretation. In this context, assessments provide a means of reviewing the performance of monitoring programmes and of identifying important gaps in knowledge.

This report presents an assessment of environmental conditions in that part of the maritime area which, for assessment purposes, is known as the Celtic Seas[1] or Region III *(Figure 1.1)*. The eastern boundary is defined by 5º W and the west coast of Great Britain, between 60º N and 48º N, while the western boundary follows the 200 m depth contour to the west of 6º W, also between 60º N and 48º N *(Figure 1.1)*. Together with similar quality status reports for the other four regions, this report forms the basis of a holistic and integrated summary of the quality status of the entire OSPAR maritime area.

The scientific scope of the report embraces the physical, chemical and biological conditions of the coastal and marine ecosystems, both on the seabed and in the water column, with an emphasis on spatial differences and temporal trends. The assessment also covers the patterns of human activity in the coastal zone, such as urban development, industry and recreation, as well as land use practices that may have a strong influence on the marine environment. The coverage of certain activities extends inland for up to 10 km and, in a few cases, includes parts of river catchments even more remote from the sea. Inevitably, the amount of information available for each sub-area varies considerably, depending on the extent of past research and monitoring and the availability of resources. Consequently not all topics are covered to the same depth and in the same level of detail for all parts of Region III, although in most instances the coverage is commensurate with the extent of human impact in the environments concerned.

1.2 The assessment process

The assessment is based on the most recent information available from national and international sources, including OSPAR committees and specialist working groups, the International Council for the Exploration of the Sea (ICES), published reports and the scientific literature. The information was compiled initially by scientists based in government laboratories in England, Scotland, Northern Ireland and the Republic of Ireland, who produced three sub-regional reports covering pre-selected parts of Region III such that the combined information covered the whole of Region III (i.e. Ireland’s marine areas – Boelens *et al*., 1999; the Bristol Channel and the Irish Sea – the Centre for Environment, Fisheries and Aquaculture Science (CEFAS); the Malin Shelf – the Fisheries Research Service (FRS)). Although most of the information relates to the 1990s, some topics required the use of earlier data, either because the recent record was sparse or because trend analysis involved a

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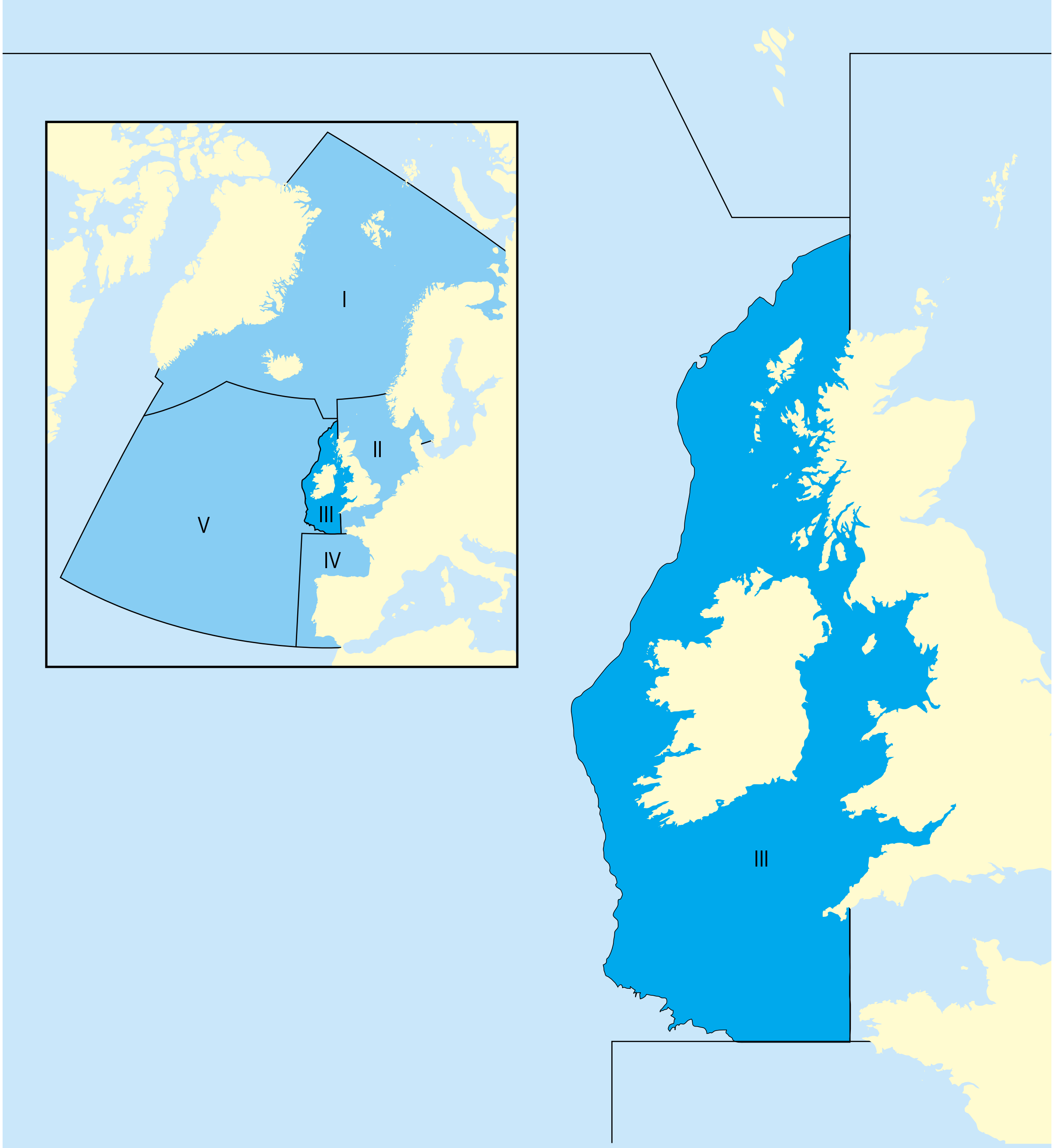
[1] Note that the Celtic Sea itself, to the south of Region III, is only part of the Celtic Seas as defined in this report.

Figure 1.1 **Region III and the other regions of the OSPAR maritime area.**



consideration of historical conditions. While every effort has been made to ensure the comparability of data from different times and locations, methodologies may have differed considerably and thus some comparisons will, inevitably, be tenuous. Where such uncertainties exist, they are indicated in the text.

1.3 Guidance to the reader

Chapter two gives a concise description of the physical geography, hydrography and climate of the area, as these have an important bearing on the types and distributions of marine habitats and communities as well as on their sensitivity to environmental change. Chapter three examines human activities that directly or indirectly impinge on marine areas, their amenities and resources, and also identifies those localities that are most affected, assessing any apparent trends. The next two chapters summarise information on the chemical and biological features of the various coastal and offshore ecosystems, focusing in particular on the causes and implications of the changes that are occurring to their natural characteristics. Finally, Chapter six draws on the preceding chapters to identify the major causes of environmental degradation within the area and, where appropriate, the managerial and scientific actions needed to redress them.

References to ‘Ireland’ are references to the Republic of Ireland unless the context otherwise requires.

chapter 2

Geography, hydrography and climate

2.1 Introduction

This chapter gives a concise account of physical features characterising the coasts and offshore areas of Region III. The first two sections (2.2 and 2.3) deal with the geography and geology of the region concentrating on the coasts and the extent to which they have been developed by human activity. Subsequent sections (Sections 2.4 to 2.10) describe the hydrographic and climatic conditions that play a dominant role in shaping the substrates, habitats and natural resources of the region. Finally, Section 2.11 identifies a number of areas (OSPAR ‘focus areas’) within the region that, due to a combination of physical, biological and anthropogenic influences, are especially vulnerable to changes that may, in the long-term, degrade or devalue the indigenous resources and ecosystems.

2.2 Description of the coastal margin

A Celtic Seas Coastal Directory is being prepared jointly by the UK and Ireland and is expected to be published in 2000. The directory will give details of the geology, ecology and various human activities around the coasts. The brief descriptions given below follow a series of adjacent coastal sectors *(Figure 2.1)*, starting with the western seaboard of Great Britain and continuing with the whole island of Ireland. The boundaries of the coastal sectors referred to in this section are marked on *Figure 2.1* by a short line transecting the coast.

Cape Wrath to Ardnamurchan Point: This is the most northerly section of the coastline, extending from Cape Wrath at the north-west corner of Scotland to Ardnamurchan Point, just north of the Isle of Mull and the most westerly point of the mainland. This coast, comprising a series of fjordic sea lochs and rocky headlands with cliffs and areas of sand dunes, is one of the least impacted in the UK, although in recent years there has been extensive development of mariculture operations. Offshore, the Western Isles have low but deeply shelving coastlines with rocky embayments and pocket dunes. The western coasts of the Hebrides are very exposed to the Atlantic and some areas may experience gales on as many as 50 days each year. There is a diversity of coastal habitats and scenery, changing markedly over short distances.

Figure 2.1 **Coastal features of Region III.**

Ardnamurchan Point to Corsewall Point: The northern part of this coast is deeply indented by fjordic inlets (sea lochs) arising from the glacial deepening of valleys during the Pleistocene Period. These inlets afford sheltered areas extensively exploited for mariculture. The geology is dominated by Dalradian schists and igneous rocks and consequently the shoreline is scenically dramatic and resistant to erosion. To the south and west there are numerous offshore islands of which the largest are Arran, Jura, Islay and Mull. From the Clyde Estuary southwards the coastline is relatively unindented and of low relief.

Corsewall Point to Colwyn Bay: This section includes the coasts of south-west Scotland, Cumbria, the Isle of Man, Solway Firth, Liverpool and Morecambe Bays and the north-east coast of Wales. From Corsewall Point to the Solway Firth much of the coastline is rocky whereas further south the hinterlands are low-lying and the shoreline is characterised by numerous sand and shingle beaches. The section contains fourteen estuaries comprising almost a quarter of the total estuarine area of the UK; all except one occupy more than 5000 ha. Morecambe Bay has one of the largest areas of intertidal mud and sand in the UK, second only to the Wash (on the east coast of Great Britain). The estuarine coast in the south of this sector is one of the most highly developed in Region III. There are major industrial and port facilities on both banks of the Mersey Estuary and to a lesser extent on the River Dee. The Isle of Man has a low population and is not heavily developed. The principal towns and their associated harbours (Douglas is the main port) are situated on the five major estuaries. The east and south-west coasts of the island consist of rocky shores and have a rich diversity of flora and fauna. Most of the sandy beaches are on the exposed north-west coast and have a low species diversity.

Colwyn Bay to Kenfig: A feature of this section of coastline is the island of Anglesey which is separated from the mainland by the narrow Menai Straits. The coasts of Anglesey and the Lleyn Peninsula to the south are rocky and their limestone habitats, cliffs and heath-covered slopes support important plant and seabird communities. At many points along this coastline there are sand dune systems and salt marshes, often associated with bays and estuaries. On the northern shore of the Bristol Channel several large estuaries and sand dune systems have been encroached on by industrial developments, including a large steelworks. Milford Haven is a sheltered deep-water anchorage with a major oil terminal and refineries. Swansea Bay is bordered by the main urban, industrial and port developments of the area.

Kenfig to Land’s End: The central feature of this coast is the Severn Estuary, one of the most extensive estuary systems in Region III. Cardiff and Newport on the south coast of Wales, and Avonmouth on the southern shore of the Severn Estuary, are large industrial centres and all are major trading ports. As the prevailing winds are from the south-west, the coasts of Devon and Cornwall to the south are far more exposed than those of the Severn Estuary and Bristol Channel. There is limited industrial activity in this region and the hinterlands are used mainly for low-intensity agriculture. The more southerly part of this coast is noted for its sea cliffs, including the headlands of Land’s End and Cape Cornwall.

Malin Head to Carlingford Lough: The Malin Sea coast of Northern Ireland, from Lough Foyle to Larne, is thinly populated with only light industries and the hinterlands are devoted largely to pasture-based agriculture. Lough Foyle is an extensive embayment containing a large area of sandy shore (Magilligan strand). To the east there is a remarkable basalt pavement formation known as the Giant’s Causeway which attracts half a million visitors annually. There are large sandy beaches that attract tourists. The Bann River catchment, which includes the largest lake (Lough Neagh) in Region III supports a population of approximately 360 000 people. There are major ports at Londonderry (Lough Foyle) and at Larne. Larne, one of the main ports in Northern Ireland (other east coast ports are at Belfast and Warrenpoint), is situated at the entrance to Larne Lough. To the south there are three other major sea loughs (i.e. Belfast, Strangford and Carlingford Loughs). These large inlets are characterised by fine sand as well as extensive areas of intertidal mud and salt marsh. There are sandy beaches on the southern approaches to Belfast Lough and on the Ards Peninsula north of Carlingford Lough. Intertidal rock is most extensive in the south of the region, occasionally associated with coarse shingle banks (e.g. in Strangford Lough). Belfast is the largest town on this coast and the most important industrial centre.

Carlingford Lough to Carnsore Point: Ireland’s east coast is less indented than other Irish coasts and is approximately 480 km in length. The hinterlands are among the drier parts of the country, having on average less than 150 days per year with more than 1 mm rainfall. From Carlingford Lough to Howth Head, the shoreline is characterised by softer forms of intertidal substrate and includes extensive linear sandy beaches. With the notable exceptions of Dublin Bay and Wexford Harbour, the coast from Dublin Bay to Carnsore Point is distinguished by an absence of bays and inlets and a transition from mainly harder intertidal substrates in the north to extensive sandy beaches in the south. A notable feature is the long stretch of shingle beach between Killiney and Wicklow. There are several inlets and estuaries of importance to birds, marine life, recreation and shipping. Dublin and Rosslare, the two major ports on the east coast, have developed around the estuaries of the Liffey and Slaney. Other significant inlets are Carlingford Lough at the border with Northern Ireland and, to the south, the estuaries at Rogerstown, Malahide and Baldoyle which have relatively narrow entrances and large expanses of intertidal substrate. Dublin, Ireland's capital city, occupies a central position on the east coast. The city and surrounding areas support a large population and a wide range of commercial activities. Today, much of the east coast and its hinterland is used intensively for residential, recreational, agricultural and commercial purposes but there are also extensive habitats for flora and fauna. There are regionally important ports at Drogheda and Dundalk and major fishery ports at Skerries, Howth, Arklow and Wexford.

Carnsore Point to Mizen Head: The southern coastline of Ireland is much more rocky and indented than the east coast and approximately 1300 km in length. There are numerous small bays and estuaries and large, navigable estuaries at Cork Harbour and Waterford Harbour. The south coast is moderately sheltered from the prevailing west to south-west winds. The coast to the east has sandy beaches for more than half its length with rocky and muddy substrates comprising about 16% and 13% respectively. Westwards, the intertidal substrates become increasingly rocky with a corresponding reduction in sand and varying amounts of mud. Cork is the largest city on the south coast and a centre of manufacturing and commerce. Cork Harbour is a large natural inlet with a narrow entrance from the sea, providing port facilities for cargo vessels up to 100 000 t. There are important fishery ports at Dunmore East, Duncannon and Kilmore Quay in the vicinity of Waterford Harbour and at Union Hall and Baltimore in County Cork.

Mizen Head to Clew Bay: This coastline is very rocky with a series of large bays and inlets that provide a degree of shelter from the prevailing south-westerly winds and large Atlantic waves that are prominent features of the west coast environment. To the south of the area there is a series of long, narrow inlets (i.e. rias) separated by mountainous peninsulas. These attract large numbers of tourists as does the Galway coast further north. The inlets also support an important mussel cultivation industry. From Tralee Bay to Galway Bay there are stretches of more linear coastline, including some long sandy beaches, although the foreshore remains predominantly rocky with steep cliffs in many areas. North of Galway Bay the shoreline is once more highly indented and characterised by an irregular series of rocky bays with small sandy beaches. The Corrib system, which enters Galway Bay through a short estuary at Galway city, includes two large lakes – Lough Corrib and Lough Mask – which support important salmonid fisheries. The Shannon Estuary extends about 100 km from the tidal limits at the Ardnacrusha hydroelectric power station to the mouth at Loop Head. The Shannon river is 250 km in length and has a catchment area of 11 200 km^2. A deep-water port is located at Foynes and smaller vessels (6.5 m maximum draft at spring tide) can navigate the upper estuary to Limerick dock. Apart from a few major towns the population is thinly dispersed. The main centres of population and commerce are Tralee, Limerick, Ennis and Galway. On the Shannon Estuary, industrial estates at Limerick and Shannon are important centres of manufacturing industry. In addition to the commercial ports at Foynes and Limerick, the only other port handling general cargoes is at Galway. The most important fishery harbours in terms of landed catches are at Castletownbere, Dingle, Valentia and Fenit in County Kerry and Rossaveal on the northern side of Galway Bay.

Clew Bay to Malin Head: Ireland's north-west coast is predominantly rocky but has many large bays with fine sandy beaches. It is also heavily indented and has a number of large promontories exposed to strong westerly winds and some of the largest waves in Region III. There are many small islands, especially in Clew Bay and off the west coast of County Donegal. Prominent features of the north coast are the three large sea inlets of Sheephaven Bay, Mulroy Bay and Lough Swilly which support important mariculture operations. The north-west is one of the more remote and undeveloped regions of the country and this, combined with some notable upland and coastal scenery, makes it a popular destination for tourists. There are important fishery ports at Killybegs, Greencastle, Rathmullan, Burtonport and Downings in County Donegal.

2.3 Geology and sediments

Contemporary seabed sediments across the region are derived from coastal erosion, limited fluvial input and, most importantly, reworking of the glacial sediments. The sediments have been redistributed and fashioned by tidal currents since sea level reached its present position about 5000 years ago. Sediment input into the region since that time has been minimal except for debris derived from shells and other calcareous organisms. Sediment accumulation in the estuaries arises from riverine sources, coastal erosion or offshore sources. Loss of sandy sediment off the shelf into the deeper water of the continental slope has been minimal.

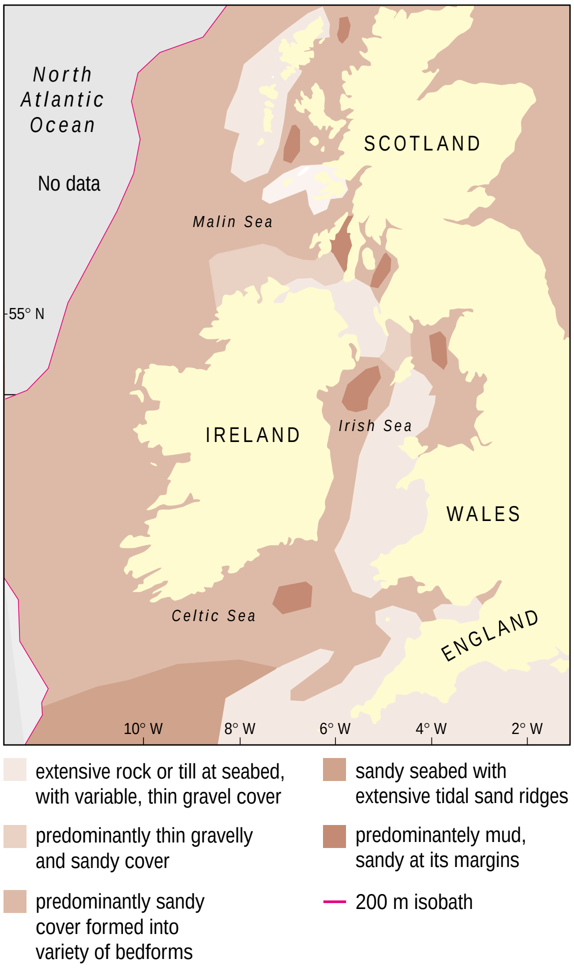
The seabed across the region may be divided into a number of broad types as illustrated in *Figure 2.2*. These results are a simplification of data obtained from the thousands of seabed samples and seismic profiles collected from the region. The distribution of different sediment types is largely a function of the tidal streams; where the tides are strongest, only gravelly sediment persists but, where they are weak, mud accumulates. Slight variation in the strengths of the ebb and flood currents lead to a slow movement of sandy sediment across the region. The direction of net sediment transport may be deduced from the asymmetry of sand waves and numerical modelling of the tidal streams.

2.4 Hydrography and climate

Region III extends from oceanic conditions at the shelf break to the west, through the relatively shallow semi-enclosed Irish Sea, to estuarine and fjordic inlets on its eastern boundary. In very general terms the overall water movement is from south to north, with oceanic water from the North Atlantic entering from the south and west of the region and moving northwards through the area, to exit into Region I (Arctic Waters) to the north or, after flowing around the north of Scotland, to enter Region II (the Greater North Sea). There are however, complex intermediate water movements, particularly within the Irish Sea. The detail to which these are understood has developed substantially in recent years through the application of modelling techniques, drifting buoys, continuous current profilers and towed devices for continuously recording temperature and salinity.

The incoming oceanic water, and the water to the west of Ireland and the Western Isles of Scotland and within the Celtic Sea, is relatively (although not completely) unaffected by human activities. Only that component which flows into the Irish Sea from the south receives much in terms of land-based inputs of contaminants (see also Chapter 4). The numerous offshore islands of the Malin Shelf tend to shelter the Scottish mainland from the extremes of the generally westerly airflow and also tend to segregate the northward flow of water out of the Irish Sea from the oceanic current to the west. Further information on the detail of the water circulation in Region III and the extent to which it is dependent on, or influenced by, the overall climate and weather fluctuations, is provided in the following sections.

Figure 2.2 **Major seabed sediment types within Region III. Source: BGS.**



Simplified from the BGS 1:1 million map of seabed sediments around the UK (1987)

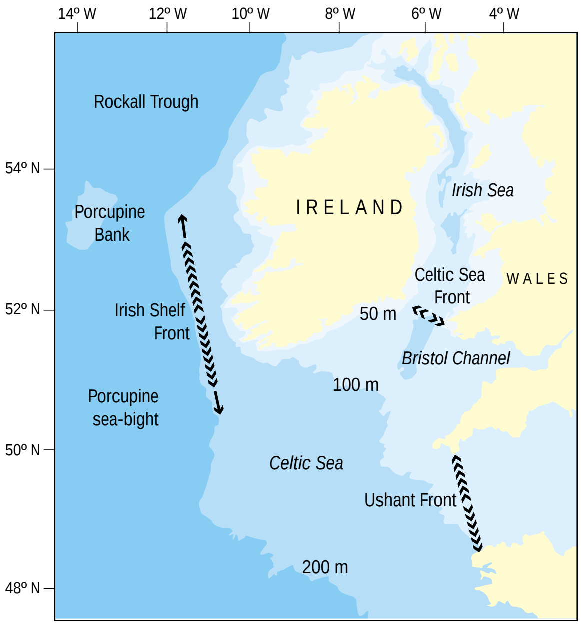
2.5 Water masses

The general pattern of salinity distribution derived from long-term data sets shows that, in winter, near shore salinities to the west of Ireland and eastwards to approximately 8° W, average 35 or greater, indicating the water is mainly of Atlantic origin. In summer the 35 isohaline moves offshore and a band of surface water in the range 34.5 – 35.0 surrounds the Atlantic and Celtic Sea coast of Ireland. Surface salinities increase steadily towards the open ocean reaching approximately 35.5 at the shelf break. Partly due to lack of data, the general pattern of bottom water salinities is more difficult to define, but there is a tendency for Atlantic water to extend somewhat further eastwards at the bottom than at the surface. This results in pronounced vertical salinity gradients, especially in early summer when warmer stratified water overlies the cooler mixed Atlantic water.

On the Malin Shelf off Scotland there are three water masses. The main body originates in the North Atlantic and has a salinity $>$ 35.0. Water flowing north out of the Irish Sea has a salinity that is normally 34.0 – 34.5 and inshore of this lies coastal water with an even lower salinity due to land run-off. These three water masses also show different seasonal variations in temperature; the Atlantic water temperature ranges from 8 to 13 °C, whereas the inshore waters range from 6.5 to 13 °C and in sea lochs the range can be even greater.

In the Malin Sea area haline stratification is relatively weak. However, as in the Irish Sea, stratification due to surface heating develops over much of the Malin Shelf during late spring and summer. In the Atlantic water zone the thermocline is very marked (4 – 5 °C temperature difference) and usually lies at 30 – 50 m. Inshore the temperature difference between surface and bottom waters is less and in the Minch and Sea of the Hebrides

Figure 2.3 **Frontal systems of the Celtic Sea and Atlantic seaboard.**



the water column may remain mixed even in summer, leading to the development of fronts. Fronts tend to inhibit lateral dispersion and are often marked by along-front currents and a high phytoplankton standing crop. The Islay front, which runs from Tiree to Malin Head, separating the Atlantic water from Irish Sea water and deflecting the latter into the Sea of the Hebrides, is a typical example and has an along-front current of 20 cm/s.

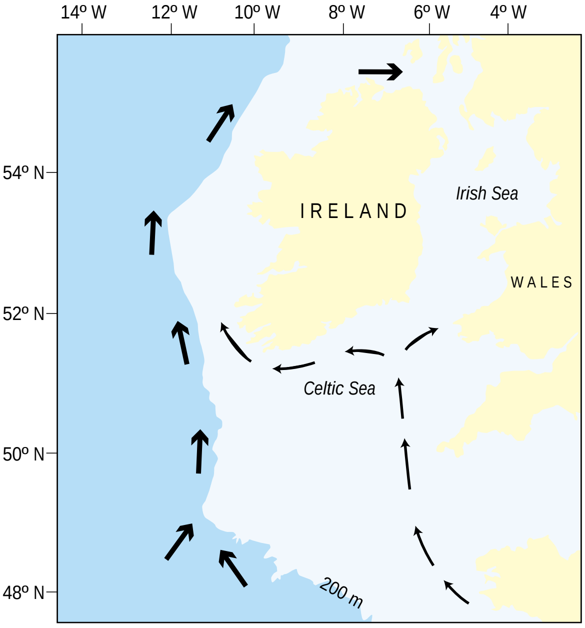
Sea surface temperatures on the shelf, both to the west and south of Ireland, are several degrees warmer in winter than those found in the comparatively shallow Irish Sea, which loses heat more rapidly than the waters west of Ireland and Scotland, that are both deeper and influenced by warmer Atlantic water derived from the North Atlantic Drift. During the summer, bottom temperatures in stratified areas may be 5 – 6 °C cooler than the overlying surface water. Frontal systems tend to develop in late spring at the confluence of mixed and stratified areas, for example the Celtic Sea front to the south of the Irish Sea and the Irish Shelf front to the west of Ireland *(Figure 2.3)*. These break down with the onset of winter cooling and increased wind-induced mixing. Stratification also occurs in the Irish Sea, especially to the west of the Isle of Man where the water is deeper and the tides weaker than to the east of the island. This stratification is due primarily to the strong temperature differences that develop between surface and bottom waters because the tides are not strong enough to cause mixing throughout the water column. The resultant thermocline lies between 20 and 40 m depth depending on the year and breaks down in autumn and rebuilds in spring.

The long inlet of the Bristol Channel between south Wales and the south-west of England peninsula, is exposed to the mainly south-westerly winds from the Atlantic and strong tidal flows (the tidal range being among the largest in the world e.g. 12 m at Avonmouth near Bristol). As a consequence there is intense vertical mixing throughout the estuary east of 5° W. There is substantial freshwater input to the Bristol Channel from the River Severn, accounting for 60% of the total freshwater input at the extreme east of the inlet, and the Welsh rivers to the north account for a further 30%. The consequence is that salinity throughout the area is typically < 35 with a clear north-south gradient. West of about 5° W stratification does occur in summer months with surface waters reaching 17 °C or more and waters below the thermocline remaining < 11 °C.

2.6 Circulation and volume transport

The general pattern of water transport around and within the region is shown in *Figure 2.4*. On the basis of current measurements it is known there is a persistent north-westerly current, which averages about 6 cm/s and follows the slope edge from the Bay of Biscay to the south-west of Ireland. There is also known to be a weak, variable but persistent flow from the coast of Brittany across the mouth of the Channel. North of the Isles of Scilly part of this flow moves west along the south coast of Ireland with the remainder flowing weakly northwards.

Figure 2.4 **General circulation on and around the Irish Shelf. Source: adapted from Pingree and Le Cann (1989).**



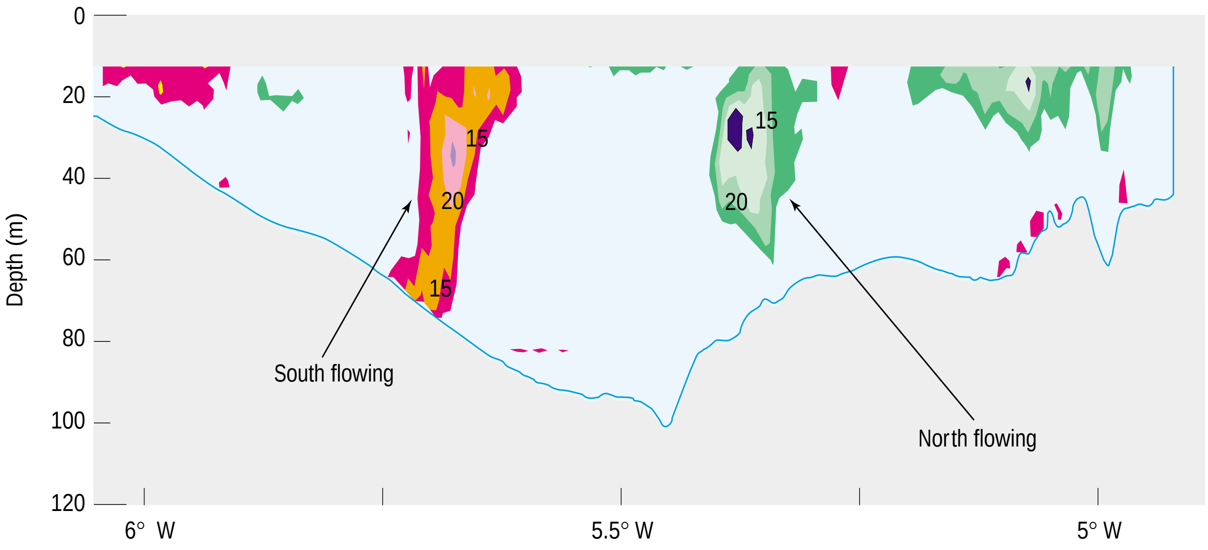
Evidence from tracer studies suggests the net long-term transport through the Irish Sea occurs at an overall speed typically of 1 – 2 cm/s. However, the day-to-day pattern is much more complex than these statements imply.

In the centre of the Celtic Sea flow is weak (< 2 cm/s). During summer the Celtic Sea is strongly stratified and a pronounced surface front stretches across St George's Channel. To the south is a deep pool of cold, saline Atlantic water bounded by strong fronts that intersect the seabed. These features drive strong (> 20 cm/s) but narrow (20 km wide) flows, moving water initially eastward across the mouth of the Bristol Channel, into St George's Channel and back into the Celtic Sea. This circulation restricts circulation between the Irish and Celtic Seas during summer. Tidal movement is the most energetic component and the large spatial variation in amplitude of the tidal currents determines many of the processes within the Irish Sea. However, wind-driven currents are important particularly around coasts, especially where the 200 m isobath is close to the coast as it is north-west and south-west of Ireland.

The boundary between the stratified region west of the Isle of Man and the surrounding vertically well-mixed water is marked by surface and bottom fronts. The surface front, extending from Dublin to the Isle of Man, is visible in infra-red satellite images. The bottom fronts drive strong (> 20 cm/s) but narrow (10 km wide) currents in an anticlockwise direction around a dome-shaped pool of colder water *(Figure 2.5)*. This gyre tends to retain material in that subregion and means there is a southerly flow along the Irish coast. When the stratification breaks down in the autumn the long-term mean northerly residual flow resumes until stratification rebuilds the following spring. However, water movements counter to this residual have also been detected in the north-eastern Irish Sea running south-east parallel to the Cumbrian coast and in the North Channel southerly along the Irish coast. These currents are of variable persistence and may be wind-induced. Wind-induced currents are in fact important in Region III and can, during long windy periods, induce flows of up to 50 cm/s throughout the entire water column. The development of such strong wind-induced currents illustrates the limitations of the concept of normal residual flow; there are frequent variations about the norm including complete reversal at times. On average though, water transport is northwards through the North Channel (estimated to be 30 000 – 100 000 m^3/s) with the greatest transport being on the eastern (Scottish) side.

Water movements on the Malin Shelf basically follow the same overall residual northerly direction, however the short-term flow is equally variable and strongly influenced by weather systems. Depressions passing north of Great Britain tend to induce a strong northward pulse whereas those passing further south tend to induce weaker southerly currents. Based on dilution of two caesium isotopes it has been estimated that the volume transport to the west and east of the Outer Hebrides is of the order of 20 000 and 90 000 m^3/s respectively. Although most of the water passes into the Sea of the Hebrides, a small proportion is recirculated around Barra Head to the west as evidenced by the path taken by drifting buoys. This recirculation is thought to be forced by intrusion of deep Atlantic water which forms a cyclonic surface circulation similar to the deep water 'domes' of cold water found elsewhere.

Figure 2.5 **Seasonal subsurface anticlockwise currents (cm/s) in the Irish Sea to the west of the Isle of Man in July 1994. Source: CEFAS.**



Based on transport models and radionuclide distributions, water moving up the west coast of Scotland typically takes 4.5 to 6 months to pass from the North Channel to the north of Scotland. Similarly, the overall flushing period for the Irish Sea is estimated to be of the order of 1 to 2 yr. The Bristol Channel flushing time is estimated to be between 150 and 300 days. Such figures need to be treated with considerable caution, for example it is estimated that 20 – 30% of the water from the Irish Sea was removed by a single storm event in February 1994.

The numerous sea lochs (fjordic estuaries) on the western coast and islands of Scotland are more responsive to changes in temperature and rainfall than the adjacent coastal water. Most west coast rivers discharge into these lochs; the resultant surface layers exhibit wide-ranging temperatures and reduced salinity. Shallow sills restrict exchange with coastal water. Water renewal usually occurs every few weeks but in Loch Etive it takes on average fifteen months. Anoxic conditions are rarely reported in sea lochs, although very low oxygen concentrations have been observed in the deep water of Loch Ailort. Circulation is typically estuarine with seaward flowing currents on the surface and a deeper return flow. Over the sills tidal currents can reach speeds of around 1 m/s. Many sea lochs have internal tides that contribute to mixing between deep and surface layers.

The Firth of Clyde is a wide fjord containing a deep basin separated from the North Channel by a sill. Thermal stratification remains strong throughout the summer. Haline stratification is variable but persists throughout the year. The deep waters of the Clyde are replaced during winter. A front exists above the sill throughout the year, separating tidally mixed water in the North Channel from the stratified Clyde. Depth-averaged currents across the sill are about 20 – 30 cm/s.

Numerical models offer a holistic view of large-scale spatial and temporal variability not possible with limited observations. Since the 1970s two-dimensional models of the region have been used primarily for tide and storm surge prediction and for simulating the dispersion of contaminants. However, the resolution of these models was hampered by computing power until the late 1980s when increased horizontal resolution three-dimensional circulation models were developed. These models include atmospheric forcing and tides, allowing the determination of density fields and associated flows at a resolution of up to 1 km on the regional scale. Such models now replicate accurately tidal dynamics and the principal response of the Irish Sea to wind forcing. Provided they are of sufficiently high resolution these models can be developed further to examine specific issues such as sediment and contaminant transport pathways and the dynamics of fisheries recruitment on more local scales.

Thus, for example, when good quality tidal models are combined with models of the seasonal cycle of surface heating, a detailed picture of the seasonal evolution of stratification is obtained. This approach lends itself to the simulation and understanding of biological production and transport pathways. In this latter respect, only when this approach was adopted, allied to observations, was the existence and significance of the western Irish Sea circulation understood. Three-dimensional, fully baroclinic models are being developed for the Malin Shelf and should similarly assist the understanding of processes such as the surface recirculation around Barra Head.

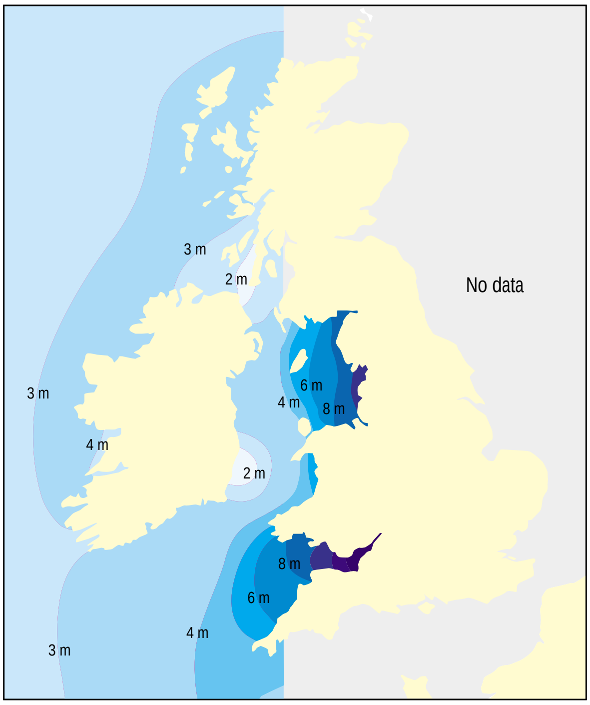
2.7 Waves, tides and storm surges

Surface waves depend upon the duration and fetch of the wind. The coastline of the west of Ireland and the Western Isles of Scotland are exposed to a vigorous wave climate. There is a general tendency for waves to be smaller south of approximately 52° 5’ N and east of 11° 5’ W as swell waves from the Atlantic diminish due to the effects of bottom friction. Within the Irish Sea the waves tend to be locally generated and are of fairly short period (50-yr mean values of the order of 10 s within the Irish Sea and 15 s at its outer entrances). They are, however, relatively steep with 50-yr significant wave heights ranging from 8 m within the Irish Sea to 12 m at its entrances. Very similar figures are reported for the Bristol Channel; 12 m at its mouth and 8 m east of the Gower Peninsula. The effect of waves within the shallow eastern Irish Sea, and inner Bristol Channel in particular, can thus be significant during storms, with marked sediment resuspension. There is some evidence that, in recent years, mean wave heights in the North Atlantic have been increasing by an average of 1 – 2% per year. It is however, unclear whether this is just natural variability as, although storm frequency appears to be showing an upward trend, wind strength does not appear to be increasing.

Figure 2.6 shows the spring tidal ranges experienced throughout Region III. In the open Atlantic tidal waves are generally small but they increase as they move eastwards across the shelf and are further enhanced by the funnelling effect of bays and estuaries. Thus, for example, halfway up the Shannon Estuary on Ireland’s west coast the average tide is 4.5 m but at the head of the estuary it is almost 1 m higher.

The tidal waves in the Irish Sea are propagated from both north and south and meet to the south-west of the Isle of Man causing this area (an amphidromic point) to have very weak tidal currents (< 35 cm/s). There is another amphidromic point south of Islay on the Malin Shelf. However, around Anglesey and the Mull of Galloway, tides are much stronger and peak flows exceed 120 cm/s. It should be noted that the tidal currents are averages for the areas in question and local sudden changes in depth or coastal topography, for example

Figure 2.6 **Spring tidal ranges in Region III. Source: adapted from ECOPRO (1996); Lee and Ramster (1981).**



around a headland, may generate much higher velocities. The tidal currents in the Bristol Channel generally exceed 150 cm/s at spring tides at which times a tidal bore forms in the Severn Estuary which can be up to 2 m high on occasions. Off the west coast of Ireland tidal currents are generally weaker with maximum speeds generally < 50 cm/s. The turbulent kinetic energy generated by the high tidal currents in the Bristol Channel maintains high levels of particulate material in suspension. However, the asymmetrical tidal current also means that there is a general westward transport of suspended material with a bed load parting region between Barry and Bridgwater, which lie on opposite sides of the Bristol Channel.

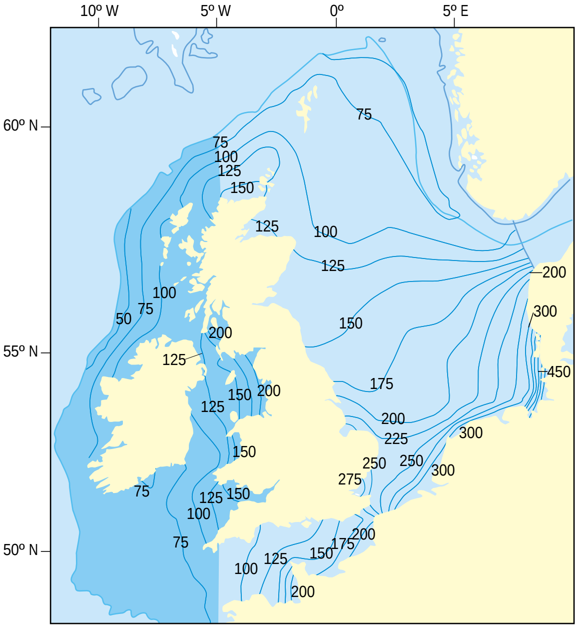
Tidal ranges on the Malin Shelf are from 0.5 m on a neap tide (1 m on a spring tide) in the Sound of Jura (just south of the amphidromic point south of Islay) to 1.6 m on a neap tide (4.5 m on a spring tide) east of the Isle of Skye. Further offshore and north of Skye the tidal range is reduced. Within the Irish Sea maximum tidal ranges occur on the Lancashire and Cumbrian coasts where the mean spring tides have a range of 8 m, contrasting with Carnsore Point on the south-east Irish coast where the range is only 1.75 m. The funnelling effect of the Bristol Channel, together with overall dimensions which cause its natural period to be close to the 12.5 hr tidal period, means the area has one of the largest tidal ranges in the world; for example at Avonmouth it exceeds 12 m on spring tides.

Storm surges occur when water is forced up against the coast through the combined action of wind and low atmospheric pressure. The largest surges are generally associated with storms tracking eastwards between Inverness and the Shetlands. Maximum surge levels within Region III are predicted to occur in the north-eastern Irish Sea and may reach 2 m above normal *(Figure 2.7)*. Surge levels of between 0.75 and 2 m are predicted for the Irish Sea coast and across St George's Channel. These predictions are borne out by experience. In February 1990 the storm surge throughout the Irish Sea was of the order of 0.5 – 1 m but exceeded 2 m on the North Wales coast causing serious flooding. Only two months earlier a strong south-westerly wind and an atmospheric pressure of 941 mb caused a surge in Cork Harbour on the south coast of Ireland of 0.56 m. The low-lying coasts on the southern side of the Bristol Channel are particularly vulnerable due to the very high tidal range. Estimates of extreme sea level suggest a 1 in 50 year maximum level of 8.69 m at Avonmouth.

2.8 Transport of solids

The sand transport pattern is complex with a zone of divergence across the Irish Sea west of Anglesey and in the North Channel, and a dominant westward trend out of the Bristol Channel and across the Celtic and Malin Seas. The sand-grade sediment moves along near the seabed while the mud-grade sediment moves largely in suspension.

Figure 2.7 **Fifty-year average storm surge elevations (cm) for sea areas surrounding the British Isles. Source: Flather (1987).**



Thus they may have different transport pathways. Where the seabed is rock and gravel, tidal and storm-wave currents have a limited effect on the seabed, however the abundance of bedforms such as sand waves across sandier areas indicates the transport of large volumes of sand. Earlier sections of this chapter refer to the influence of wind on currents. In the shallower areas of Region III wind-generated waves cause the resuspension of seabed sediments during storm events. In the Bristol Channel, and to a lesser extent other major estuaries such as the Shannon and Mersey, high levels of particulates remain in suspension due to the strong tidal currents.

2.9 Meteorology

Within Region III calm conditions (wind speeds < 0.2 m/s) are likely to occur less than about 2% of the time. The strongest winds come from the west and south, with a tendency for the strongest winds to be experienced to the north and west of the region. Based on 30-yr records, there is no evidence of any trend in wind patterns or their strength, although there are indications of an increase in the frequency and severity of storms. The rainfall in the coastal regions bordering Region III is strongly influenced by the topography, with west facing coasts generally experiencing the heavier rainfall, especially where there are mountains close to the coast. In the Malin Sea area some mountains in Scotland average more than 300 mm of rain per month, whereas less hilly regions receive only about one third of that amount. The strong winds and high rainfall experienced in these west coast regions, together with their generally lower temperatures, severely restricts the human activities that can be practised in these areas.

Average sea surface temperatures to the west and south of Ireland range from 8 – 10 °C in February or March, to 14 – 17 °C in August. The winter temperatures are several degrees warmer than those experienced in the Irish Sea. This is a consequence of greater heat loss in the coastal waters compared to the deeper Atlantic waters influenced by the North Atlantic Drift. However in summer shallower parts of the Irish Sea warm more quickly in response to the warmer summer air temperatures. Regions that stratify in summer can be lower in temperature than normal after a hot summer and conversely warmer than normal following a cool summer. This is because in a hot summer wind strengths are generally lower; this in turn limits the depth of the surface mixed layer so that less heat is stored, whereas in a cool windy summer the thermocline is driven deeper and the mean temperature of the water column as a whole is higher.

The temperature of the water column is a major factor in determining the time of spawning of some species of fish and crustacean. In addition, the timing of formation of the thermocline has implications for the timing of the spring phytoplankton bloom and thus, overall productivity. Accordingly, temperature differences on a year by year basis and any long-term trend have implications for both species composition and recruitment.

2.10 Climate variability

Long-term fluctuations in surface heat exchange, wind-field, freshwater input and exchanges with the outer shelf can be expected to play a role in the inter-annual and decadal variability of physical processes. Unfortunately, continuous time series of hydrographic parameters over decades do not exist for Region III. However, the limited size and rapid flushing time of the Irish Sea make it likely that hydrographic changes influenced by climate will occur rapidly. Whilst the effect of global warming is notoriously difficult to detect in coastal waters, it is possible that decadal variability in climate over the North Atlantic might affect the region’s hydrography. Broadly, the atmospheric pressure distribution over the North Atlantic in winter can be characterised by two alternate states: the first, an intense Icelandic low and a strong Azores ridge to the south, and the second, a weak Icelandic low and Azores high. The oscillation between these two characteristic patterns is the dominant mode of atmospheric behaviour over the North Atlantic and is termed the North Atlantic Oscillation (NAO). The first state, termed a positive index, is associated with strong mid-latitude westerly winds, higher frequency Atlantic storms and increased wave height in the North-east Atlantic when compared to the second state, a negative index.

A direct link between the NAO and the hydrography and climate of the Irish Sea has not been established; however it is reasonable to expect a degree of correlation. For example, a positive index results in a higher frequency of Atlantic storms, the centres of which track to the north of Great Britain, favouring more frequent resuspension of sediment in shallow coastal environments through increased wave activity. Additionally, depressions passing to the north of the Irish Sea promote northerly and westerly winds over the region which are likely to increase the incidence of storm surges in the eastern Irish Sea.

As the regions of significant freshwater influence are limited to Liverpool Bay and the Bristol Channel, and to a lesser extent the Shannon Estuary and the Irish east coast from Dundalk Bay southwards, the impact of significant variability in rainfall is likely to be localised. In Liverpool Bay, exceptionally low freshwater input may mean that the characteristic near-bed inflow and surface outflow is greatly diminished. Alternatively, periods of prolonged flow are likely to enhance the flushing of the region. It has been suggested that increased freshwater input on the western side of the Irish Sea is likely to promote greater southward flow and, dependent on timing, may act to promote the normal formation of seasonal stratification.

Changes in rainfall patterns, increased temperature or the increased frequency of westward-tracking storms could all have impacts on the living resources of the region. If, as predicted, global warming continues to occur, there will be attendant increases in sea level due to thermal expansion of the water column and melting of the polar ice caps. This could result in increases in sea level of 15 – 95 cm within the next century. As the southern regions generally have lower coastal profiles they are more likely to be subject to flooding and coastal erosion. Thus in Ireland it is estimated that up to 176 000 ha of land could be at risk, with a real possibility that major disruption could be caused in Belfast, Dublin, Cork and Galway. Areas particularly vulnerable to sea level rise include the Shannon Estuary and the coasts of Cork, Kerry, Clare, Galway, Mayo and Donegal, together with areas along the Bristol Channel, the north Wales coast and around the embayments of the north-eastern Irish Sea such as Morecambe Bay. Many of these areas are currently protected by engineered coastal defences such as sea walls, but these have a relatively short structural life even under stable conditions and alternative approaches to coastal protection, or even the abandonment of areas most likely to be affected, will be necessary (see also Section 3.7).

2.11 **Focus areas**

It is clear that physical geography and hydrography are key factors in determining the actual and potential effects of human activities on marine and coastal ecosystems. For example, some estuaries and areas with restricted water circulation are under pressure as a result of high population density, industrial and/or port-related activities. Examples are the Severn Estuary and Mersey Estuary/ Liverpool Bay area on the west coasts of Wales and England, the Clyde Estuary on the south-west coast of Scotland, Belfast Lough in Northern Ireland, and the inner parts of Dublin Bay and Cork Harbour in Ireland.

In certain areas such as Liverpool Bay, weak circulation allows relatively high rates of deposition and accumulations of fine sediment that tend to retain contaminants. Such conditions may also occur offshore due to the presence of seasonal gyres. A notable example is the mud patch to the west of the Isle of Man that is also a prime habitat for the commercially valuable Dublin Bay prawn, *Nephrops norvegicus.* Monitoring trends in contamination within these depositional areas can provide a useful indication of the extent of contamination over much larger areas.

Most of the west-facing coasts of Ireland and Scotland and the Western Isles off Scotland are important in the contexts of fisheries, mariculture, tourism and wildlife conservation and would be vulnerable to the effects of oil or chemical spills should accidents occur to passing ships. Traffic separation schemes are intended to minimise the risk of collisions and, except in bad weather, ships are expected to avoid inshore routes. Although organic wastes from mariculture have caused localised impacts in some sheltered inlets, improved management has led to a reduction of such impacts as well as the number of areas affected. A less manageable problem is that caused by seasonal upwellings of nutrient-rich oceanic water that can stimulate the growth of toxin-producing algae. Where this coincides with valuable mariculture sites (e.g. south-west Ireland), temporary closures of shellfisheries are sometimes necessary. In Ireland, this is an important focus for research.

chapter

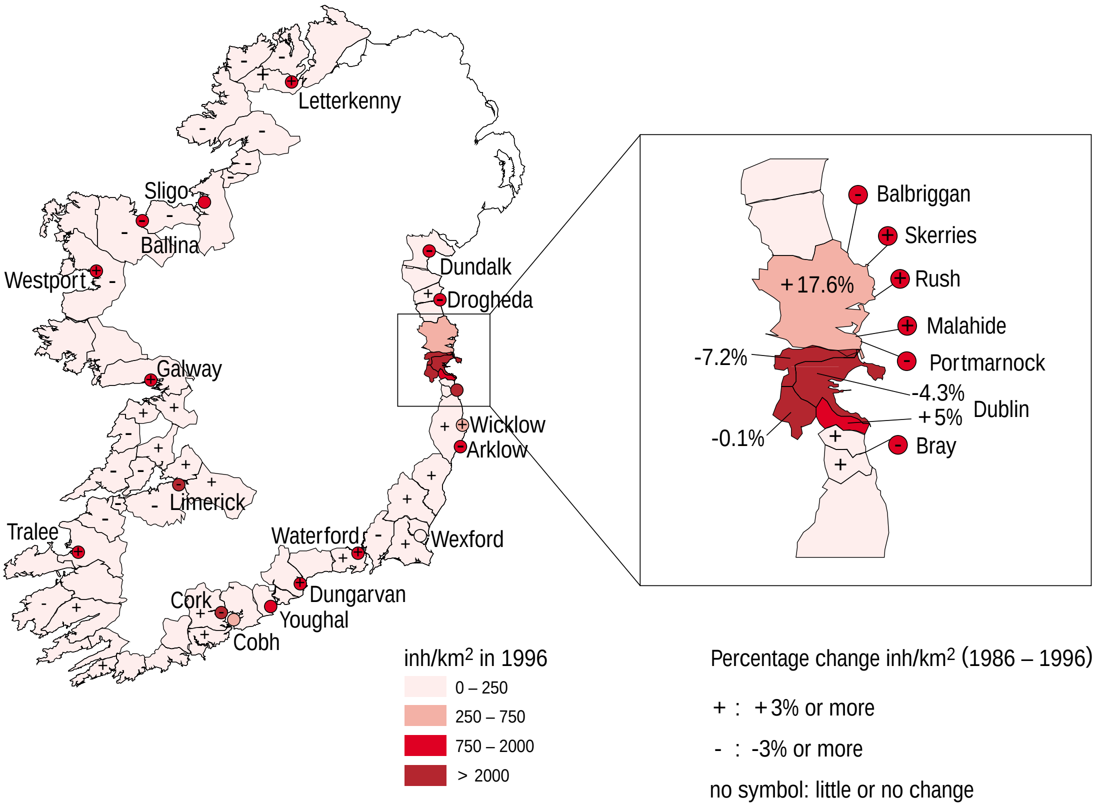
3

Human activities

3.1 **Introduction**

This chapter summarises existing information on social, commercial and recreational activities that take place either at sea or in coastal areas. Such information not only helps in diagnosing the causes of existing environmental degradation, it can also help in predicting future trends, pressures and impacts. Good predictive capabilities are invaluable to environmental managers, assisting planning and enabling informed, pre-emptive actions. Several sections of the chapter highlight the increasing competition for the use of certain facilities and amenities on, or adjacent to, the coasts. There is a growing requirement for housing, commercial sites, rented accommodation and improved services. There is also an increasing demand for clean beaches, watersports, angling, ecotourism and unspoilt coastal landscapes. These varied interests are not always compatible and there are few locations that can accommodate an array of activities without conflict. An integrated, multi-sectoral approach to coastal zone management that facilitates agreement on the optimum use of particular facilities and amenities provides the best means of preventing such conflicts. Here, too, reliable information on patterns and trends in the use of coastal areas is a major advantage.

Figure 3.1 **Population density and percentage change from 1986 to 1996 in coastal urban (population < 5000) and rural areas in Ireland. Source of data: Central Statistics Office (1986, 1993, 1997).**



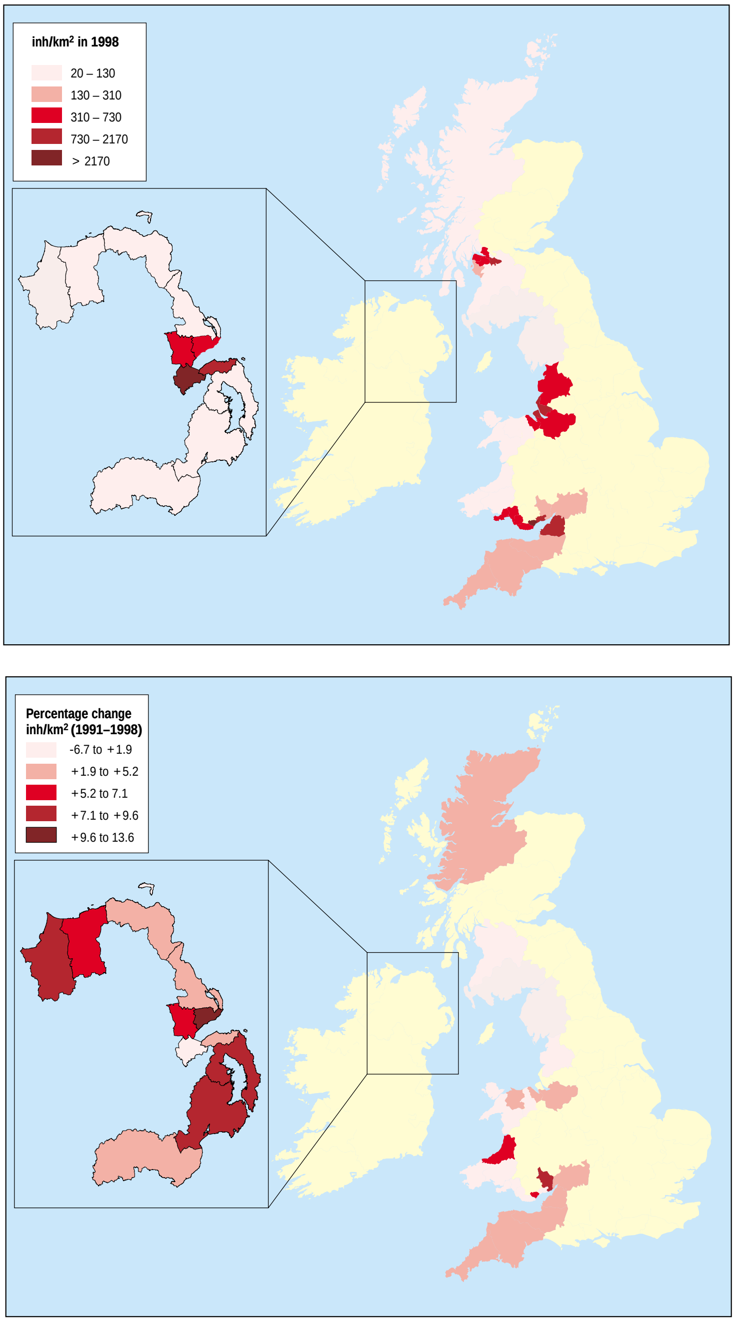
3.2 Demography

The general pattern of population change in the coastal areas of Region III is one of declining numbers in the largest city centres, growing populations in the suburbs of major towns, steady increases in many industrialised counties and stable or declining populations in more rural and remote regions. Although much of the population growth is occurring along the east and west shores of the Irish Sea, significant increases are also apparent in urban areas on the mid-west and south-west coasts of Ireland.

Coastal towns, especially those with major port facilities, attract manufacturing and service industries which provide more employment opportunities and these, in turn, attract more residents. Large urban/industrial complexes also generate substantial amounts of sewage, contaminated stormwater and refuse, as well as airborne pollutants from vehicle exhausts and industry. The demand for waterside accommodation and sea-based recreational facilities such as marinas encourages development along the shore. As towns expand they incorporate more of the surrounding land, thus reducing the stock of farmland and natural habitat. In attempting to evaluate and explain changes in environmental quality, demographic trends are therefore of considerable relevance.

Ideally marine environmental assessments should provide information on population densities within some standard geographical unit (e.g. within 10 km of the coast) and any changes in density over a particular time period (e.g. five or ten years). Unfortunately, conventional approaches to population mapping employ administrative units used in compiling census statistics and these have no relationship to distance from the coast. A further complication is that the timing of censuses does not coincide in the different jurisdictions. Thus at present it is not possible to provide comparable data throughout the region. In the case of Ireland however, an estimate of the population living within 10 km of the coast was made by reworking census statistics on the basis of electoral divisions (which tend to cover small areas). This shows that in 1997 about 52% of the national population of over 3.6 million resided within this coastal strip. The combined population of the

Figure 3.2 **Population density and percentage change from 1991 to 1998 for counties or council areas in the UK bordering Region III. Source of data: official UK statistics.**



fifteen coastal counties (some of which extend well inland) was about 80% of the national population.

The coastal areas bordering Region III support some of the highest population densities in Europe as well as some of the lowest. Densities vary from > 2000 inh/km^2 in Merseyside (on the north-west coast of England) and Dublin (on the east coast of Ireland) to < 2 inh/km^2 in Sutherland, a Highland district on the west coast of Scotland. Outside towns and the heavily urbanised and industrialised areas bordering the Irish Sea population densities are generally < 300 inh/km^2. The demographic distributions for coastal regions of Ireland are shown in *Figure 3.1* and for the United Kingdom in *Figure 3.2*.

Dublin, Glasgow and Liverpool are the only coastal cities with populations in excess of 500 000. The centres of these cities have shown significant population decline in recent years coinciding with substantial increases in surrounding areas. Coastal towns with populations in the range 100 000 to 500 000 include Bristol, Gloucester, Cardiff, Swansea, Belfast and Cork. With the exception of Limerick and Galway other Irish coastal towns have populations below 50 000. The Isle of Man is sparsely populated with a total of 71 000 people of which 75% live in coastal towns.

There are numerous resort towns on the coasts of Region III where populations increase substantially during the summer months due to the influx of visitors. At some of the more popular Irish resorts populations may be three times higher in summer than in winter while the increases at some English and Welsh resorts are even greater.

With regard to population trends, two areas in particular have shown marked increases in population since the mid-1980s. These are the coastal counties of south-west England (south of the Bristol Channel), where population increases of 9 – 13% have been recorded in the five years 1991–5, and the area to the north of Dublin City where population increased by more than 17% in the ten years 1986–96. Significant population growth (averaging approximately 2 – 7%) also occurred in the coastal boroughs of Northern Ireland, both on the North Channel and the Malin Shelf coasts, in the period 1991–6. The city of Derry (Malin Shelf) showed particularly strong growth during this period (9.5%). In contrast, decreases in population have occurred in the Strathclyde region of south-west Scotland, Merseyside and most rural counties along the western seaboard of Ireland. Areas surrounding the cities of Galway and Limerick, Cork City and much of the coast south of Dublin have shown increases in population during the last decade in excess of 3%. Future increases in population are expected in all coastal counties of Great Britain bordering the Irish Sea apart from Merseyside where the present population is estimated to fall by about 9% by 2001.

3.3 Conservation

Whereas it is generally not possible to exclude human activities from any part of the environment, the protection of rare or endangered species of plants, animals, communities or ecosystems does require there to be some form of control. Similarly, controls over human interference are required at sites of archaeological interest. However, the extent to which designated areas can be protected is a matter that has to be considered carefully if conflicts are to be avoided. Many sites receive some form of protection but it is impossible to assess how adequate this is or how consistently controls are applied. This is because, *inter alia*, pressures vary according to season and the popularity of particular features or recreational activities.

Box 3.1 Protected marine areas

International designations include:

- **Biosphere Reserves** as designated under the UNESCO Man and Biosphere programme. Such sites are considered to have particular value as benchmark sites but, unless given protection under separate national designations, are not necessarily protected. Thus, for example, the four Scottish Biosphere Reserves within Region III are also designated National Nature Reserves.

- **Biogenetic Reserves**, of which there are only two coastal sites in Ireland and none in the UK, are designated by the Council of Europe following the 1973 European Ministerial Conference on the Environment and are intended to be representative of European flora, fauna and natural habitats.

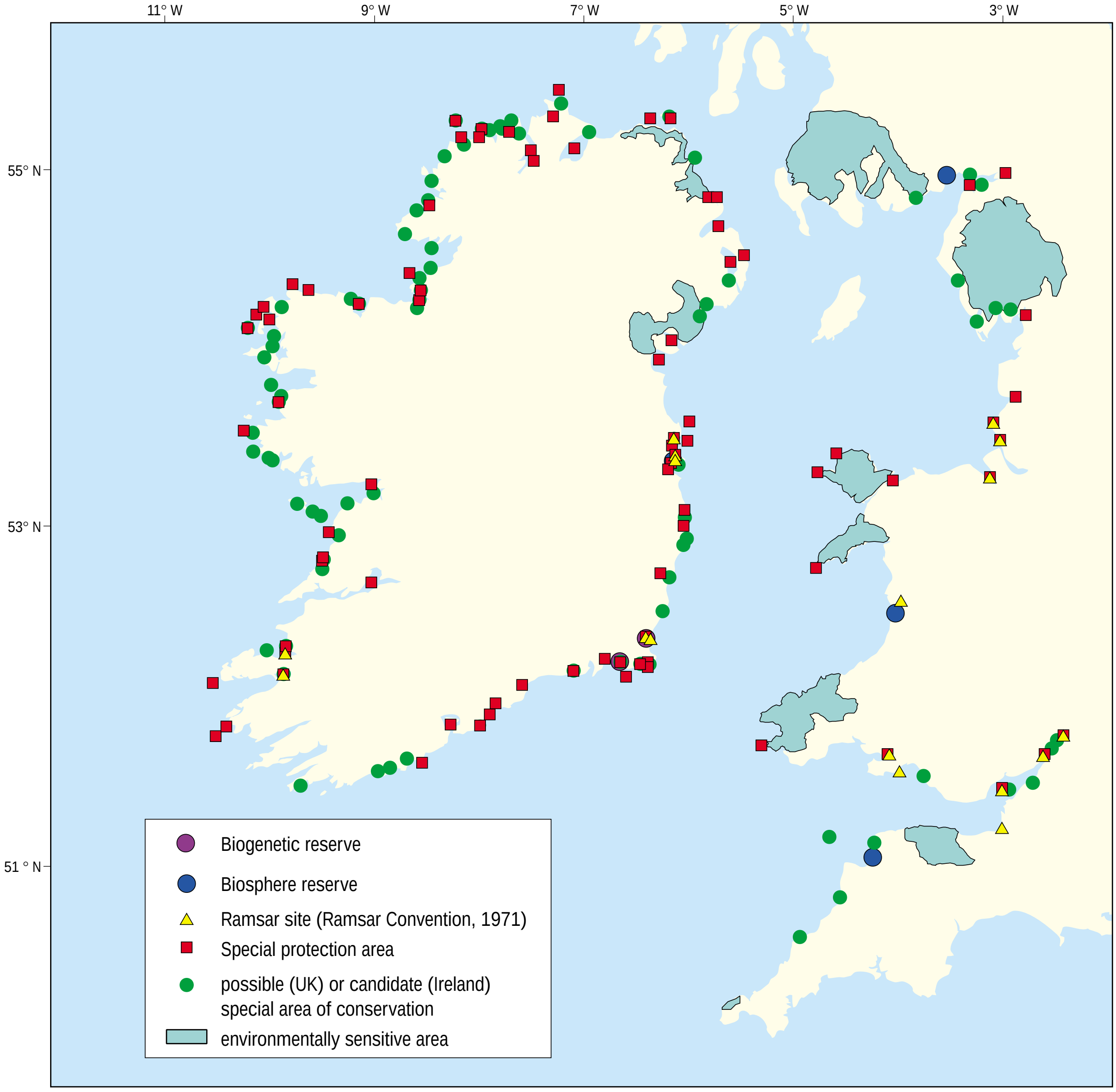
- **Ramsar sites** are designated under the terms of the 1971 Convention on Wetlands of International Importance especially as Waterfowl Habitats. Within Region III there are twenty-two coastal Ramsar sites in Ireland, nine in England, Wales and Northern Ireland and nine more in Scotland.

- **Special Protection Areas** (SPAs) and **Special Areas of Conservation** have been and are still being designated by the UK and Ireland under the terms of two EC Directives (the Conservation of Wild Birds and the Habitats Directives respectively).

National designations include:

- **Sites of Special Scientific Interest** (SSSIs) in England and Wales and **Areas of Special Scientific Interest** in Northern Ireland. In such areas activities and developments are intended to be limited or prevented if they could be particularly damaging to wildlife interests. Some areas are considered to be of such special interest that they are designated as **National Nature Reserves**; all such sites are also SSSIs or **Marine Nature Reserves**. ***Figure 3.3*** illustrates the location of these sites in England, Wales and Northern Ireland. Because of their number and the overlap of designations, there are many practical and legal difficulties involved in protecting all of these (and the internationally designated sites) from the effects of human interference. A similar situation exists in Ireland where proposed coastal **Natural Heritage Areas** (NHAs), which have evolved from **Areas of Scientific Interest**, are in many cases also SPAs. In addition there are a number of **Refuges for Fauna**, all the coastal examples of which are also SPAs and a number of **Statutory Nature Reserves**.

Figure 3.3 **Environmental designations of coastal sites in Ireland and conservation areas of the Irish Sea designated under international conventions and directives.**



3.3.1 Ecological conservation

Region III has a large number and variety of habitats, many of which are listed for protection under one or more designations (see *Box 3.1*). *Figure 3.3* shows the sites designated by the respective national authorities as nature conservation areas under the terms of various international and national requirements. This figure shows that much of the coastline is designated for one or other conservation purpose.

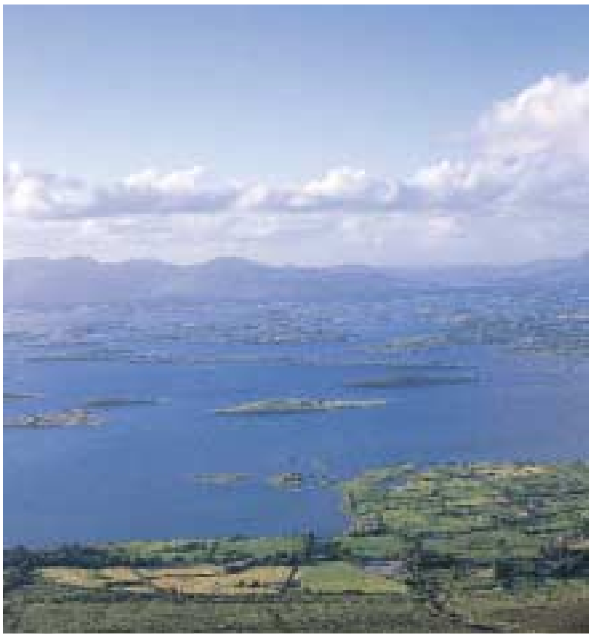
The coastlines of the region are both extensive and varied. The landmasses hold examples of most temperate zone habitat types, although their relative distribution and the degree of interaction with human activities, both past and potential, differ according to land-use, geology and population density.

In Ireland, sand dunes and sandhills are a major feature of the coastline with important examples of the former at Inch Bay, Dog’s Bay and Rosapenna on the west coast, and of the latter at Cahore Point and Duncannon on the south coast and Inisbofin on the west.

Lagoons are also a feature of the Irish coastline with important examples being Lady’s Island Lake, Tacumshin Lake and Lough Gill. Machair, a priority habitat under the EC Habitats Directive (92/43/EEC), is found in Ireland only on the west coast where it occurs between Galway Bay and Malin Head; most is used for grazing and/or amenity purposes. Rocky cliffs are also a feature of the coastline and there are several good examples of inaccessible cliffs providing important nesting areas for seabirds, for example Saltee Island, the Cliffs of Moher and Horn Head. Shingle beaches develop in high-energy environments and, although not in themselves species-rich habitats, can provide protective barriers for other more productive regions. For example the stretch of shingle from Greystones to Wicklow protects the north Wicklow coastal marshes which are important waterfowl sites. There are also extensive intertidal areas of salt marsh, sand and mudflats as well as both rocky and sandy shores. Lough Hyne in County Cork was designated as a Marine Nature Reserve in 1981.

The Northern Ireland coast and the eastern coastline of the Irish Sea feature a similar range of sites, many of which are of marine natural heritage importance. These range through the tide-swept reef communities of the Menai Straits and the glacial moraine ‘scars’ of the Cumbrian coast or ‘sarns’ of Cardigan Bay, to extensive areas of mud and sandflats, such as those in Morecambe Bay and the Solway Firth, which provide feeding grounds for wintering and migratory birds. Strangford Lough is a fjordic system and one of only three Marine Nature Reserves designated in the UK. Cardigan Bay is one of two locations in the UK to hold a semi-resident population of bottle-nose dolphins *(Tursiops truncatus)*. There are important bird colonies on islands off the Welsh coast. Lundy in the Bristol Channel and Skomer Island off Pembroke, are the two other UK designated Marine Nature Reserves within Region III. The extensive sandflats and mudflats of the Severn Estuary are of major national and international importance for wintering and migratory wildfowl and the well-developed and extensive ria habitats of Daucleddau and Milford Haven are of international renown. The Isles of Scilly and the rocky coasts and offshore islands of the south-west of Wales are home to significant populations of grey seals *(Halichoerus grypus*).

The Malin Shelf coastline is of equal significance and is much more sparsely populated and subject to less human interference. The offshore island of St Kilda west of Scotland and the Giant’s Causeway in Northern Ireland are the only sites on the UK coast thus far designated as World Heritage Sites. St Kilda is also designated as a British Biosphere Reserve, as are Rum, Taynorth and Loch Druidberg. The Scottish coastline features many long sea lochs, islands and cliffs, several of which support major seabird colonies. Nineteen areas on the Scottish west coast have been identified for protection under the EC Directive on Conservation of Wild Birds (79/409/EEC). From south Harris to Barra there are large areas of sand dunes and machair.


Clew Bay

The coastal waters between Malin Head and Lough Larne in Northern Ireland support important colonies of seabirds in the breeding season, with some usage at other times of the year. In Lough Foyle for example, Slavonian grebe *(Podiceps auritus)* reach internationally important numbers in some winters. The main breeding colonies are on the cliffs of Rathlin Island with nationally important assemblages of Manx shearwater *(Puffinus puffinus)*, kittiwake *(Rissa tridactyla)*, puffin *(Fratercula arctica)* and guillemot (*Uria aalge*) and internationally important numbers of razorbill *(Alca torda)*. Nearby Sheep Island holds a nationally important colony of cormorant *(Phalacrocorax carbo)*. Further east, waters in the vicinity of Larne Lough are the feeding grounds for nationally important numbers of Sandwich tern *(Sterna sandvicensis)*, common tern *(Sterna hirundo)* and roseate tern (*Sterna dougallii)* that breed on islands in the lough.

3.3.2 Archaeological conservation

There is evidence of human occupation of the land regions around the southern areas of Region III at least as far back as the mesolithic and neolithic times. In Scotland the earliest signs of human occupation are somewhat later (around 10 000 BC). During the last ice age, sea level was about 40 m lower than it is today (the Bristol Channel was merely a river valley) so when the ice melted some 10 000 years ago many sites of human occupation were submerged. Nevertheless many sites have been found and it is clear, for example from the widespread distribution of stone axes from Antrim in Northern Ireland, that there has been extensive trade both across the Irish Sea and along the coasts of south-west England, Wales and Scotland since at least 4500 BC. There is also evidence of early trade with areas further afield, particularly during the Roman occupation of England and Wales. Further evidence of human occupation, of trade associated with farming and discoveries of various useful minerals, is provided by the numerous shipwrecks (3000 off the coast of Northern Ireland alone) that litter the seabed around the coastline of the region.

The various shipwrecks and sites on land are important in helping to understand past human activities in the region. Accordingly a number of measures have been taken, and are being taken, either to prevent the disturbance of sites of archaeological interest or to avoid the loss of valuable information when development at a site, or even its destruction, is unavoidable. In Ireland a computerised Maritime Sites and Monuments Record has been under development since 1997 with a view to assisting in planning decisions. Within the UK there are similar listings of archaeological sites, many of which are protected by Acts of Parliament.

3.4 Tourism and recreation

The contemporary pattern of coastal recreation is moving from the more traditional coastal resorts offering ready-made amusements and attractions towards a diverse range of more individual pursuits such as angling, surfing, walking and nature watching on less developed parts of the coast. This steady encroachment of tourism and recreation into previously unfrequented areas is often followed by physical alterations to improve access and to extend accommodation, thereby changing coastal landscapes and imposing new pressures on natural habitats and water quality (see also Section 5.8).

To the east of Region III, sectors of coastline with traditionally high influxes of visitors in summer are those bordering the Bristol Channel, Cardigan Bay and Colwyn Bay, the Isle of Man, the Cumbrian coast, the Firth of Clyde, Strangford Lough, outer Dundrum Bay and the south-east coast of Ireland. In 1996 the coastal county of Cornwall, to the south of the Bristol Channel, received an estimated 3.5 million visitors. Further west, on the Celtic Sea and Atlantic coasts of Ireland, there are many small resort towns interspersed with sandy beaches that have traditionally attracted large numbers of Irish holidaymakers and the scenic coastlines of the south-west and west draw increasing numbers of foreign tourists. Ireland's offshore islands alone hosted 189 000 foreign visitors in 1995.

Outside resort towns, the most conspicuous sign of coastal recreation tends to be the proliferation of caravan parks, campsites, bed and breakfast accommodation and golf courses. Along one section of coastline on the south-west coast of Great Britain (Land's End to Kenfig) there is a total of 217 caravan parks or campsites, 7 holiday camps and 38 golf courses. Of the 70 golf courses constructed in Ireland since 1990, 20 are on the coast. Sailing and other water sports are growing in popularity, resulting in rapid expansion in the number and size of marinas, yacht clubs, mooring and boat-launching facilities. In 1989 approximately 56 000 overseas visitors to Ireland engaged in some form of boating.

Statistics on tourism, and recreational activities generally, tend to be compiled on a national or district (e.g. county) basis and the coastal component can only be estimated. More systematic recording of trends and changes would greatly facilitate future environmental assessments and make an important contribution to coastal zone management. In parts of Region III there are clear indications of increasing use of coastal amenities. In Ireland, for example, it is estimated that in the period 1970–95 the number of day-trips to the coasts increased almost sixfold. In some Irish coastal locations poorly planned holiday developments combined with seasonal influxes of tourists are placing considerable strain on the local infrastructure, such as water supply, sewage and waste disposal facilities. The number of Irish residents participating in sea-angling has increased by more than 50% in the last ten years. For many of the less industrialised coastal areas, tourism and recreation make a vital contribution to the local economy. In north-west England, for example, tourism supports over 250 000 jobs and in 1994 had a turnover of £ 1500 million. Tourist expenditure in the popular and historic resort of Blackpool is around £ 545 million annually.

An EC promotional programme has been introduced to attract tourists away from intensively visited coastal sites of west Wales and to promote visits to lesser-known inland areas. Intensive tourist-related developments are discouraged and restrictions on new coastal caravan and camp sites exist in some areas. Where new marinas are being created in populous areas, such as those at Dun Laoghaire and Greystones on the Irish east coast, careful planning will be needed to facilitate public access and to avoid excessive road traffic, conflicts between user groups and pollution from wastes and hydrocarbon releases.

There is increasing evidence that, in the absence of stringent planning controls and sensitive development policies, the attributes of coastal areas that are most attractive to visitors (such as unspoilt landscapes, clean uncrowded beaches, sea water fit for bathing and wildlife refuges) can be harmed by the sheer number of visitors, construction, and excessive vehicle and pedestrian traffic. Some of the more widespread impacts of tourism and recreation on coastal ecosystems, and the measures being introduced to address them, are described in Section 5.8.

3.5 **Fishing**

3.5.1 Introduction

During the twentieth century technical developments have led to more efficient exploitation of the various commercial fish stocks. Fisheries can be ‘directed’ at single species but more commonly a variety of species is caught in what are called ‘mixed fisheries’. In addition to target species, a particular fishery may take a by-catch of other species, some of which may be landed. Part of the catch of exploited species may also be discarded. The fishing industry can be categorised into four distinct sectors: pelagic, demersal, shellfish and industrial (see *Box 3.2*).

Box 3.2 Fishing sectors

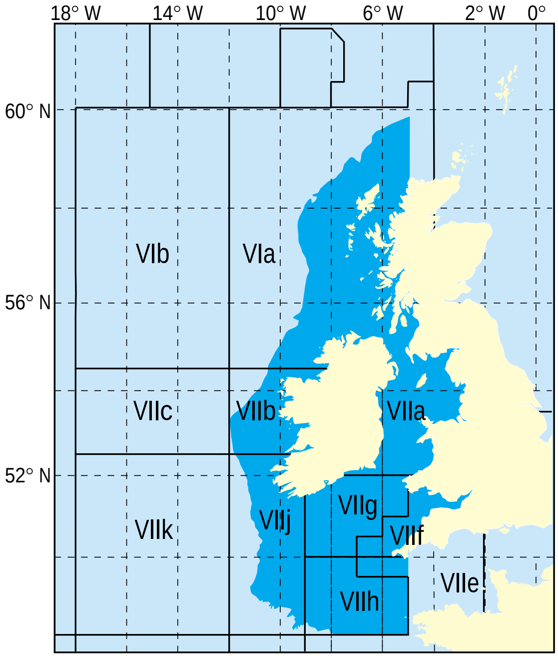
Fishes living in the water column, such as herring, mackerel, horse mackerel and tunas are called **pelagic**. Pelagic fish are caught by gears such as pelagic trawls, purse seines, drift nets and longlines.

Demersal fish live on or near the bottom and are mostly taken in bottom trawls e.g. beam trawls and otter trawls, and set nets. The fish landed by the demersal sector can be further divided into a number of groups. **Flatfish** include many species but the main ones landed in Region III are sole (*Solea solea*), plaice (*Pleuronectes platessa*), megrim (*Lepidorhombus whiffiagonis*) and lemon sole (*Microstomus kitt*). **Roundfish** generally refers to fish belonging to the cod family (gadoids) e.g. cod (*Gadus morhua*), whiting (*Merlangius merlangus*) and haddock (*Melanogrammus aeglefinus*) but also includes hake (*Merluccius merluccius*). Demersal fish which do not fit into either of these categories include anglerfish and John Dory (*Zeus faber*). Although elasmobranchs (sharks, skates and rays) can be either pelagic or demersal the bulk of landings in Region III are of demersal species e.g. spurdog (*Squalus acanthias*) and rays. These are included in the description of the demersal sector.

The term **shellfish** includes crustaceans (shrimps/prawns, crabs and lobsters), bivalve molluscs (mussels, oysters, clams and scallops) and gastropods (e.g. periwinkles and whelks), as well as cephalopods (squids and octopuses). The fisheries for shellfish can be divided into **offshore** and **inshore** components. The offshore component targets crustaceans, such as Norway lobster (*Nephrops norvegicus*), and scallops, using a variety of gears, including adapted otter trawls. The inshore fisheries can be further divided into pot fisheries for crabs and lobsters and those for shrimps and bivalve molluscs netted or collected in shallow subtidal and intertidal areas.

Fish taken by the **industrial fisheries** and processed for fishmeal and oil include Norway pout (*Trisopterus esmarki*), pouting (*Trisopterus luscus*) and sandeels (*Ammodytes* spp.).

Figure 3.4 **ICES Sub-areas (VI and VII) and Divisions.**



The divisions used by ICES for assessing the fisheries and for reporting fish landings are shown in *Figure 3.4*. The total average landings (excluding industrial fisheries) reported from Region III for the years 1990–5 (all fleets) were 926 000 t, with the demersal, pelagic and shellfish

Table 3.1 Landings (tonnes) of fish and shellfish from Region III by country in 1995. Source of data: ICES STATLANT 27A database; ICES (1997a,b; 1998a,b,c).

	Ireland	Scotland	UK (E,W & NI)
Herring	46 644	40 654	9 626
Mackerel	72 213	143 135	29 230
Horse mackerel	177 648	10 323	10 193
Roundfish	25 811	29 736	20 018
Flatfish	7 749	4 591	7 353
Elasmobranchs	6 169	5 828	4 816
Other fish	4 887	15 222	7 436
Total	341 121	249 489	88 672
%	33.5	24.5	8.7
Crustaceans	16 750	20 231	8 325
Molluscs	27 273	7 819	12 645
Total	44 023	28 050	20 970
%	43.7	27.9	20.8

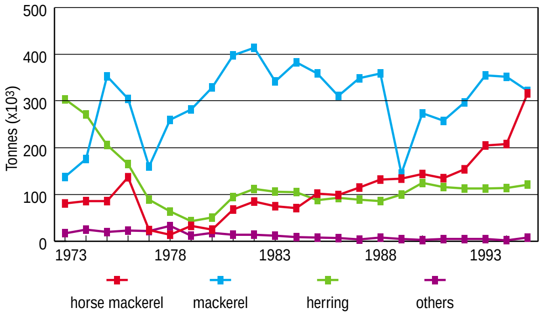
sectors accounting for 67.4%, 23.4% and 9.2% respectively.

The contributions of the various countries to the fish and shellfish landings in Region III in 1995 are given in *Table 3.1*. In 1995, Irish and Scottish vessels accounted for 34% and 25% respectively of all fish and shellfish landed in the region. The national contributions to total landings vary considerably between ICES divisions, for example Irish landings accounted for 75% of the 1995 total for the west of Ireland (Division VIIb), whilst Scottish landings in the Irish Sea (Division VIIa) amounted to less than 6% of the total for the area. For the purposes of the remainder of this description of the fishing industry the statistics used are those reported by fishermen using the EC logbook scheme. Reductions in quotas and Total Allowable Catch (TAC) in the 1990s increased incentives to misreport landings both in terms of quantity and origin; some improvements have been noted recently. Statistics post-1995 reflect only landings and not total catch which includes quantities of organisms discarded because they are undersized, over-quota or of no commercial value.

3.5.2 Pelagic fisheries

These fisheries operate mainly using mid-water trawl or purse seine nets. The three principal species taken within the region by the pelagic sector are mackerel (*Scomber scombrus*), horse mackerel (*Trachurus trachurus*) and herring (*Clupea harengus*), which accounted for 42%, 41% and 16% respectively of total pelagic landings reported in 1995 (760 000 t). Other species of pelagic fish landed included sprat (*Sprattus sprattus*), pilchard (*Sardina pilchardus*) and tunas. Scottish trawlers catch roughly 74% of the total herring landings from Region III in autumn and winter on the Malin Shelf (Division VIa). Herring landings from the Celtic Sea comprise a further 14% of the total and the remainder is divided equally between the Irish Sea and west of Ireland. The Celtic Sea herring fishery is dominated by Irish trawlers operating inshore and targeting the ‘roe’ fishery in winter and spring. As with all stocks in Western Europe, the herring stocks in Region III went through a period of decline during the 1970s. This is reflected in the landings over the period 1973–95 *(Figure 3.5)*. In terms of landed weight, mackerel and

Figure 3.5 **Landings of pelagic fish in Region III for 1973–95. Source of data: ICES STATLANT 27A database; ICES (1997a, 1998a).**



Isle of Man	Belgium	Denmark	France	Germany	Netherlands	Spain	Others	Total
615	-	91	3 872	4 164	9 889	-	5 782	121 337
1	-	54	10 178	23 067	33 788	4 509	5 761	321 936
-	-	4 800	-	17 314	95 950	25	-	316 253
140	1 331	24 439	38 647[*]	612	8	14 000[†]	3 719	158 461
37	3 114	5	4 823[‡]	-	-	6 129[§]	57	33 858
33	743	-	-	180	-	-	99	17 868
32	1 335	740	13 466[≠]	141	94	4 672[≠]	59	48 084
858	6 523	30 129	70 986	45 478	139 729	29 335	15 477	1 017 797
0.1	0.6	3.0	7.0	4.5	13.7	2.9	1.5	
325	27	-	4 500[¶]	-	-	-	1	50 159
2 551	200	-	-	2	-	-	-	50 490
2 876	227	-	4 500	2	-	-	1	100 649
2.9	0.2	-	4.5	< 0.01	-	-	< 0.01	

[*] cod, whiting, haddock and hake (all include VIIc), saithe (includes VIb);

[†] hake only;

[‡] plaice and sole (include VIIc), megrim (includes VIIIa,b);

[§] megrim only (includes VIIIa,b);

[≠] anglerfish only;

[¶] *Nephrops* only;

-: no landings reported.

horse mackerel now exceed that of herring. The locally exploited Clyde herring fishery has declined sharply in recent years as the stock has suffered from a series of low recruitments. Recent TACs have not been achieved and catches have been less than 1000 t since 1991.

3.5.3 Demersal fisheries

The demersal fisheries in Region III are mixed fisheries targeting primarily cod, whiting, haddock, hake, anglerfish, megrim, plaice and sole. Most of the demersal landings are made up of roundfish. These contributed 64% of the total demersal landings of 250 000 t in 1995, but have been highly variable during the last twenty-five years *(Figure 3.6)*. In 1995 flatfish, anglerfish and elasmobranchs accounted for 13%, 11% and 7% of landings respectively, the balance comprising other demersal species (e.g. gurnards and seabass (*Dicentrarchus labrax*)). The bulk of demersal landings are taken in the Celtic Sea (44% in 1995) by French, Spanish, Irish and UK trawlers and in the Malin Sea (40% in 1995) primarily by Scottish trawlers.

The principal gears used in the demersal fisheries throughout Region III are otter and beam trawls. The targeting of sole and plaice using beam trawls, particularly by boats from southern England and Belgium fishing in the Irish and Celtic Seas, increased considerably in the 1970s and led to an increase in the landings of these two species. In the Irish Sea there has been a development of mid-water trawling for cod, whiting and hake, predominantly by vessels from Northern Ireland. There has been an increase in the last decade in the number of Irish seiners fishing for whiting and haddock in Sub-area VII. In addition, a bottom-set gillnet fishery has developed in the Celtic Sea over the last decade aimed primarily at hake, anglerfish and turbot (*Psetta maxima*).

3.5.4 Shellfish fisheries

The major commercial shellfishery in Region III is for Dublin Bay prawns, which contributes approximately 32% (average for 1990–5) to the total landings (96 000 t in 1995) of all shellfish in the region. Fishing takes place in the Irish Sea, on inshore grounds west of Scotland, along the west, south-west and south coasts of Ireland and in the Celtic Sea. Landings have increased over the period 1973–95 *(Figure 3.7)*, primarily due to increases in the landings from the west of Scotland (Division VIa). The principal gear used is an otter trawl with square-mesh panels, although some small-scale local fisheries use pots. Larger vessels, which normally target roundfish, may also use twin trawls when targeting both roundfish and *Nephrops*.

Other important shellfisheries include those for scallop and queen scallop (*Chlamys opercularis*). These are fished using dredges and, to a lesser extent, trawls. Mussel, clam and cockle fishing, by small boats using dredges, is concentrated in near shore waters and estuaries. Crab, lobster and shrimp are also caught, mainly by small vessels using pots. In recent years, potting effort on whelks (*Buccinum undatum*) has increased. Total landings of molluscs have increased since the 1970s but in recent years have been extremely variable as demand for whelks, in particular from south-east Asia, has fluctuated.

3.5.5 Industrial fisheries

The industrial fisheries in Region III are much smaller than in Region II (the Greater North Sea). An irregular fishery started in Sub-area VIa in the early 1980s and peaked in 1986 and 1988. There is a small fishery for Norway pout in Sub-area VI conducted by Danish vessels. Most horse mackerel are sold for human consumption but some go for fishmeal. Landings used for fishmeal are included in *Table 3.1* but only

Figure 3.6 **Landings of demersal fish in Region III for 1973–95. Source of data: ICES STATLANT 27A database; ICES (1998b,c).**

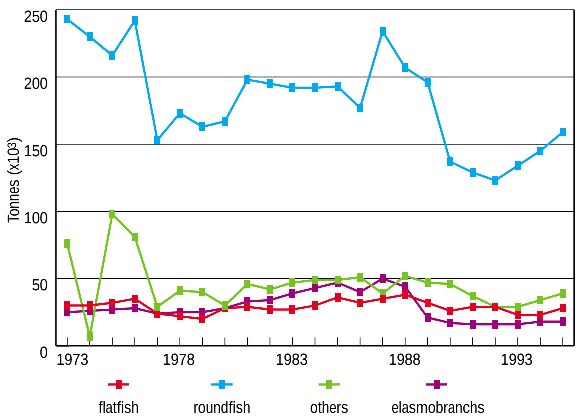
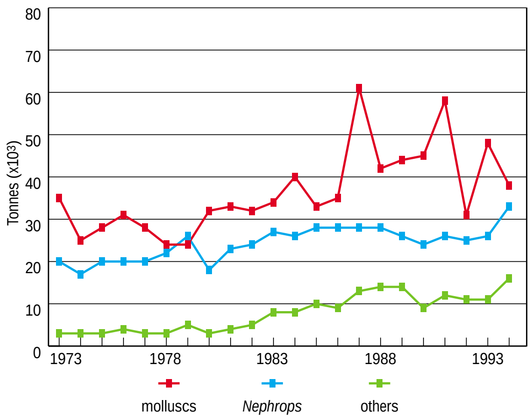


Figure 3.7 **Landings of shellfish in Region III for 1973–94. Source of data: ICES STATLANT 27A database; ICES (1997b).**



comprise a small percentage of the total landings. For example in Sub-area VIa the three main industrial species account for only 3.5% of the total fish and shellfish landings between 1991 and 1995. Norwegian and Danish boats operate large industrial fisheries for blue whiting (*Micromesistius poutassou*) off the west and north-west coast of Ireland (Divisions VIa and VIIb) but within Region V (the Wider Atlantic) rather than Region III.

3.5.6 Fishing effort, fleet size and composition

Fishing effort is a measure of the activity of the fleet and depends on the number of vessels, their size and power, time spent fishing and the effectiveness of the vessels in catching the target species. Effort should therefore be measured in different ways for different types of fishing gear, but is often estimated simply on the basis of days at sea or days spent fishing. Data on fleet composition for Region III are complicated by a number of factors that make assessment of current fishing effort, and comparison between years, extremely difficult. Many vessels, particularly the smaller ones, may fish using several techniques of different efficiencies. For example the medium (15 – 20 m) and large (> 20 m) Irish polyvalent fleet target flatfish and roundfish in the summer and switch to herring in the winter and spring. Vessels may also switch areas and target species according to market or weather conditions and changes in management criteria.

The Irish fleet consists mainly of inshore and mid-water boats that fish for periods of one to ten days. In 1995 over 64% of the fleet consisted of inshore vessels less than 12 m in length, with an average age of about twenty-two years; these vessels fish mainly for demersal species. Although the dedicated pelagic fleet then comprised only 6% of the Irish fleet it is among the most modern in Europe. It is based mainly in the north-west and operates as far afield as the coast of Norway. The number of vessels in the fleet has declined in recent years although newer vessels are now considerably larger.

As with the Irish fleet the majority of boats registered at, and operating from, Scottish ports within the region are small. Of the total number of boats registered at the end of 1996 almost 70% were < 10 m in length and only nine were > 35 m. Almost all the boats > 30 m were registered at the ports of Ayr (thirteen) and Stornoway (three) with the only other large boat > 35 m registered in Mallaig. Stornoway (with 364) and Mallaig (with 259) account for almost half the total number of registered boats. Shellfish dominate landings at most of the ports.

In 1991 Northern Ireland had 264 registered fishing vessels > 10 m in length but this had fallen to 190 by 1998. Of these, 180 were based at the three main ports – Kilkeel, Portavogie and Ardglass – all but eleven being classed as demersal *Nephrops* and seine boats. There is a small (40 – 100 t/yr) scallop fishery off the coast of Northern Ireland and an important mussel fishery in the Foyle Estuary. The latter is controlled by a cross-border body (the Foyle Fisheries Commission) and is operated mainly by fishermen from south of the border with Ireland.

RFV Celtic Voyager leaving Dublin Port

An attempt was made to review the trend in fishing effort in the Irish Sea from 1971 to 1991. However, given the data deficiencies, which varied between countries, total effort could only be examined for the period 1986–91, during which there was an increase of 40%.

3.5.7 Management

The overall objective of fisheries management is to ensure long-term sustainable use of fisheries resources. The principal instrument within the EC to secure their long-term rational development is the 1983 Common Fisheries Policy (see *Box 3.3*). The fisheries in Region III are managed under a system of TACs. Introduced in 1983 these impose an upper limit on the landings of each stock. TACs are set for the main commercial species and are established each year on the basis of advice from the ICES Advisory Committee on Fishery Management. They are divided into fixed percentage quotas allocated to each state participating in the fishery. The TAC system is an indirect method of fishing effort control and does not directly take into account the fact that large quantities of fish are discarded. Without sufficient direct controls on the amount of fishing effort, fish caught in excess of the TAC have been landed or reported as having been caught, in another division. This practice contributed to the deterioration in catch statistics referred to earlier and the stock assessments which depend upon them.

In addition to TACs the EC adopts a regime of technical measures such as restrictions on mesh shape and size, minimum landing size and definition of areas within which fishing is prohibited or restricted, for example the ‘Mackerel Box’ off the coast of Cornwall. The EC has developed guideline plans for reductions in fishing effort through its Multi-Annual Guidance Programmes (MAGPs). These aim to match fleet capacity to the resource base and address the problem of overcapacity in the fleets by setting targets for tonnage and fishing power for each member state. The first set of programmes sought to arrest the increase in fleet capacity. The (1987–91) generation of MAGPs set targets of 3% reduction in tonnage and 2% reduction in power over the whole period. These targets were not always met. The number of boats registered in the Irish Sea by Ireland, England, Wales, Northern Ireland and France rose from 294 in 1983 to 374 in 1991.

The problem of overcapacity was addressed more firmly in a more recent generation of programmes which called for reductions of 20% for roundfish trawl fisheries, of 15% for flatfish and other fisheries using towed gear, and a stabilisation for pelagic and fixed gear fisheries. These targets were to be achieved by the end of 1996 but were not generally met. Decommissioning reduced the size of the Northern Ireland fleet > 10 m by 27% between 1991 and 1996. In line with the 1996 target, the number of Irish vessels fishing in the Irish Sea also declined in recent years. This has been mainly due to redistribution of effort by larger vessels to fishing areas off the south and west coasts. The current generation of MAGPs aim to achieve targets partly through reduction in fishing effort, as opposed to decommissioning alone. There is an agreement to reduce the total EC fleet capacity by 4 – 5% by 2001. It is uncertain that this target can be met.

With the exception of *Nephrops*, which are subject to TACs, regulation of shellfisheries is primarily a matter for national authorities. In England and Wales these controls have been devolved to local Sea Fisheries Committees which can set size limits for the various species landed in their area. A similar system is about to be introduced in Scotland. Generally these local regulations are observed by the fishermen.

Box 3.3 Common Fisheries Policy

The Common Fisheries Policy was adopted by the European Community in 1983 and reviewed and modified in 1992 (Council Regulation No. 3760/92). This review introduced major changes in principle, in order:

- to provide for rational and responsible exploitation of the resources, while recognising the interests of the fisheries sector and taking into account the biological constraints with respect to the marine ecosystem;
- to facilitate improvement in the selectivity of fishing methods in order to optimise utilisation of the biological potential and to limit discarding; and
- to establish measures in order to ensure the rational and responsible exploitation of the resources on a sustainable basis.

The Common Fisheries Policy contains several measures relating to the conservation and management of fish and shellfish resources. These include rules on the use and allocation of resources among member states, technical conservation measures, special measures for inshore fisheries and supervisory measures.

3.6 Mariculture

Cultivation of wild stocks of shellfish has been practised in Ireland and on parts of the English, Welsh and Scottish coasts for more than a century but in recent times attention has turned to the culture of shellfish and finfish using hatchery-reared stocks. *Table 3.2* gives details of the way production increased between 1980 and 1996 in Ireland. By 1996 the total value of the Irish mariculture industry (£ 51 million) was comparable to that of the demersal and pelagic sectors of the fishing industry.

Finfish mariculture started in the 1970s and is now an important industry in both Ireland and Scotland. The first species to be farmed was rainbow trout (*Oncorhynchus mykiss*) reared in sea cages, but this was followed by cage production of Atlantic salmon (*Salmo salar*). The salmon farming industry developed rapidly during the 1980s and production has risen steadily since then. Production in Ireland (14 000 t in 1996) is dwarfed by the Scottish industry which in the Malin Sea area alone had 432 sites registered in 1996 producing around 83 000 t. The main salmon farming areas are on the south, west and north coasts of Ireland and along the west coast of Scotland *(Figures 3.8 and 3.9)*. There is considerable interest in extending the range of species farmed and small quantities of turbot and halibut (*Hippoglossus hippoglossus*) are now being produced in Ireland and Scotland.

Seaweed is used in crofting areas as a fertiliser and soil conditioner. There is renewed interest in alga culture in Ireland where large quantities (40 000 t/yr) of naturally grown seaweed are harvested, mainly for processing into alginates. The production of alginates, also mainly from naturally grown seaweed, is also practised in Scotland, with two factories in the Western Isles employing around 70 people in total. Throughout Region III small quantities of seaweeds are harvested locally for food e.g. dulse (*Rhodymenia palmata*) in Northern Ireland.

In England and Wales, and in Northern Ireland where the value of cultured shellfish doubled between 1991 and 1995, mariculture activity is almost exclusively focused on shellfish *(Figure 3.8)*. In Scotland shellfish cultivation is much less important than that of finfish in overall production terms, but

Table 3.2 Mariculture production (tonnes) in Ireland 1980–96. Source of data: Bord Iascaigh Mhara.

	1980	1985	1990	1995	1996
Mussels (bottom)	4 557	8 722	15 000	5 570	7 500
Mussels (rope)	175	1 636	3 380	5 501	7 000
Pacific oysters	60	101	361	2 539	4 000
Native/flat oysters	422	216	420	397	400
Clams	-	-	60	103	125
Scallops	-	-	-	28	-
Total Shellfish	5 214	10 675	19 221	14 138	19 025
Salmon	21	700	6 323	11 811	14 025
Rainbow trout (sea)	160	60	324	470	690
Turbot	-	-	-	15	30
Total Finfish	181	760	6 647	12 296	14 745
Total	5 395	11 435	25 868	26 434	33 770

-: no information (zero production assumed).

in Ireland the position is reversed. The main species cultivated in all areas are mussels and oysters (both native/flat oysters (*Ostrea edulis*) and Pacific oyster (*Crassostrea gigas*), but there is increasing interest in scallop and queen scallop, and in Ireland small-scale operations for the hatchery and on-growing of both European abalone (*Haliotis tuberculata*) and Pacific abalone. Small quantities of clams are also produced in both Ireland and Wales. Mussel cultivation is roughly equally spread between the rearing of naturally settled and relaid stock and the cultivation of mussels settled on ropes. The cultivation of native/flat oysters has declined markedly following the spread of *Bonamia* disease, with Pacific oysters filling the gap.

3.7 Coastal protection and land reclamation

Coastal erosion is an ongoing natural process and soft shorelines exposed to the action of waves, whether caused by the prevailing winds or storms, will always be at risk. For

Figure 3.8 **Location of the main mariculture areas in England, Wales, Ireland and Northern Ireland. Source: Bord Iascaigh Mhara; CEFAS.**

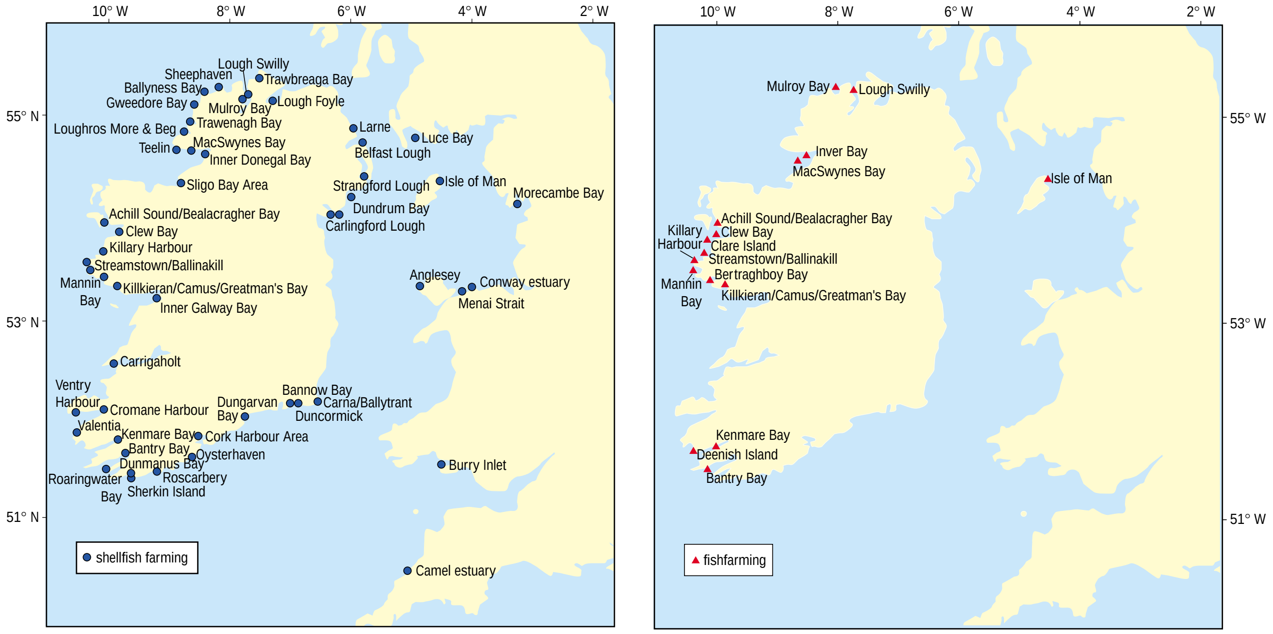
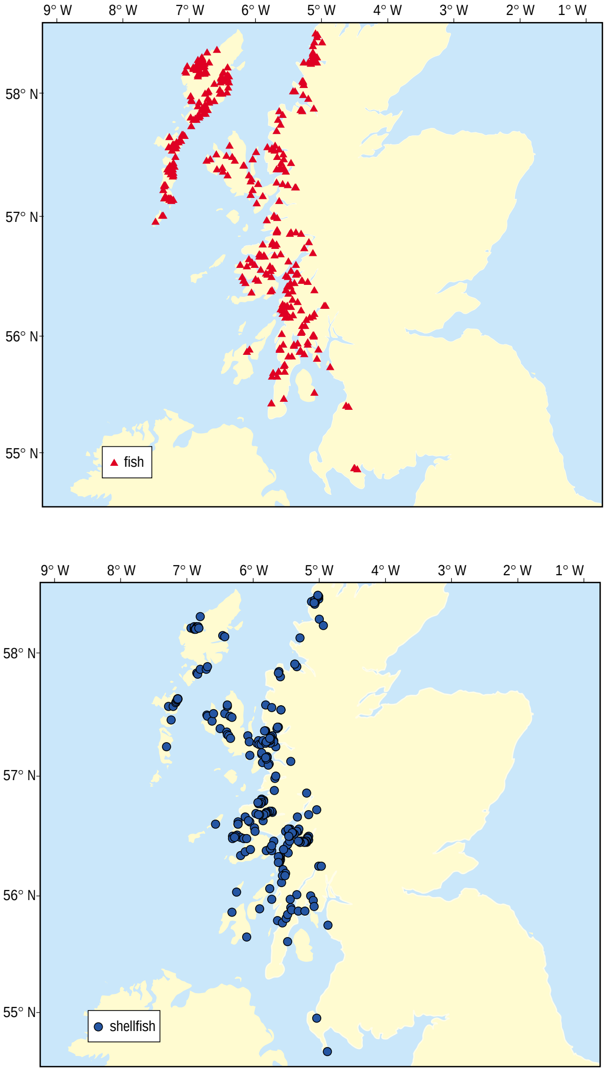


Figure 3.9 **Fish and shellfish production on the west coast of Scotland. Source: FRS.**



most of the coast, public policy has been to accept the changes and accommodate the consequences. Reference was made in Section 2.10 to the possible effect of global climate change on sea level and hence coastal erosion and increased risk of flooding. At present the extent of coastal erosion depends largely on the nature of the coast, its degree of exposure and the extent of human interference.

The Scottish coastline is mainly rocky and windswept but a few areas of dune and machair in the Western Isles are affected by erosion. Irish records of coastal erosion go back at least to the 1840s, with erosion rates quoted as being in the range 0.5 – 1.5 m/yr. Similarly the north-west coast of the Isle of Man suffers severely and erosion rates of up to 1.2 m/yr have been observed. At Dundrum Bay in Northern Ireland, coastal protection works have been instigated to limit coastal erosion but more are required to prevent serious problems. Sea defence works have also been undertaken using rock armouring in the vicinity of Larne and Belfast Lough. On the south-west side of the Wirral peninsula (between the Dee and Mersey estuaries) erosion rates can be similar to the worst observed in Ireland (0.5 – 1.5 m/yr) and extensive coastal protection works have had to be created. North of Liverpool, erosion of the sand dunes is occurring at up to 2 m/yr even though 60% of the coastline has some form of protection.

Large areas of land bordering estuaries or the coast close to centres of population or industry have been protected by sea walls designed to channel normal estuary flow or to avoid flooding on particularly high tides or during storms. Thus for example, much of the coastline of the Mersey Estuary in England, the Clyde Estuary in Scotland, Belfast Lough in Northern Ireland and areas around Dublin and the inner Shannon Estuary in Ireland are largely artificial. In the upper reaches of the Bristol Channel and the Severn Estuary much of the shoreline is protected from flood damage by embankments. Shoreline Management Plans are being drawn up for the whole coastline of England and Wales, and similar plans either exist or are in preparation for the few areas considered to be at risk in Scotland. These take account of anticipated sea level rise due to climate change and for geological reasons. In Ireland a detailed analysis of areas at risk and the state of coastal defences has been carried out but coordinated plans for future action have still to be drawn up.

3.8 Wave, tide and wind power generation

There is considerable potential for tidal power generation in the upper reaches of the Bristol Channel, in the Conwy, Dee, Mersey, Wyre and Duddon estuaries and in the Solway Firth. Detailed plans have been developed in some cases (see *Table 3.3*) with the estimated capacity for a Severn barrage scheme amounting to 6% of UK needs. However, the cost projections at present, coupled with concerns over environmental impact, militate against actual construction and none of the plans are currently proceeding.

Given their exposure to the prevailing westerly winds and waves there is considered to be much potential for both wave- and wind-generated power schemes on the coasts of Ireland and Scotland. There is one coastal wind farm site on Rathlin Island in Northern Ireland and several wind power generators have been built at coastal sites in England and Wales and on the west coast of Ireland. To date all the existing and proposed wind farms are land-based and have no impact, other than visual, on the marine environment. However there are plans to develop an extensive array of wind power generators to be sited off the coasts of the UK and Ireland.

Table 3.3 Potential tidal barrage performance in the Irish Sea. Source of data: ISSG (1990a); Welsh Office.

	Morecambe	Solway	Dee	Dovey	Severn	Mersey
Mean tidal range (m)	6.3	5.5	5.9	2.9	10.5	6.4
Basin area (10^6 m^2)	350	860	90	13	48 000	70
Barrage length (m)	16 600	30 000	9 500	1 300	16 000	1 750
Maximum water depth (m)	30	28	29	11	33	25
Installed capacity (MW)	3 000	7 200	840	20	8 640	620
Annual energy output (GW)	4 630	10 250	11 160	50	17 000	1 320
Cost of energy - 1990 (pence/KWh)	4.3	5.1	6.4	7.2	3.0*	3.6

* costs for 1984.

3.9 Sand and gravel extraction

Seabed deposits of sand and gravel are valuable sources of aggregates for building and road construction as well as beach replenishment and protection. The extraction of aggregates at offshore sites in Region III is presently confined to the Bristol Channel (seven sites) and the north-eastern Irish Sea (two sites). In 1997 these sites yielded around 2.3 million t, of which just over 2 million t were taken from the Bristol Channel.

In the UK, extraction of marine aggregates peaked in 1989 and has since fallen steadily. Statutory controls are being introduced in 1999 to meet EC/EIA Directive obligations. In Ireland, sources of aggregates on land are seriously depleted and there is growing demand for licences to exploit offshore deposits. No such licences have been issued to date. There are substantial gravel resources parallel to the coast from Dublin Bay to Carnsore Point and an EU-funded project is currently assessing these and other aggregate resources inside the 30 m depth contour. Near shore sandbanks such as those off counties Wicklow, Wexford and Cork have been exploited in the past by local authorities for beach replenishment and as infill for harbour development. Maërl (a mineral formed from calcareous algae) deposits at near shore sites off the west coast of Ireland have also attracted considerable attention because of their value as a fertiliser and soil conditioner. At present extraction is licensed at only one site; Bantry Bay on the south-west coast. On the Scottish coast of the Malin Shelf there are nineteen sites, mostly in the Western Isles, at which small quantities of beach sand and gravel have been extracted for use in construction and agriculture.

3.10 Dredging and dumping

The disposal of wastes at sea (i.e. dumping) is controlled under Annex II of the OSPAR Convention (1992) and, at global level, by the London Convention (1972). Both Ireland and the UK are contracting parties to these conventions and dumping activities in Region III are therefore controlled by national legislation in accordance with international protocols and agreements. In line with these agreements, the dumping of most forms of industrial waste has been prohibited since 1994 and the dumping of sewage sludges from the UK was phased out at the end of 1998. The disposal of sewage sludge in the Bristol Channel ceased in 1992. The disposal of Dublin sewage sludge ceased in mid-1999.

A licence for the disposal of waste at sea is issued only where it can be shown that there is no practicable option for disposal on land and that the material is not seriously contaminated. Dump sites are designated by the national licensing authorities and are subject to periodic monitoring to ensure impacts are acceptable.

The quantities of sewage sludge, dredged material and industrial wastes disposed of in different sea areas of Region III over the period 1988–96 are given in *Table 3.4*. Sludges generated by coastal sewage treatment plants are spread on agricultural land or deposited in landfill sites, but with the cessation of the sea disposal option there is likely to be increasing use of incineration. In Ireland, sludge from the Ringsend treatment plant in Dublin has historically been the most important source of settled sewage sludge subject to sea disposal. The amounts of sludge generated by the Ringsend plant were relatively stable during the later years of disposal, averaging about 350 000 t/yr ww. Sludges from UK sources, deposited in Liverpool Bay, outer Belfast Lough and the Bristol Channel remained at around a constant 2.3 million t/yr ww from 1988 to 1996. During the same period, the annual input of sewage sludge to the Garroch Head disposal site in the outer Firth of Clyde (Malin Shelf), was a relatively constant 1.65 million t/yr ww.

The bulk of the material eligible for sea disposal now comes from dredging operations. Dredging of ports and navigation channels is an essential activity. The largest dredging operations occur in the vicinity of large ports such as those on the Bristol Channel, Mersey Estuary, Firth of Clyde and at Dublin. There are approximately fourteen dump sites for dredged material in the eastern

Table 3.4 Materials (wet tonnes) dumped at sea under licence in Region III 1988–96.

	Sewage sludge	Dredged material	Solid industrial waste	Liquid industrial waste
1988				
Eastern Irish Sea/Bristol Channel*	2 194 636	17 046 380	174 656	2 202
Irish coastal waters†	243 000	425 639	0	533 703
Malin Shelf (Scotland only)	1 755 633	696 971	0	0
Total	4 193 269	18 168 990	174 656	535 905
1989				
Eastern Irish Sea/Bristol Channel	2 272 902	17 559 704	86 676	0
Irish coastal waters	347 636	1 610 159	0	458 210
Malin Shelf (Scotland only)	1 693 000	635 238	0	0
Total	4 313 538	19 805 101	86 676	458 210
1990				
Eastern Irish Sea/Bristol Channel	2 286 747	13 689 973	117 296	0
Irish coastal waters	288 200	1 103 565	0	4 740
Malin Shelf	1 671 500	453 932	0	0
Total	4 246 447	15 247 470	117 296	4 740
1991				
Eastern Irish Sea/Bristol Channel	2 460 300	19 731 200	85 336	0
Irish coastal waters	339 890	1 230 552	0	348 971
Malin Shelf	1 698 000	510 082	0	0
Total	4 498 190	21 471 834	85 336	348 971
1992				
Eastern Irish Sea/Bristol Channel	2 393 054	7 687 849	99 169	0
Irish coastal waters	380 397	493 927	0	111 692
Malin Shelf	1 686 000	1 481 973	0	0
Total	4 459 451	9 663 749	99 169	111 692
1993				
Eastern Irish Sea/Bristol Channel	2 226 441	8 683 259	57 043	0
Irish coastal waters	312 640	829 470	0	77 847
Malin Shelf	1 632 000	1 788 752	0	0
Total	4 171 081	11 301 481	57 043	77 847
1994				
Eastern Irish Sea/Bristol Channel	2 207 411	8 156 448	91 935	0
Irish coastal waters	336 346	937 905	0	0
Malin Shelf	1 603 000	290 525	0	0
Total	4 146 757	9 384 878	91 935	0
1995				
Eastern Irish Sea/Bristol Channel	2 297 896	9 823 119	0	0
Irish coastal waters	332 025	620 267	0	0
Malin Shelf	1 576 200	965 079	0	0
Total	4 206 121	11 408 465	0	0
1996				
Eastern Irish Sea/Bristol Channel	2 309 492	17 850 227	0	0
Irish coastal waters	391 933	1 388 734	0	0
Malin Shelf	1 697 200	436 760	0	0
Total	4 398 625	19 675 721	0	0

* UK sector of the Irish Sea, east of approximately 5º 40’ W (including the Isle of Man and North Channel) plus the Bristol Channel;

† Irish sector of the Irish Sea, west of approximately 5º 40’ W plus the Celtic Sea and Atlantic seaboard.

Irish Sea/Bristol Channel, seventeen on the Malin Shelf and nineteen in Irish coastal waters. Dredged sediments consist predominantly of naturally-occurring sand and silt and, unlike the disposal of wastes, their disposal consists essentially of the transfer of materials from one part of the seabed to another. The concentrations of certain heavy metals and synthetic substances in sediments from the potentially more contaminated sites are checked as part of the licensing procedure. However, estimates of the actual amounts of contaminants transferred to disposal sites are inherently imprecise (due to sediment inhomogeneity). Such limitations are necessarily taken into account when using data for site management purposes.

3.11 Oil and gas

Offshore gas production in Region III started in 1985 *(Table 3.5)* following construction of a 34 km pipeline to Barrow-in-Furness. Oil was found in 1990 in the Douglas Field and is transported ashore by tanker while gas is conveyed to north Wales by a 20 km pipeline. Exploration for oil and gas in the Irish sector of the northern Celtic Sea basin began in 1969. Since that time 131 exploration and appraisal wells have been drilled around Ireland; 60% in the Celtic Sea basin and central Irish Sea. However, 28 wells were drilled in the deep Porcupine basin west of the 200 m isobath (i.e. strictly speaking in Region V) and seven in the north-western offshore basins of Slyne Trough, Erris Trough and Donegal Basin (four of these just fall within Region III, the other three are just outside in Region V). The only commercial discoveries to date in Irish waters were made in 1971 and 1980, when the Kinsale Head gas field and Ballycotton Field respectively were found. These fields are linked via a 55.4 km pipeline to the coast near Cork *(Figure 3.10)*; they are now in decline and are expected to become economically unviable sometime after 2005. To meet present Irish requirements, a 290 km gas interconnector has been constructed between Ireland and the UK. A similar pipeline connects Scotland with Northern Ireland. Exploration drilling continues in the Irish Sea and Celtic Sea, with some eight to fifteen wells typically drilled each year between 1987 and 1996 in the Irish and UK sectors.

Following discoveries of oil west of Shetland and the development of the technology required to exploit such deep water areas there has been renewed interest in exploration off Scotland, west of the Hebrides. The Foinavon and Schiehallion oilfields began production in 1998; gas is also present but quantities do not justify a pipeline at present. Most of the area inside the Minches is regarded as onshore for the purposes of exploration/exploitation and is subject to strict regulation under EC Directive 97/11/EC. Thus far only one exploratory well has been drilled in the North Minch and no exploitable reserves have been reported.

3.12 Shipping

Region III has for centuries been traversed by major shipping routes, notably to the north and south of Ireland and through the Irish Sea between the Western Approaches and the North Channel. There are in addition numerous cross Irish Sea routes connecting Ireland with the UK and European ports. *Figure 3.11* shows the main ports in Region III with details of the most important shipping routes and traffic separation schemes. In addition to the traffic separation schemes there is a voluntary code of practice, which was adopted by the International Maritime Organization (IMO) in 1993, under which laden tankers of more than 10 000 GRT should, except in poor weather, use the Deep Water Route west of the Hebrides rather than pass through the Minch. Excluding ferry traffic, fishing vessels, warships and offshore supply vessels, it has been estimated that in the late 1980s there were approximately 150 000 merchant vessel movements annually through Region III. Many of these involved vessels on passage between ports outside the area. More recently (1995) 13 000 tanker movements alone were recorded.

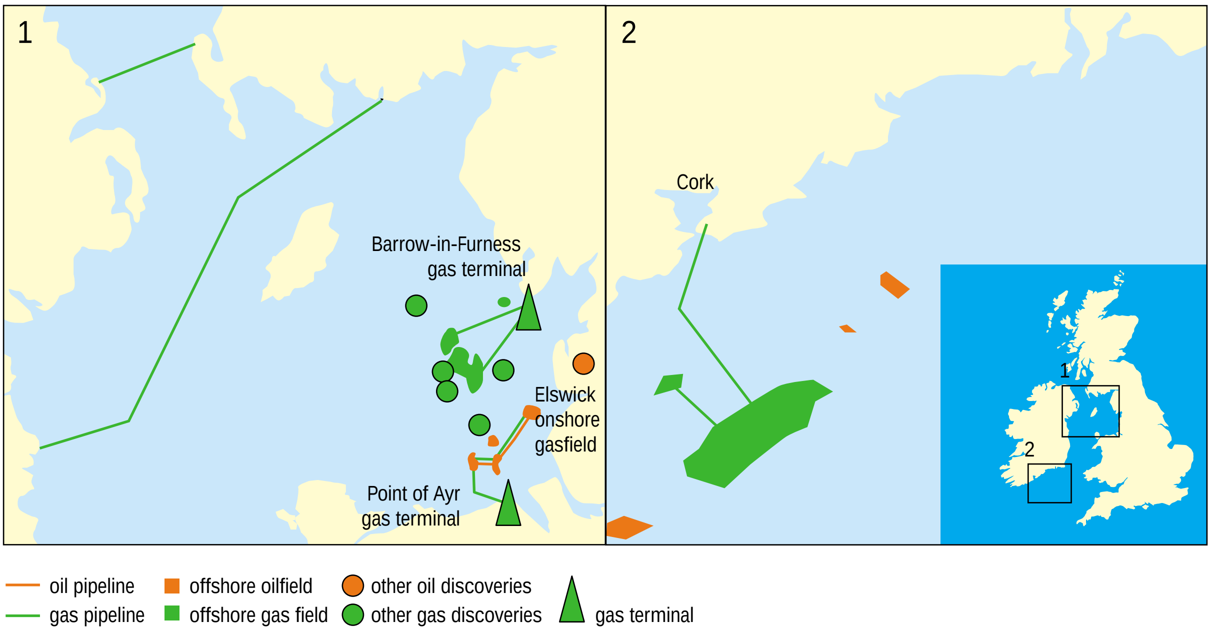
Eighty percent by volume of Ireland's exports and imports pass through its ports and trade is forecast to continue to rise. Passenger traffic increased by 36% between 1985 and 1995 and car, bus and lorry traffic increased by more than 60% in the same period. Similarly the number of vessels arriving at Irish ports increased by 45% between 1985 and 1995 with the tonnage increasing by

Table 3.5 Oil and gas fields in production in the Irish Sea.

Field	Discovered	Hydrocarbon	Production started	Originally estimated recoverable reserves*
Douglas	1990	oil	1996	11.3
Hamilton	1990	gas	1996	14.6
Hamilton North	1991	gas	1995	6.7
Lennox	1992	oil	1996	7.6
Morecambe Bay North	1976	gas	1994	26.4
Morecambe Bay South	1974	gas	1985	136.3

* recoverable reserves are expressed in bm^3, except those for the Douglas and Lennox Fields which are expressed in Mt.

Figure 3.10 **Location of oilfields and gas fields.**



more than 60% to 32 million t. Ports in the west and south saw an increase in trade of around 14% between 1985 and 1995. In 1998, Ireland’s only oil refinery, at Whitegate in Cork Harbour, imported 3.1 million t of crude oil and exported 2.6 million t of product. Cork Harbour also handles around 500 000 t of chemicals annually. Over 1 million t of oil products were imported via the Shannon Estuary and the 1 million t capacity Whiddy Island Oil Terminal in Bantry Bay was reopened for transhipment and storage purposes in 1998, having been closed for twenty years.

On the UK coast bordering Region III, the most important ports are situated on the Mersey Estuary and at Milford Haven but other major ports are found at Avonmouth (Bristol), Swansea, Port Talbot and the Clyde. Along the Irish Sea coast of England and Wales the seven major ports handle more than 77 million t of traffic with about 18 500 ship movements each year. On the Bristol Channel the main ports handled more than 27.5 million t of traffic annually, involving 4485 ship arrivals in 1995. Milford Haven deals mainly with oil traffic and can handle ships of up to 250 000 t. Barrow-in-Furness at present handles relatively small volumes of cargo but has specialist facilities for gas condensate from the Morecambe Bay gas fields and cargoes moving to and from the nuclear fuel reprocessing facilities at Sellafield on the Cumbrian coast.

Although there are numerous island ferry ports scattered along the west coast of Scotland, the Clyde is the only large port on the Scottish west coast and it handles around 1200 vessel movements annually. The number of vessels visiting the port has remained fairly constant in recent years. This has been achieved despite greater trade volumes and more activity at the deep-water port of Hunterston through the use of larger vessels.

The major ports in Northern Ireland are Belfast, with 60% of the traffic, Larne with 25% and Warren Point with 7.5%. Inward traffic to Northern Ireland has increased by 20% since 1990 and exports have risen by almost 30% in the same period. Belfast is also the largest ferry port in the whole of Ireland with 1.8 million passengers, 300 000 freight vehicles and 200 000 cars annually. Ship movements are approaching 2000 per year.

3.13 Accidents

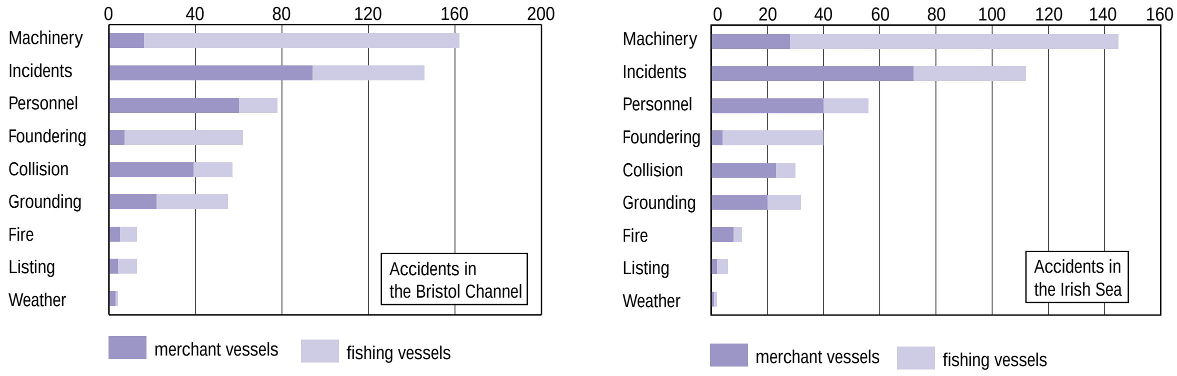
Within UK waters the Marine Accident Investigation Branch keeps a record of all accidents involving merchant and fishing vessels. Between 1991 and 1997 there were 434 accidents reported in the Bristol Channel and 590 in the Irish Sea. A breakdown of these is provided in *Figure 3.12*; many were minor but that involving the Sea Empress in 1996 caused a major oil pollution incident extending to the Irish coast. There have been various other accidents involving oil spills, details of which are given in Section 4.2.5. The Irish authorities maintain a similar register of accidents occurring within their waters and between 1994 and 1997 recorded 184 incidents involving merchant ships alone. Almost half of these involved incidents such as medical emergencies and false alarms but 78 involved incidents that placed the ship and/or its cargo at risk *(Table 3.6)*. Only one collision was reported in the period involved.

Figure 3.11 **Location of major ports, ferry ports, shipping routes and traffic separation schemes.**

3.14 **Coastal industry**

The largest aggregations of industry occur on the coasts of the northern Irish Sea, the Bristol Channel, the Clyde Sea and the east and south coasts of Ireland. On the eastern side of the Irish Sea, the major industrial location is in Merseyside where activities include shipbuilding and the manufacturing of foodstuffs, chemicals, vehicles, petrochemicals, paper and metal products. The Mersey Estuary has two oil refineries and one of Europe’s largest ports; surrounding industries include electrical engineering, flour milling, sugar refining and car manufacturing. North of Merseyside, the Cumbrian coast has seen a reduction in its traditional heavy industries, shipyards and collieries, although it is the location of the nuclear fuel reprocessing plant and Calder Hall power station at Sellafield. Nuclear power stations are also located at Hunterston, Chapelcross (Malin Shelf), Heysham, Wylfa (Anglesey) and Berkeley, Oldbury and Hinkley Point on the Bristol Channel. There is a large gas terminal at Barrow-in-Furness. On the western side of the Irish Sea, industry is concentrated in the vicinity of Dublin City and focuses largely on the chemicals, electronics and software sectors.

Figure 3.12 **Accidents reported by merchant and fishing vessels for 1991 to mid-1997. Source: MAIB.**



At the inner end of the Bristol Channel (Avonmouth), there are a number of refineries, industrial estates, docks and storage facilities. On the northern coasts of the Bristol Channel, especially around Port Talbot, Neath and Swansea, there is a high density of heavy industry including metal refining and steel manufacturing which depend on the importation of raw materials. In the vicinity of Pembroke and Milford Haven docks there are oil refineries and other petrochemical industries.

To the north of the Irish Sea, the Clyde Sea coasts (Strathclyde region) support a range of industries which include power generation, steel manufacturing, chemical production and information technology enterprises. Further north (Highland region), most coastal industries are associated with the fishing industry (e.g. fish processing and chandlers). The Western Isles are essentially rural in nature with only two industrial sites occupying just three hectares.

In Ireland, apart from the Dublin area, Cork Harbour (south coast) and the Shannon Estuary (west coast) have the largest concentrations of manufacturing industry. Cork Harbour contains the majority of Ireland’s heavy industries including metal engineering, oil refining, steel manufacturing and the production of fine chemicals and pharmaceuticals. The Shannon Estuary contains an alumina plant and two power stations, and there are large industrial estates at Limerick and Shannon with a mixture of enterprises. There are proposals to develop a major deep-water port facility in the estuary. Elsewhere on the Irish coastline, there are concentrations of food processing industries in the south-east and fish processing around the main fishery ports in counties Donegal, Galway, Kerry and Wexford. There has been a recent increase in small enterprises such as tool, clothing, textile and software production in previously under-developed parts of the north-west coast.

Table 3.6 Incidents involving merchant vessels (over 100 GRT) around the coast of Ireland (within the Ireland Search and Rescue Region) which placed the ship and/or its cargo at risk 1994–7. Source of data: IMES; Lloyds List 1997.

	Bulk carriers	RoRo/ Passenger ferries	Cargo	Tankers (oil and chemical)	Others*	Total
Machinery failure†	2	-	14	10	9	35
Collision and contacts	-	-	-	1	-	1
Stranding and grounding	-	-	9	-	5	14
Listing and capsizing	1	-	1	-	1	3
Heavy weather damage‡	3	-	-	1	-	4
Fires	-	2	-	-	-	2
Loss of cargo	-	-	2	-	-	2
Others§	2	6	6	1	2	17
Total	8	8	32	13	17	78

* includes tugs, barges and unidentified vessels;

† includes engine failure, breakdowns, steering gear and rudder damage;

‡ includes damage to the vessel and pilot boats;

§ includes bomb alerts, searches for missing vessels, dragging anchor, loss of communication with vessel;

-: no incidents in this category.

3.15 Military activities

Military activities within Region III fall into two main categories: naval exercises involving surface ships and submarine movements. The former are infrequent and cause minimal interference but the essentially secret movements of submarines have had a high profile due to their entanglement in fishing gear. Prior to 1990 this involved the loss of 15 – 20 fishing vessels and over 50 lives. Incidents of this nature have been less frequent in recent years.

There are numerous military installations around the coasts of Ireland and the UK which are used for a variety of training purposes, as practice firing ranges and for the testing of weapons systems. All such activities involve the periodic closure of the sea areas down range and the coastal land over which training or firing takes place. There are 45 sites on the west coast of Great Britain and in England and Wales alone these involve 13 375 ha of coastal land.

Almost all of the 27 military sites in England and Wales are designated as Sites of Special Scientific Interest or have similar nature conservation status, largely because public access is prohibited or severely restricted and wildlife is left relatively undisturbed. In the Malin Sea area, which is generally remote and sparsely populated, the American base at Holy Loch has closed but there are still two British naval bases in the Clyde. There are also several torpedo, missile and bombing ranges in the area and military exercises are held irregularly.

Table 3.7 International instruments applicable to protection of the environment in Region III.

Instrument	Purpose
OSPAR Convention 1992	Sets comprehensive framework for all Contracting Parties to protect marine environment of North-east Atlantic
Ramsar Convention 1971	To protect internationally important wetlands
London Convention 1972	Prohibits dumping at sea, and bans disposal of radioactive waste at sea
World Heritage Convention 1972	Protection of natural and cultural treasures of exceptional interest and universal value. The only sites in the UK are St Kilda (Scotland) and the Giant’s Causeway (Northern Ireland)
MARPOL 73/78 – IMO Convention on Marine Pollution from Ships	Limits operational discharges of oil, noxious liquids and ship generated garbage. From August 1999, all UK waters designated a special area for oil discharges
Bonn Convention 1979	Conservation of Migratory Species of Wild Animals, including: ASCOBANS 1991, international agreement to protect and conserve small cetaceans in North and Baltic seas
Berne Convention 1979	Conservation of European wildlife and natural habitats
UN Convention on the Law of the Sea (UNCLOS) 1982	Establishes rights and duties of the states regarding resource management and protection of the marine environment
UNEP 1995	Global programme of action for protection of the marine environment from land based activities
Amsterdam Treaty 1997	Sets environmental policy objectives
EC Directive on Bathing Water (76/160/EEC)	Sets cleanliness standards for bathing water
EC Directive on the Conservation of Wild Birds (79/409/EEC)	Special conservation measures to protect habitats of rare or vulnerable species, and migratory birds
EC Directive on Dangerous Substances (76/464/EEC)	To eliminate, or reduce, pollution by chemicals
EC Directive on Shellfish Growing Waters (79/923/EEC)	To ensure a suitable environment for shellfish growth
EC Environmental Impact Directive (85/337/EEC superseded by 97/11/EC)	Requires developer to provide information to competent authority about likely significant environmental effects
EC Directive on Aquaculture Animals and Products (91/67/EEC)	To increase productivity, introduce health rules and limit the spread of infections or contagious diseases
EC Urban Wastewater Treatment Directive (91/271/EEC)	To stop the discharge of raw sewage into the sea
EC Nitrates Directive (91/676/EEC)	Protection of waters against pollution caused by nitrates from agricultural sources
EC Directive on the Conservation of Natural Habitats and Wild Fauna and Flora (92/43/EEC)	To designate and implement conservation measures for Special Areas of Conservation
EC Integrated Pollution and Control Directive (96/61/EEC)	Control of emissions from industrial processes to air, water and land

Table 3.8 National instruments for environmental protection within Region III.

UNITED KINGDOM

Measures applying in England and Wales	Purpose	Equivalent primary legislation applying in Scotland	Equivalent primary legislation applying in Northern n Ireland
Diseases of Fish Act 1937 and 1983	Protection of live fish and eggs of fish from disease	Applies in Scotland	Does not extend to Northern Ireland. Fish Health Regulations (Northern Ireland) 1998. Diseases of Fish Act (Northern Ireland) 1967
Coast Protection Act 1949	Protection of coast from erosion and encroachment by sea	Applies in Scotland	NI does not have any legislation specifically dedicated to coastal erosion
Sea Fish (Conservation) Act 1967, as amended by the Fisheries Act 1981	Sets size limits for caught sea fish	Applies in Scotland	Fisheries Act (Northern Ireland) 1966 (as amended)
Conservation of Seals Act 1970	Protection and conservation of seals	Applies in Scotland	Common and grey seals protected under Wildlife (Northern Ireland) Order 1985
Fisheries Limits Act 1976	Extends UK fisheries limits up to 200 miles from coast	Applies in Scotland Inshore Fisheries (Scotland) Act, 1984	Extends to Northern Ireland with the exception of certain subsections
Wildlife and Countryside Act 1981	Protection of birds and other marine species	Applies in Scotland with the exception of certain sections	Birds and a few other marine species including cetaceans, seals and otters are protected under the Wildlife (Northern Ireland) Order 1985
Food and Environmental Protection Act 1985	Regulates and controls dumping at sea	Applies in Scotland	This Act extends (with modifications) to Northern Ireland
Environmental Protection Act 1990 Control of Pollution Act 1974 Pollution Prevention and Control Act 1999	Integrated pollution control of inputs of dangerous substances to air, land and water	Applies in Scotland	Industrial Pollution Control (Northern Ireland) Order 1997 - SI1973/70 (NI2)
Water Industry Act 1991	Discharges to sewers require consent from sewerage undertakers	Water Industry Act 1991, plus Water Scotland Act 1980, Local Government etc., (Scotland) Act 1994	The Water and Sewerage Services (Northern Ireland) Order 1973-SI1973/70 (NI2)
Water Resources Act 1991	Discharges to waters up to 3 miles from coast require consent from National Rivers Authority	Sewerage Scotland Act 1968 Control of Pollution Act 1974	The Water Act (Northern Ireland) 1972 – (c.5)

IRELAND

Measures applying in Ireland	Purpose
Fisheries Acts 1959 to 1998	Generally prohibit the deposition of deleterious matter in waters
Harbours Act 1946	Control by harbour authority of deposition of material in harbour waters
Oil Pollution of the Sea (Civil Liability and Compensation) Acts 1988 to 1998	Provides for civil liability for oil pollution from oil tankers
Foreshore Act 1933 to 1998	Controls in relation to development on the foreshore
Marine Institute Act 1991	Marine research and development
Continental Shelf Act 1968	Prohibits discharge/escape of oil during exploration or exploitation
Sea Pollution Act 1991	To ratify MARPOL Convention and deal with prevention of pollution from ships
Sea Pollution (Amendment) Act 1999	To give effect to the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC), 1990
Dumping at Sea Act 1996	Implementation of OSPAR Convention: prohibition and control of dumping at sea
Local Government (Planning and Development) Acts 1963 to 1998	Planning and control of development, protection of the environment
Local Government (Water Pollution) Acts 1977 to 1990	Planning for water quality, control of discharges to waters, prevention of water pollution
Environmental Protection Agency Act 1992	Control of activities with high pollution potential, environmental research, establishment of databases, advice to public authorities
Wildlife Act 1976	Protection and conservation of wild flora and fauna
Whale Fisheries Act 1937	Protection of whales, dolphins, porpoises
Numerous Regulations under the European Communities Act 1972	To give effect to Directives of the European Union e.g. environmental impact

In Ireland the number of sites used for training, firing ranges etc. is smaller than in the UK. Nevertheless there are a number at strategic locations around the coast. The largest are the naval base in Cork Harbour, Finner Camp in County Donegal and Bere Island on the south-west coast. As in the UK, military use can be of conservation value; Finner Dunes in Donegal is close to a major military camp and is classed as a Natural Heritage Area on account of its conservation importance.

3.16 Agriculture

The significance of agriculture to the marine environment stems mainly from contamination due to run-off of nutrients, animal slurries and pesticides. These are dealt with as far as practicable in the sections on inputs (4.2), nutrients (4.9) and eutrophication (5.7). Certain developments in agriculture influence the degree to which impacts arise. For example, the move away from mixed farming and the focus on livestock has led to larger numbers of animals and pressure for feed production which has, in turn, caused local microbiological pollution and in some areas increased nutrient levels in rivers and coastal areas.

Several factors seem likely to reduce problems caused by agriculture. The EC Nitrates Directive (91/676/EEC) calls for the adoption of codes of ‘good agricultural practice’ in the use of fertilisers and animal slurries. These will reduce contamination in run-off. Reductions should also occur in fertiliser use as a consequence of the EC set-aside scheme and other measures designed to reduce surplus production.

3.17 Regulatory measures

Tables 3.7 and 3.8 summarise the main legislative instruments currently in force in Region III that contribute to protection of the marine environment.

chapter 4

Chemistry

4.1 Introduction

This chapter summarises the most recent information for Region III on the inputs and environmental concentrations of heavy metals, persistent organic substances, nutrients, radionuclides and oil.

Contaminants introduced into the sea are either natural or synthetic. The presence of synthetic substances in the environment always represents contamination. Many substances such as nutrients and metals are commonly found in soils, plants and animals and it is therefore important to differentiate between the normal geochemical fluxes of these materials (e.g. through rivers) and fluxes augmented by human activities. Such distinctions, although often difficult to make, are essential to environmental protection. Clearly, measures to prevent pollution from excessive inputs of nutrients and metals need to be focused on the component of land-sea fluxes that results from human activities.

A key element of the strategy to prevent marine pollution within the OSPAR area is to reduce as far as practicable the quantities of contaminants entering the sea from all sources. This involves a combination of regulatory and management measures designed to reduce waste and encourage cleaner production. It also requires accurate data on the sources and pathways of the more common pollutants to determine quantities entering the sea and the trends in inputs over time. High variability and low sampling frequencies, combined with very low concentrations in large volumes of carrier medium, dictate that in most cases only rough estimates of contaminant inputs are possible. Accordingly, the rate of change and the period for which records are available will determine whether and when a trend can be determined with reasonable confidence. At present, for most inputs to Region III, either the change is too slow or the record too short for trends to be discernible.

4.2 **Inputs of contaminants**

Agencies responsible for monitoring inputs to Region III are working to improve their monitoring techniques in order to quantify more accurately the trends in contaminant inputs, focusing in particular on inputs via rivers and industrial and municipal outfalls. Atmospheric inputs are determined largely through modelling. At present, any apparent trends should be viewed with considerable caution. Records on inputs to each of the major sea areas are incomplete and in most cases cover less than a decade. Furthermore, the cumulative errors associated with sampling, analysis and flow estimation dictate that most calculations of contaminant loads provide only very rough estimates. These factors, and the inherent inter-annual variability in inputs, restrict current capabilities for input trend assessment.

4.2.1 Direct and riverine inputs

Where some concentrations are below the analytical detection limits the assumptions made in calculating loads affect input assessments. Two approaches are used: ‘low load estimates’ treat any result recorded as less than the detection limit as having a true concentration of zero, whereas ‘high load estimates’ treat such results as having a true concentration equivalent to the detection limit. Where the products of these calculations are widely different (as is the case for many organic contaminants), it is probable that the high loads significantly overestimate the true value. For the purposes of the tables summarising direct and riverine inputs *(Tables 4.1 and 4.2)* metals and nutrients are given as high loads and, unless otherwise indicated, organic contaminants as low loads.

The data records on direct and riverine inputs available for the current assessment cover the period 1990 to 1996. It is quite possible that the input trends identified in the following paragraphs may have changed in more recent years. Nevertheless, it seems reasonable to expect that downward trends in response to improved management measures (e.g. reductions at source) would continue.

Direct inputs

Direct inputs consist mainly of discharges to coastal waters from industrial and municipal outfalls. Overall responsibility for controlling direct inputs in accordance with national legislation and the relevant EC Directives rests with the Environment Agency in England and Wales, the Scottish Environmental Protection Agency, the Department of the Environment in Northern Ireland and, in Ireland, the Environmental Protection Agency and local authorities.

Although an increasing number of coastal sewage discharges receive some form of treatment, an estimated half of the total sewage entering the coastal waters of Region III, in terms of both total volume and population served, is either untreated or receives only primary treatment. Much of the latter is associated with major urban/industrial centres (e.g. Merseyside and Dublin) where very large volumes of sewage are generated and the process of upgrading treatment systems is technically complex and therefore takes some time to complete. In other coastal areas significant progress has been made. For example, along the coasts of Wales and the Bristol Channel (Anglesey to Land’s End) about two-thirds of the sewage receives either primary (18%), secondary (38%) or tertiary (10%) treatment. In response to the EC Urban Wastewater Treatment Directive (91/271/EEC) many coastal sewage works are in the process of being upgraded to provide a minimum of primary treatment and there is increasing use of secondary, or even tertiary, treatment in areas vulnerable to the effects of organic enrichment and eutrophication.

A compilation of data on direct inputs of contaminants from 1990 to 1996 is given in *Table 4.1*. Records of contaminant inputs in direct discharges around the coasts of Ireland are limited; this is currently being improved. The most complete coverage is for the eastern Irish Sea and Bristol Channel. There are strong indications that in the mid-1990s direct inputs of some heavy metals (i.e. cadmium, mercury and zinc) to these areas were decreasing. On the other hand it appears that inputs of lead have risen slightly and that copper inputs are more or less stable. There are also signs that the amounts of PCBs (and possibly γ-HCH) in direct inputs to the eastern Irish Sea, Bristol Channel and Malin Shelf have decreased since the early 1990s, but more recent data are needed to determine whether or not these trends are genuine.

With the possible exception of phosphorus inputs to the Bristol Channel, which suggest a slow decrease, direct inputs of nutrients to all parts of Region III for which temporal data exist were relatively stable to the mid-1990s. The amounts of nitrogen were invariably greater than the amounts of phosphorus. As no time series data were available on direct inputs from sources in Ireland (i.e. the mid-western Irish Sea, Celtic Sea and Atlantic seaboard), trends in direct inputs across Region III as a whole cannot yet be evaluated.

Direct inputs of radionuclides are discussed in Section 4.8.

Riverine inputs

Overall, the record on contaminant inputs via rivers *(Table 4.2)* is considerably better than that for direct inputs. Although trends can be determined, data on riverine inputs are inherently prone to errors that tend to mask spatial or temporal differences. With this caveat, to the mid-1990s there were indications of a slight decline in inputs of mercury and γ-HCH, and possibly also

Table 4.1 Direct inputs of contaminants to sea areas in Region III 1990–6.

			Cd (t)	Hg (t)	Pb (t)	Cu (t)	Zn (t)	γ–HCH (kg)	PCBs (kg)	NH_4-N (kt)	NO_3-N (kt)	PO_4-P (kt)	Total N (kt)	Total P (kt)	SPM (kt)
Eastern Irish Sea		1990	22.10	2.78	2.8	23.0	316	0.23	0.73	-	0.24	4.81	3.57	4.81	317
		1991	8.41	1.74	1.4	52.3	156	0.14	-	-	0.17	6.49	3.77	6.49	333
		1992	7.26	1.60	17.3	19.5	160	17.10	-	-	0.19	3.17	3.06	3.17	15
		1993	5.65	0.87	57.8	14.3	138	17.30	-	3.30	1.10	1.90	5.60	2.10	59
		1994	3.39	0.60	34.8	34.3	112	3.40	0.30	5.70	0.50	3.80	5.60	4.30	69
		1995	3.21	0.38	28.5	17.3	84	3.50	0.30	2.70	0.40	2.70	3.00	3.10	57
		1996	3.91	0.33	35.8	15.5	90	4.40	0.10	4.48	0.73	3.14	11.60	3.39	59
Western Irish Sea	ROI only	1990	0.06	-3.3	7.5	63	-	-	-	-	-		6.83	1.58	38
	ROI sewage*	1994–6	0.06	0.02	4.2	7.4	29	-	-	-	-	-	-	-	-
	NI only	1993	0.33	0.12	1.1	3.2	17	1.94	-	-	-	-	5.45	0.52	14
	NI only	1994	0.49	0.07	4.1	11.0	25	2.87	-	-	-	0.72	1.20	0.95	24
	NI only	1995	0.23	0.04	2.2	6.5	15	3.12	-	-	-	0.36	2.17	0.50	18
	NI only	1996	0.64	0.02	2.1	4.6	19	1.46	-	-	-	0.32	6.41	0.57	13
Bristol Channel		1990	3.92	0.06	16.9	26.0	308	18.30	1.37	-	1.03	2.07	9.85	2.04	96
		1991	0.34	0.03	14.9	20.6	460	5.75	140.10	-	0.69	1.51	6.91	1.51	72
		1992	4.10	0.05	19.7	37.5	179	4.52	109.30	-	1.32	2.36	15.10	2.36	331
		1993	2.66	0.05	19.3	26.0	159	6.10	26.70	7.30	1.50	1.20	9.00	1.20	61
		1994	2.21	0.06	27.4	29.8	189	6.40	10.10	8.70	1.90	1.40	6.00	1.40	123
		1995	2.18	0.03	25.5	21.2	176	4.00	5.80	8.10	1.90	1.40	10.10	1.40	65
		1996	1.56	0.00	9.2	6.3	96	2.80	32.90	5.25	1.84	1.01	7.24	1.01	29
Celtic Sea	ROI only	1990	0.02	-	3.20	0.01	21.50	-	-	-	-	-	2.67	0.65	18.6
	ROI sewage*	1994–6	0.00	0.00	1.20	2.10	8.30	-	-	-	-	-	-	-	-
Atlantic seaboard	ROI only	1990	0.00	-	0.40	0.80	7.70	-	-	-	-	-	0.70	0.21	4.3
	ROI sewage*	1994–6	0.00	0.00	0.60	1.00	4.10	-	-	-	-	-	-	-	-
Malin Shelf south (NI)		1993	0.59	0.04	1.29	1.66	1.48	0.04	-	-	0.05	0.06	0.37	0.09	3.9
		1994	0.72	0.01	2.23	3.48	2.20	3.18	-	-	0.02	0.07	0.06	0.10	1.4
		1995	0.07	0.03	2.89	3.45	2.65	3.08	-	-	0.06	0.09	0.39	0.12	2.2
		1996	0.87	0.03	2.87	3.19	1.72	0.14	-	-	0.07	0.06	0.30	0.21	2.0

Figures for metals and nutrients are ‘high estimates’; figures for organochlorines are ‘low estimates’

* estimated annual input; ROI: Republic of Ireland; NI: Northern Ireland; -: no data reported.

Table 4.2 Riverine inputs of contaminants to Region III 1990–6.

			Cd (t)	Hg (t)	Pb (t)	Cu (t)	Zn (t)	γ-HCH* (kg)	γ-HCH† (kg)	PCBs* (kg)	PCBs† (kg)	NH_4-N (kt)	NO_x-N (kt)	PO_4-P (kt)	Total N (kt)	Total P (kt)	SPM (kt)
Eastern Irish Sea		1990	4.33	1.74	80.5	72.5	324	-	7.7	-	76	-	24.1	2.67	31.2	2.67	300
		1991	6.65	0.90	51.7	51.7	313	-	200.0	-	70	-	22.9	2.19	29.4	2.19	161
		1992	4.91	1.07	66.3	61.4	407	-	113.0	-	84	-	28.5	2.41	35.6	2.41	208
		1993	10.70	2.91	124.0	134.0	491	50.3	134.0	88.1	1040	8.2	30.6	4.50	44.8	4.90	365
		1994	4.04	1.40	71.3	82.1	397	3.4	89.7	0.2	514	7.0	33.0	3.30	43.1	3.50	325
		1995	3.26	1.11	50.8	78.4	309	33.6	85.6	0.1	282	8.1	27.3	3.00	33.5	3.20	257
		1996	1.61	1.02	32.8	50.5	313	13.3	45.9	7.3	188	6.3	35.1	2.80	44.9	3.10	152
Western Irish Sea	ROI only	1990	0.69	-	6.0	20.7	165	-	-	-	-	3.7	12.2	0.23	24.0	0.49	-
	ROI only	1991	-	-	-	-	-	-	-	-	-	5.9	15.3	0.22	31.9	0.38	-
	ROI only	1992	0.46	-	4.3	27.4	132	-	-	-	-	2.5	8.9	0.22	22.5	0.31	39
		1993	0.63	0.04‡	7.4	29.5	222	-	2.6‡	-	-	6.3§	14.8§	0.62	37.1	0.86	13‡
		1994	0.69	0.07‡	8.3	30.6	240	-	2.9‡	-	-	3.9§	14.9§	0.62	30.4	1.16	6‡
		1995	1.10	0.66‡	10.2	43.0	239	-	2.9‡	-	-	1.5§	13.1§	0.43	21.5	0.76	7‡
		1996	0.94	0.07‡	8.1	27.3	219	-	2.5‡	-	-	1.1§	19.7§	0.35	27.4	0.73	58
Bristol Channel		1990	3.39	0.88	121.6	62.4	371	25.8	40.9	40.9	671	-	28.4	2.98	28.8	2.98	325
		1991	9.51	0.72	47.5	88.9	391	-	102.0	-	495	-	36.7	1.84	45.4	1.84	326
		1992	3.26	0.58	44.6	58.3	407	-	66.7	-	402	-	41.9	2.49	45.6	2.49	470
		1993	5.81	1.28	76.1	91.6	450	29.4	129.0	34.8	627	9.2	41.9	3.70	51.6	3.70	700
		1994	4.24	0.31	72.6	79.8	378	24.9	87.8	2.7	439	1.5	49.9	3.10	51.1	3.10	1252
		1995	3.06	0.29	51.9	61.4	293	18.0	67.3	-	445	2.5	43.0	2.80	50.5	2.80	631
		1996	1.05	0.13	40.9	33.4	232	29.0	43.8	1.5	88	1.3	38.4	2.20	39.4	2.20	268
Celtic Sea		1990	0.40	-	6.9	18.9	147	-	-	-	-	0.91	26.3	0.61	35.8	1.13	-
		1991	-	-	-	-	-	-	-	-	-	0.46	29.5	0.49	37.8	0.87	-
		1992	0.59	-	9.5	50.0	197	-	-	-	-	0.76	16.5	0.70	24.1	1.09	-
		1993	0.30	-	13.8	28.7	140	-	-	-	-	1.10	25.3	0.95	38.6	1.73	-
		1994	0.42	-	17.2	38.3	218	-	-	-	-	1.49	31.9	1.03	46.5	2.53	-
		1995	0.40	-	9.1	27.8	186	-	-	-	-	1.23	32.3	0.77	41.6	1.19	-
		1996	1.06	-	34.9	22.4	182	-	-	-	-	1.46	38.6	0.85	50.3	2.22	-
Atlantic seaboard		1990	1.14	-	26.5	33.6	236	-	-	-	-	0.52	22.1	0.54	35.9	1.15	-
		1991	-	-	-	-	-	-	-	-	-	0.44	23.0	0.49	30.6	0.99	-
		1992	0.45	-	23.4	59.7	498	-	-	-	-	0.34	14.9	0.61	27.5	1.06	-
		1993	0.37	-	4.5	36.2	165	-	-	-	-	0.63	14.7	0.64	27.8	1.08	-
		1994	0.54	-	14.5	67.6	183	-	-	-	-	0.67	16.4	0.79	33.0	1.46	-
		1995	0.46	-	16.9	62.5	419	-	-	-	-	0.86	14.8	0.77	27.3	1.30	-
		1996	0.77	-	7.6	19.3	138	-	-	-	-	0.54	24.0	0.50	35.0	1.24	-
Malin Shelf south (NI)		1993	0.72	0.01	2.1	11.1	30	8.5	9.5	0	-	-	5.9	0.41	17.4	0.63	60
		1994	1.13	0.84	12.0	26.7	61	18.7	19.5	0	-	-	5.6	0.48	5.8	0.82	77
		1995	0.58	1.32	3.2	18.8	28	14.4	15.5	0	-	-	6.9	0.43	8.0	0.84	78
		1996	0.61	0.79	2.6	18.9	33	7.5	9.8	0.04	-	-	8.6	0.42	9.4	0.81	85

Figures for metals and nutrients are 'high estimates'

* 'low estimate'; † 'high estimate'; ‡ NI only; § ROI only; ROI: Republic of Ireland; NI: Northern Ireland; -: no available or reliable information.

cadmium, through rivers discharging to the eastern Irish Sea and Bristol Channel. The trends in PCB inputs to these areas are uncertain because of the wide and varying differences between the high and low load estimates. For all other contaminants and areas the inter-annual variations in riverine inputs are too great, and the records too short, for trends to be apparent. Inputs of nutrients were generally stable but inputs of total nitrogen and total phosphorus to the Celtic Sea and eastern Irish Sea were slowly increasing. Inputs of nitrogen from rivers are at least an order of magnitude greater than those from direct discharges.

In summary, between 1990 and 1996 there were apparent decreases in the inputs from land-based sources of cadmium, mercury, zinc and PCBs. Most of these decreases were associated with direct discharges (i.e. sewage and industrial effluents); principally in those areas that received relatively high loads of these substances at the start of the 1990s (i.e. the eastern Irish Sea and Bristol Channel). Slight decreases in the inputs of γ-HCH and total phosphorus to the Bristol Channel were also apparent. The loads of other substances monitored in inputs from land were relatively stable.

4.2.2 Inputs from the dumping of wastes at sea

A summary of the quantities of waste and dredged material dumped in various sea areas of Region III over the past decade is given in Section 3.10. As calculations of the quantities of individual contaminants contained in these materials provide only very rough estimates, no data on the input loads from dumping are presented in this report. In accordance with decisions taken by the OSPAR Commission, the disposal at sea of industrial waste is no longer practised in Region III and the sea disposal of sewage sludge has also recently been discontinued. The disposal of dredged material is subject to stringent controls, including a requirement for land disposal of sediments containing persistent substances at potentially harmful concentrations.

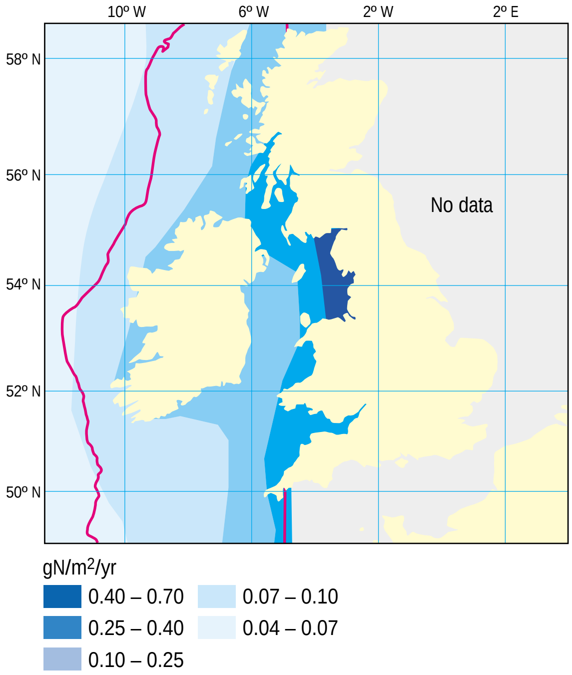
Following recent publicity with regard to the stranding of phosphorus flares on coasts of the Irish Sea, attention has been drawn to the past practice of munitions disposal at deep water sites. In the period between 1945 and 1963 approximately 1 million t of munitions were dumped by the UK in the Beaufort's Dyke, a 200 m deep trench in the North Channel to the north of the Irish Sea. Following the signing of the Oslo and London Conventions in 1972, the UK ceased dumping of munitions at Beaufort's Dyke in 1973, with the exception of an emergency dump of a small number of 40 mm munitions in 1976. A further 1160 t were also dumped in the Beaufort's Dyke area by Ireland between 1970 and 1985, including small arms munitions, bombs, depth charges, fuses, primers, shells and grenades. It is not possible to produce a full inventory of munitions dumped by British military authorities as many of the records were routinely destroyed after the disposals. However, the bulk of the munitions dumped were similar in type to those disposed of by Ireland, but with the addition of 14 600 t of five-inch rockets charged with phosgene and an unspecified number of phosphorus flares.

4.2.3 Atmospheric inputs

The atmosphere is an important and sometimes dominant pathway for the transfer of contaminants from anthropogenic sources to distant marine and terrestrial areas. As the prevailing winds over Region III are predominantly westerly, atmospheric contamination is generally low on a European scale. However, even westerly air flows contain measurable concentrations of contaminants. On the other hand, easterly air flows are generally associated with dry weather and wash-out of contaminants from the east tends to be limited.

Measurements of atmospheric deposition are expressed in terms of dry deposition (the fall-out of dust and particles during dry weather) and wet deposition (wash-out during periods of precipitation including mist, rain and snow) or as total or bulk deposition; the sum of both wet and dry measurements. As there are no sampling stations within Region III specifically dedicated to, or optimally located for, the measurement of contami-

Figure 4.1 **Modelled deposition of oxidised nitrogen for 1990. Source: Sandes and Styve (1992).**



nant inputs to the sea, the best estimates come from large-scale models. These use data from an extended network of stations throughout north-western Europe, including a few sites around the coasts of Ireland and one in Brittany.

Model estimates of the oxidised nitrogen (NO_x) deposition across Region III during the early 1990s *(Figure 4.1)* indicate a clear decreasing east to west gradient. In general, measured values at coastal stations are in good agreement with these predictions.

In contrast, there are wide discrepancies between measured and predicted depositions of certain heavy metals. For example, model estimates for the deposition of mercury (< 10 µg/m2/yr) tend to be systematically ten times higher than measurements obtained at coastal sites, whereas with cadmium the position is reversed. There is some evidence of an increase in mercury deposition in Region III prior to and during the 1980s, possibly linked to increased industrial activity, especially coal burning. Predicted cadmium deposition from modelling is 10 – 50 µg/m^2/yr with the highest values occurring to the south and north of Ireland and in the Bristol Channel. Although depositional loadings measured in Brittany and on the south-west coast of Ireland are in general agreement with these values, measurements at other Irish coastal stations have been more than ten times higher, possibly due to local sources of contaminants. The latest estimate of the amount of cadmium deposited annually in the waters of Region III is 1.4 t (van Pul *et al*., 1998); this can be traced to multiple sources in Europe, including metal industries and automotive sources. In comparison, the predicted deposition patterns for lead are in good agreement with measured values, showing that the highest loads are in the central Irish Sea, North Channel and south Malin Shelf *(Figure 4.2)*. An estimated 152 t of lead is deposited annually into the waters of Region III, the lowest deposition rate per unit area within the OSPAR area. Whereas lead deposition is estimated to be between two and five times higher than in pre-industrial times, some decrease may be expected due to recent reductions in the use of leaded fuels. A substantial reduction in the deposition of organo-lead was recorded at a site on the south-west coast of Ireland between 1986 and 1988.

Figure 4.2 **Modelled deposition of total lead for 1985. Source: Bartnicki (1994).**

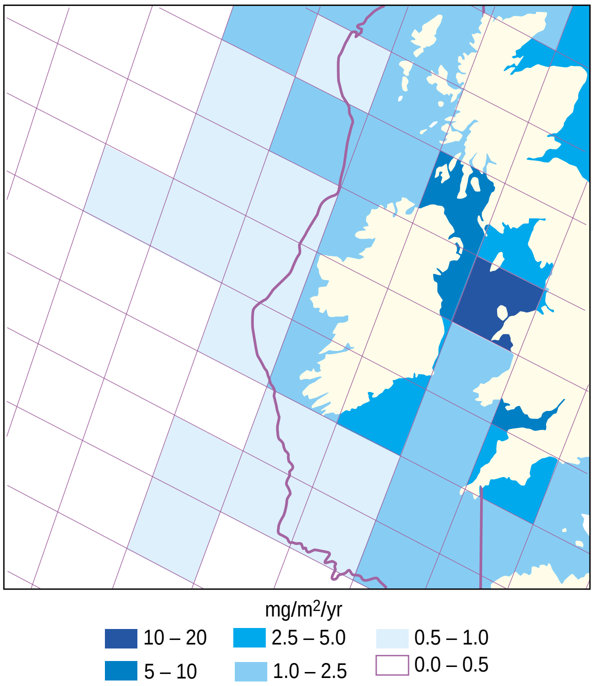


Table 4.3 Modelled bulk deposition fluxes for pesticides (µg/m^2/yr) in the Irish Sea. Source of data: Baart *et al.* (1995).

Pesticide	Deposition flux
Lindane	25 – 50
Endosulfan	2.5 – 7.5
Pentachlorophenol	< 25 – 50
Atrazine	< 25
Parathion-ethyl	< 25
2,4 D	25 – 50
Trifluralin	50 – 100
Mecoprop	100 – 250
Fentin-hydroxide	5 – 15
Diuron	< 10 – 25
Azinphos-methyl	< 1
Dichlorvos	1.5 – 7.5
Mevinphos	< 1

The levels of organic contaminants measured at atmospheric monitoring stations within Region III have generally been below the detection limits, i.e. < 1.0 ng/l for most pesticides and < 2 ng/l for PCBs. Nevertheless, studies of atmospheric contamination in north-west Europe have concluded that appreciable quantities of organic substances may be deposited over the sea and models have been developed to predict depositional patterns in areas such as the North Sea and Irish Sea. The estimated deposition fluxes of pesticides into the Irish Sea are shown in *Table 4.3*.

At UK coastal stations to the east of Region III, concentrations of 3 – 5 ng total PCBs/l were recorded in 1994, corresponding to a total deposition flux of 2.2 – 4.2 µg total PCBs/m^2/yr. These figures are in good agreement with model predictions for adjacent sea areas. On this basis, modelled deposition fluxes of 1.0 – 2.5 µg total PCBs/m^2/yr obtained for the Irish Sea in 1990 seem reasonable. Although estimates for other sea areas of Region III are unavailable at present, a deposition flux of 1.8 µg/m^2/yr estimated for the greater North Atlantic area fits well with the previous predictions. The introduction of strict controls over the use of PCBs in many countries has led to significant reductions in atmospheric emissions since the early 1970s. However there are many uncertainties regarding the rate at which residual levels of PCBs in the atmosphere will fall. Continuing losses from old electrical equipment, evaporation from contaminated soils and cycling between environmental compartments maintain a significant flux which is likely to persist for decades to come. PCB concentrations in dated peat cores from a site in rural north-west England reached a peak in 1964. This was followed by a 65% decrease until 1980 when concentrations increased again. If this pattern is representative of Region III, the decline in PCB deposition since controls were put in place has been relatively modest. At present it is estimated that 10 – 100 t of PCBs are lost to the atmosphere from OSPAR countries each year. As the majority of air masses entering Region III originate over the North American continent, the contribution of North American sources to atmospheric inputs of PCBs to Region III merits closer inspection (see Section 4.5).

The inputs of PAHs from the atmosphere have been estimated for the Irish Sea *(Table 4.4)*. The modelled deposition ranges are reasonably close to those measured in the upper layer (0 – 10 cm) of peat cores from a rural site in north-west England. Evidence from the peat cores indicates that deposition fluxes of fifteen PAHs reached a peak of 3 mg/m^2/yr in the 1930s and that the contemporary flux is approximately 0.74 mg/m^2/yr. The reduction is attributed to emission controls in Europe.

Other organic contaminants for which deposition fluxes to the Irish Sea have been estimated are trichloroethane (0.1 – 1.0 mg/m^2/yr) and total dioxins ($<$ 0.5 – 5 ng/m^2/yr). These estimates require validation through improved ground measurements.

4.2.4 Inputs from mariculture

The principal areas for mariculture in Region III are located to the west of Scotland and Ireland. The main contaminating materials from mariculture operations are faeces, excess feed and chemotherapeutic agents (mainly antimicrobial compounds and parasiticides). As shellfish production does not require commercial feeds or chemical treatments, the main ‘input’ tends to be through the deposition of organic material (digested plankton) to the sediments beneath the culture facilities. In contrast, large-scale intensive finfish farming can contribute significantly to the nutrient budgets of sheltered bays if other waste sources, and freshwater inputs, are small. In Ireland, the combined load of organic waste from salmonid mariculture is estimated to be equivalent to that from a human population of between one quarter and half a million (i.e. 12 – 24% of the coastal population; see Section 3.2).

Table 4.4 Total deposition fluxes for PAHs (µg/m^2/yr) in the Irish Sea region. Source of data: modelled fluxes (Baart *et al*. 1995); measured fluxes (Sanders *et al*. 1995).

	Modelled deposition flux Irish Sea	Measured deposition flux North-west England
Fluoranthene	30 – 100	83 – 204
Benzo[*b*]fluoranthene	50 – 500	30 – 51
Benzo[*k*]fluoranthene	5 – 30	6 – 10
Benzo[*a*]pyrene	25 – 100	20 – 68
Benzo[*ghi*]perylene	5 – 30	47 – 146
Indeno[1,2,3-*cd*]pyrene	15 – 50	-

-: no information.

Estimates of nutrient release from salmon farms to surrounding waters depend on the production : waste ratios applied which, in turn, are a function of feeding practices and food conversion efficiencies. For example, in Scottish waters of the Malin Shelf, including the Western Isles, where an estimated 86 000 t of feed were used during 1997 (production *c*. 71 000 t), an estimated 3400 t of nitrogen (particulate and dissolved) and 760 t of phosphorus were discharged annually to the area. In the same year the Irish salmon farming industry produced 16 000 t and released an estimated 1600 t of nitrogen (largely as ammonia) and 250 t of phosphorus, a comparatively higher nutrient loss. In general, food conversion efficiencies in salmon farming are improving and waste production rates (per tonne of fish produced) are decreasing.

There are no accurate statistics on the usage of chemicals by the mariculture industry within Region III. However, it is estimated that about 60% of the 1 – 2 million kg of hydrogen peroxide, 2000 – 3000 kg of oxytetracycline and potentiated sulphonamides, and 1000 – 3000 kg of oxolinic acid and dichlorvos used by the Scottish industry in 1995, were applied in the Malin Sea area. These chemicals have also been used extensively by Ireland’s mariculture industry. Reported uses of dichlorvos vary from as little as 1.6 litres at a farm in Bantry Bay (on the Atlantic seaboard) in 1994 to 820 litres at a farm in Lough Swilly (on the Malin Shelf) in 1990. At the latter site, the use of dichlorvos had declined to just 4 litres in 1994 and this is indicative of a trend towards alternative treatments for sea lice (e.g. azamethiphos, cypermethrin, ivermectin and the use of ‘cleaner fish’) in recent years. The use of antimicrobial agents is likely to be decreasing as a result of improved husbandry and more extensive use of vaccines.

The use of antifoulants on mariculture cages is common for the maintenance of good water circulation. Prior to 1987, the biocide TBT was commonly used and this undoubtedly resulted in localised effects on populations of wild molluscs (see Section 5.14.4). More recently, copper has replaced TBT as the active ingredient in some marine antifouling agents but data on use are available only for a few individual sites. For example, up to 33 000 litres of copper-based antifoulant (5% copper) have been applied annually to nets at a 1000 t farm in Lough Swilly. An estimated average leaching rate of 20% of the applied material suggests that cage aquaculture represents a significant copper source. However, as the loss rate from various formulations is likely to vary significantly, the actual quantities of copper released are difficult to estimate.

4.2.5 Inputs of oil

Although on a global scale the inputs of oil-based hydrocarbons from human activities on land and at sea are small compared with those from natural sources (e.g. biosynthesis, atmospheric fallout and seepage from the seabed), they can cause significant local damage to marine life and amenities. The principal anthropogenic sources of oil to the marine environment are shipping (both accidental and operational losses), gas and oil installations (both onshore and offshore) and discharges from rivers, industries and municipal wastewater facilities. Few of these inputs are recorded in Region III but some records do exist regarding accidental losses from shipping. Significant releases of oil are recorded in relation to thirteen incidents in Irish coastal waters between 1974 and 1996. There have been no incidents in the Malin Sea area or off the west coast of Ireland during the last twenty years. The most significant releases in Region III in recent decades were: Torrey Canyon (117 000 t) in 1967 off the coast of Cornwall; Universe Leader (2597 t) in 1974, Afran Zodiac (up to 500 t) in 1975 and Betelgeuse (up to 40 000 t) in 1979 in Bantry Bay; Christos Bitas (2420 t) in 1978 in the southern Irish Sea and the Sea Empress (72 000 t crude and 480 t heavy fuel oil) in 1996 on the south coast of Wales (see also Sections 4.7 and 5.13).

4.2.6 Summary

Although information about the inputs of contaminants to Region III is steadily improving, particularly with regard to the relative importance of different pathways, gaps and deficiencies in the database preclude the reliable analysis of patterns and trends.

In general, the loads of heavy metals from rivers and outfalls have been fairly stable during the 1990s. However, in the eastern Irish Sea and Bristol Channel, where inputs of various contaminants have been elevated in the past, there are indications that gross inputs of cadmium, mercury, zinc and PCBs are slowly decreasing.

Inputs of nitrogen and phosphorus are subject to wide inter-annual variability but, on a regional scale, appear to have been relatively stable during the 1990s. There are indications of slight upward trends in nitrogen and phosphorus inputs from the south-east and south coasts of Ireland. Inputs of nitrogen from rivers are significantly greater than from direct discharges. Evidence from models suggests that the atmosphere may also be a significant source of nitrogen, particularly in the Irish Sea. Finfish mariculture is a significant source of nitrogen in some sheltered coastal localities.

The amounts of PCBs entering Region III through the atmosphere, rivers and effluents are now extremely small and there are indications that the trends are steadily downward. Model estimates for the atmospheric deposition of PCBs into the Irish Sea in 1990 (1.0 – 2.5 µg total PCBs/m^2/yr) suggest that the atmosphere may now be the primary source of PCBs to the region.

Oil tankers at Milford Haven

4.3 Background/reference values

In the following sections of this chapter attention is drawn to those locations where concentrations of contaminants in water, sediment or biota are elevated relative to other parts of Region III. The elevated levels are associated with local geochemistry and/or known inputs, either historic or ongoing (e.g. acid mine waters, and municipal and industrial effluents). Account has also been taken of the results for the four other OSPAR regions and of the ecotoxicological profiles of the substances concerned *(see Box 4.1)*.

Instances where contaminant concentrations exceed either background/reference concentrations or ecotoxicological assessment criteria (EACs) are reviewed under the relevant sub-headings.

4.4 Metallic contaminants

Sources of metallic contaminants are covered in Section 4.2.

4.4.1 Fluxes and transport pathways

Transition metals in sea water are generally present at trace levels (ng/l) and these concentrations are influenced by a combination of geochemical, biological and anthropogenic processes. In shelf areas the concentrations of cadmium and copper can be traced primarily to riverine and other land-based sources, whereas lead and mercury may also have a significant atmospheric component. Most of the available data for metals in sea water in the Irish Sea, Celtic Sea and Malin Shelf sectors of Region III have been collected as part of the UK National Monitoring Programme. There are however, useful data sets for a number of Irish estuaries and, for the Celtic Sea and to the west of Ireland, data from a number of cruises by German research scientists. These all show lead and mercury to be strongly associated with particulate material and therefore, except very close inshore and near to sources such as rivers, dissolved concentrations are low. Copper, zinc and cadmium tend to stay in the dissolved phase, thus their concentrations tend to reflect much more closely mixing with oceanic sea water. This fits well with modelling data as illustrated by *Figure 4.3* which shows the increasing concentrations northwards through the Irish Sea due to the influence of inputs from the Irish and UK coasts.

Box 4.1 Reference values

For naturally occurring substances (e.g. metals and nutrients), background concentrations are related to the normal chemistry or geochemistry of the areas concerned. In the case of synthetic substances (e.g. PCBs) there is no natural concentration but some more widely used and persistent substances are now ubiquitous in marine media, albeit at very low concentrations. Where these ubiquitous concentrations are more or less uniform throughout a defined area, they are also termed ‘background’ concentrations. For guidance purposes, the OSPAR Commission has adopted Background/Reference Concentrations typical of the maritime area or parts thereof (OSPAR 1997a).

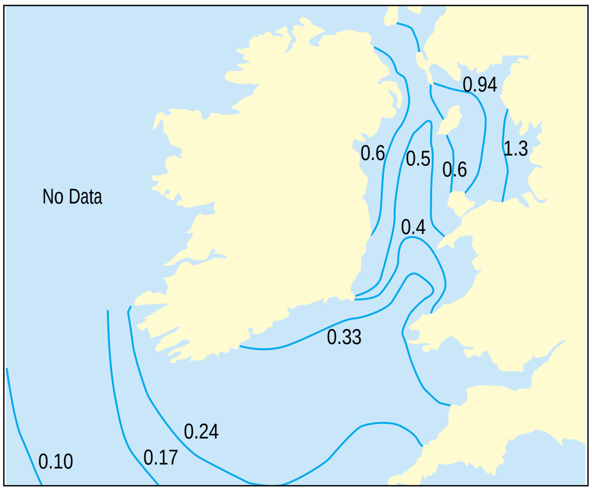
Ecotoxicological Assessment Criteria are concentrations that, according to existing scientific knowledge, approximate to concentrations below which the potential for adverse effects is minimal. For guidance purposes the OSPAR Commission has adopted EACs for the common contaminants in sea water, sediments and biota (OSPAR 1997b).

4.4.2 Distribution in sea water

Cadmium

Concentrations of dissolved cadmium in sea water from the Celtic and Irish Seas are summarised in *Figure 4.4*. This shows a negative correlation with salinities above about 34.5 but considerable scatter at lower salinities (< 32.5). In the offshore waters of the Celtic Shelf concentrations are generally of the order of 0.01 – 0.03 µg/l, which is similar to the concentration range reported for waters off the west coast of Scotland (0.01 – 0.04 µg/l). There is little difference in the concentrations of estuarine waters around Ireland, with concentrations typically in the range 0.03 – 0.1 µg/l. Concentrations in Belfast Lough are consistently reported to be < 0.04 µg/l and those for the Clyde Estuary do not exceed 0.09 µg/l. The highest concentrations of cadmium in estuarine waters were

Figure 4.3 **Predicted salinity-related distribution of dissolved copper (µg/l) in the surface waters of the Irish and Celtic Seas. Source: NERC (1992).**



found in the Severn Estuary (median 0.34 µg/l at a salinity of 19.3). These concentrations were strongly negatively correlated with salinity and are believed to reflect historic metal smelting activities at Avonmouth (near Bristol) and on the south coast of Wales. Whilst the concentrations found in estuaries exceed those regarded by OSPAR as background, only those in the Severn Estuary were clearly above the EAC range adopted by OSPAR (10 – 100 ng/l).

Mercury

Concentrations of dissolved mercury in the Celtic Sea and north of Scotland lie in the range 0.2 – 0.5 ng/l, similar to concentrations regarded by OSPAR as background for the North Atlantic (0.1 – 0.4 ng/l). In the Irish Sea concentrations of 0.62 – 0.85 ng/l reflect historic sources of mercury which still affect sediment concentrations in and around the Mersey Estuary and southern Morecambe Bay. A similar, but less marked, situation exists in Cork Harbour. Even these higher concentrations are below the lowest value of the EAC range adopted by OSPAR (5 – 50 ng/l).

Lead

Due to its high particulate reactivity, estuarine suspended solids and near shore sediments act as efficient traps for lead. Accordingly, dissolved concentrations in offshore waters tend to be low. Pooled data from a number of surveys show a distinct gradient with salinity although there is increased scatter at the lower salinities of the Irish Sea *(Figure 4.5)*. The variability of the concentrations of lead in sea water is probably due to the uneven distribution of land-based and atmospheric inputs allied to the transience of lead in the water phase. In Bantry Bay, periodic cruises have shown relatively high concentrations of lead (0.12 µg/l at a salinity of 35). This represents a significant deviation from the distribution in the adjacent Celtic Sea and it is possibly an analytical artefact. Whilst some of the higher concentrations recorded exceed those regarded by OSPAR as background, all are below the EAC range adopted by OSPAR (0.5 – 5 µg/l).

Copper

There is a strong negative correlation with salinity confirming the land-based origin of copper to Region III. This is further confirmed by data for some estuaries, for example, 0.3 – 2.9 µg/l in the Clyde Estuary and > 50 µg/l in the Avoca Estuary on the east coast of Ireland (both examples relate to the upper estuary). Elsewhere, concentrations above those regarded by OSPAR as background were found in Belfast Lough (*c*. 0.7 µg/l) and in Bantry Bay (0.31 µg/l). These concentrations compare to the EAC range of 0.005 – 0.05 mg Cu^{2+}/l, which is within the background range for total copper in sea water.

Zinc

As for most other metals, the highest concentrations of zinc are associated with the lowest salinity waters. There is however some temporal scatter in the data suggesting that inputs may change with time. Typical concentrations in oceanic waters and off the west coast of Ireland are around 0.5 µg/l, i.e. close to those regarded by OSPAR as background. However, in estuaries considerably higher concentrations have been recorded, particularly in the

Figure 4.4 **Dissolved cadmium concentrations vs. salinity in the Celtic and Irish Seas. Source of data: (a) NMP; (b) Kremling (1985), Kremling and Hydes (1988), Kremling and Pohl (1989); (c) Muller *et al*. (1994); (d) NMP; (e) Kremling and Hydes (1988).**

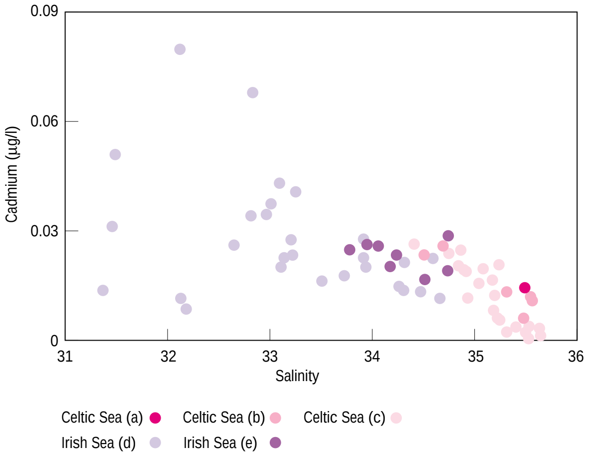
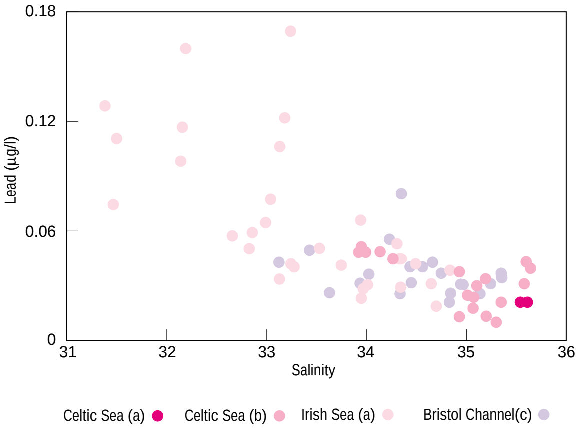


Figure 4.5 **Dissolved lead concentrations vs. salinity in the Celtic Sea, Irish Sea and Bristol Channel. Source of data: (a) NMP; (b) Muller *et al*. (1994); (c) Harper (1991).**



upper reaches, for example > 500 µg/l in the Avoca Estuary and > 40 µg/l in the Shannon Estuary. Concentrations of > 40 µg/l have also been noted in the Severn, Dee and Mersey estuaries on the eastern side of the Irish Sea. These are extreme values and concentrations in estuarine waters are more typically in the order of 10 – 30 µg/l, which exceed the upper value of the EAC range adopted by OSPAR (5 µg/l).

4.4.3 Distribution in sediments

Comparison of data on the concentrations of metals in sediments is only possible if the data are produced by comparable methods and have been treated to eliminate differences due to sediment type, origin and grain size. For reasons related to the original purpose of collecting the data, this is not the case for the different sets of data produced within Region III. The Irish data relate only to estuarine sediments and it was found that normalisation relative to an organic carbon content of 5% gave a good measure of the relative extent of contamination. Data for cadmium, mercury, lead and copper in sediments from around the Irish coast are presented in *Figure 4.6*. The elevated concentrations in the Avoca Estuary are due to acid mine drainage and in Dublin Port to losses of metalliferous ore during loading onto ships. Apart from the concentrations in Bantry Bay, for which no explanation has yet been found, the higher concentrations of mercury are believed to be due to general industrial and urban sources.

Off the Scottish west coast, sediments are typically made up of quartz, clays, feldspars and organic matter. The gravels are mainly quartz with some feldspar, whereas the muds contain more clay minerals. The two groups can be characterised by a potassium/aluminium (K/Al) ratio of greater or less than 0.5. Thus Group 1 are mainly sediments in which sand and gravel predominate and which have a K/Al ratio of > 0.5 (mean 0.66), whereas Group 2 are mainly fine sediments consisting of more clay and with a K/Al ratio of < 0.5 (mean 0.36). In order to overcome differences due to particle size normalisation to scandium can be more effective than normalisation to aluminium. This showed that in almost all cases metal levels were closely related to the types of rock found in the landmasses nearby. In a number of cases it was necessary to normalise the data to iron in order to be sure of the sediment type. This procedure showed elevated concentrations attributable to anthropogenic inputs in a few areas, most notably in the Clyde Sea area.

The most comprehensive dataset for metals in sediments in Region III was collected for the Irish and Celtic Seas between 1990 and 1995. The methods used followed the internationally agreed guidelines on sieving, pre-analysis and digestion using hydrofluoric acid. Normalisation to aluminium was adopted to minimise differences due to mineralogical composition and grain size. *Figure 4.7* shows a general tendency for higher concentrations (after normalisation) of cadmium, mercury, lead and copper in sediments close to coastal sources. Elevated concentrations occur off the coast of the industrialised north-west of England around the Mersey Estuary and in the Severn Estuary. Cadmium is also elevated off the Cumbrian coast due to past discharges from a phosphate rock processing plant.

4.4.4 Distribution in fish and shellfish

There is a considerable body of information on metallic contaminants in a variety of species of fish and shellfish, both from sam les collected within Region III and, for

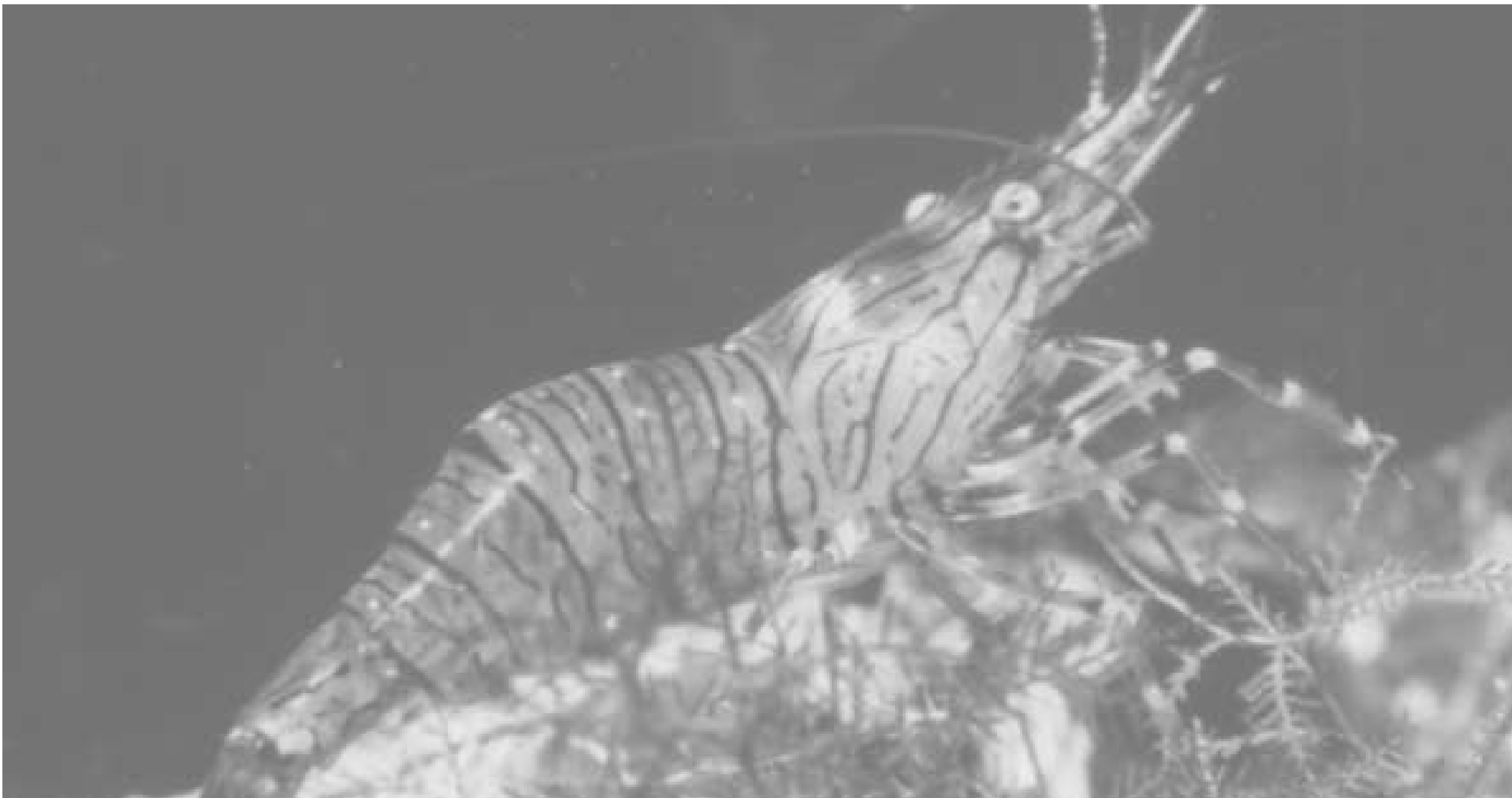


Figure 4.6 **Mean concentrations of metals in whole sediments (mg/kg dw) from Irish coastal and estuarine sites normalised to an organic content of 5%. Source of data: FRC.**

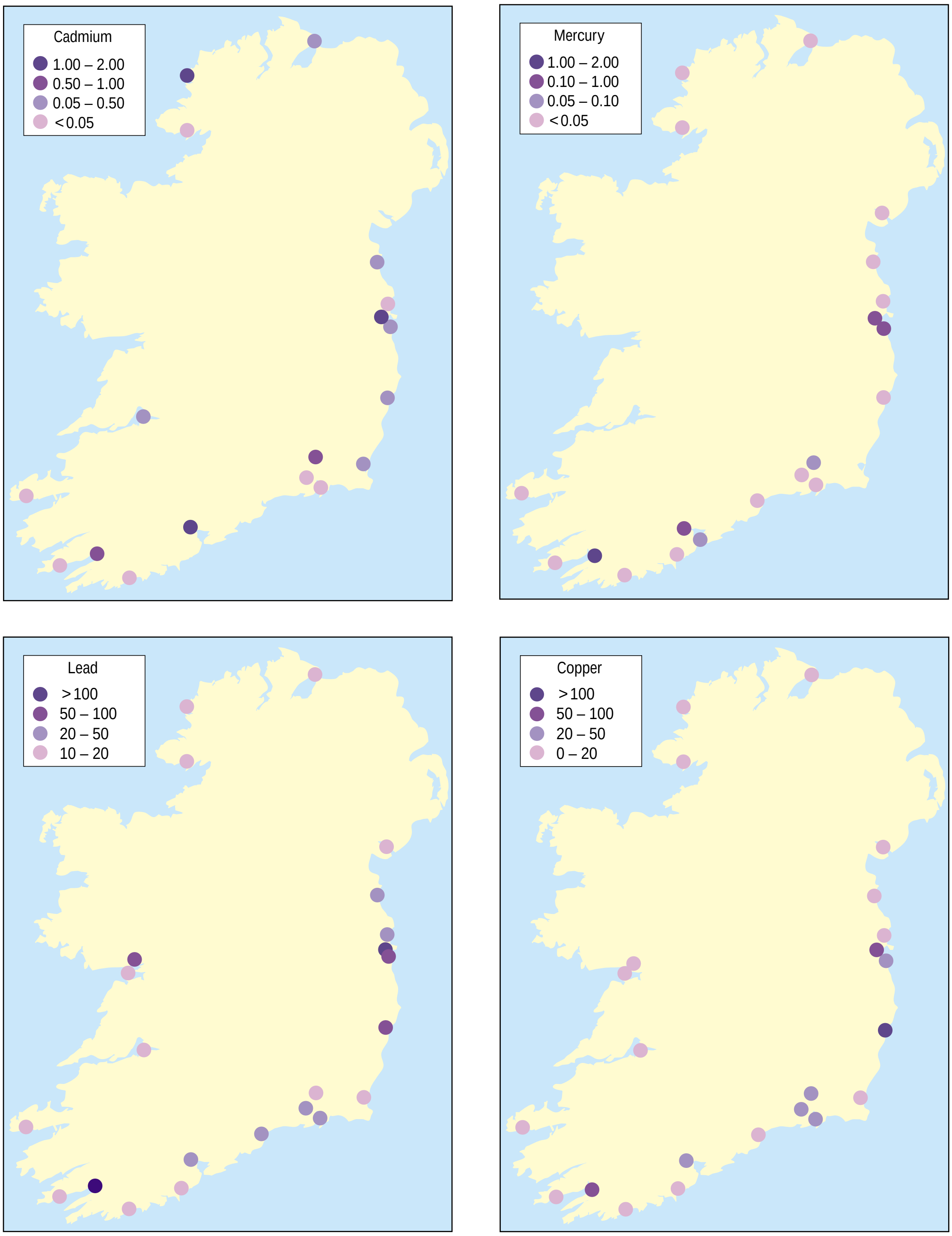
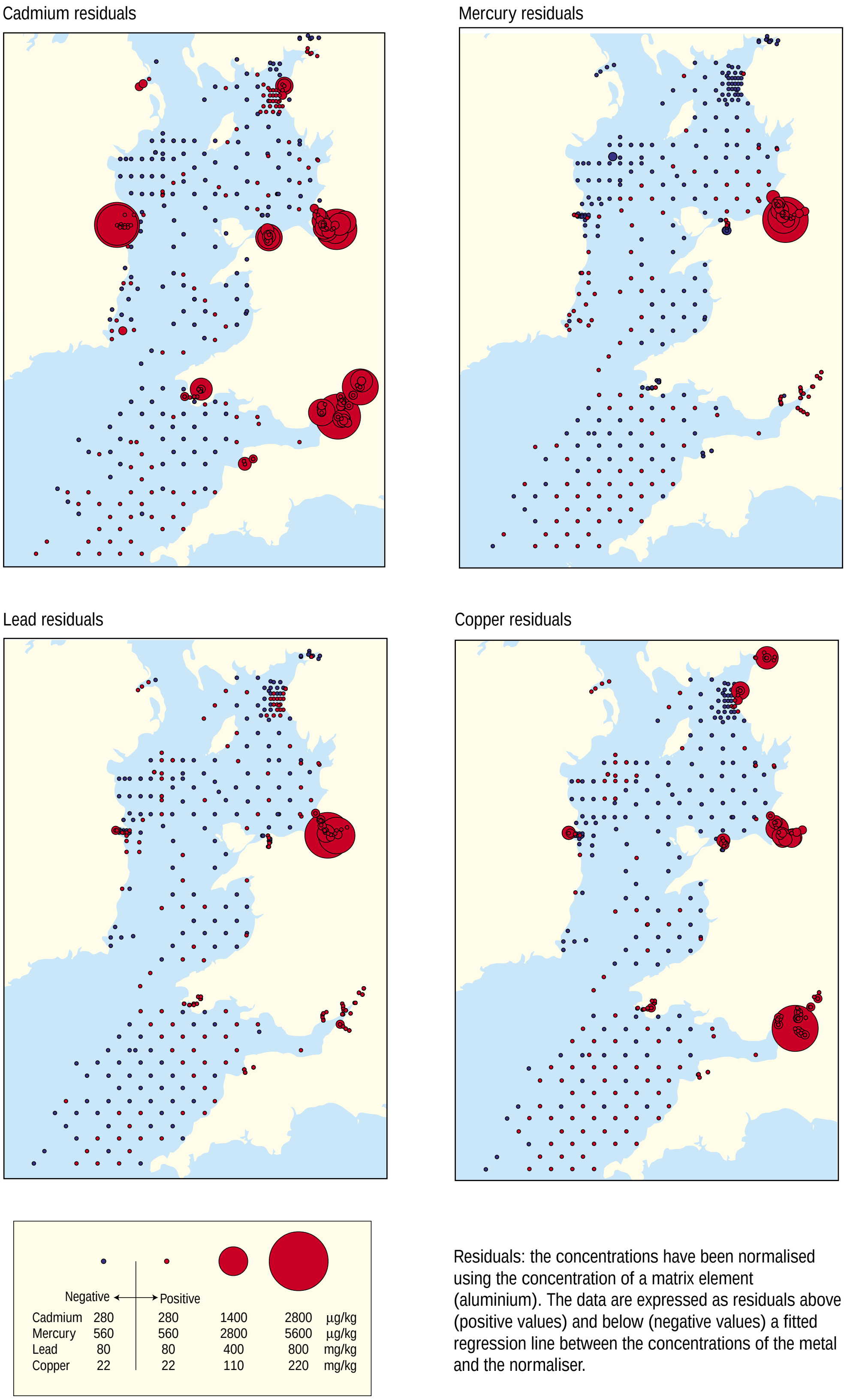


Figure 4.7 **Concentrations of metals in sediments of the Irish Sea and Bristol Channel after normalisation 1990–5. Source of data: CEFAS.**



Cadmium residuals

Mercury residuals

Lead residuals

Copper residuals

Residuals: the concentrations have been normalised using the concentration of a matrix element (aluminium). The data are expressed as residuals above (positive values) and below (negative values) a fitted regression line between the concentrations of the metal and the normaliser.

comparative purposes, from elsewhere. It is known that copper is naturally present in biological tissues and plays a role in structure and metabolism. Cadmium, mercury and lead have no known biological function but are also found in biological material. Fish accumulate mercury in their muscle tissue in proportion to environmental concentrations. Similarly, concentrations of cadmium and lead in shellfish tend to reflect their degree of exposure to these elements.

The mean concentrations of cadmium, mercury, lead and copper in mussels and cod taken from Irish waters *(Table 4.5)* are either below or marginally above those regarded by OSPAR as representative of background conditions. Cod taken from Scottish waters show little difference between inshore and offshore samples, for example 0.06 mg Hg/kg offshore and 0.05 mg Hg/kg inshore, with cadmium and lead in all cases below the detection limits of 0.001 and 0.02 mg/kg respectively. Concentrations of cadmium and lead (which are below routine detection limits) and copper in samples of fish muscle taken off the English and Welsh coasts, are all low and of no toxicological significance. Data on cadmium, mercury, lead and zinc in mussels from various sites around the Irish Sea in 1996/97 are summarised in *Figure 4.8*. Although some concentrations exceeded

Figure 4.8 **Concentrations of metals in the tissue of mussels (mg/kg ww) at sites around the Irish Sea in 1996/97. Source of data: CEFAS.**

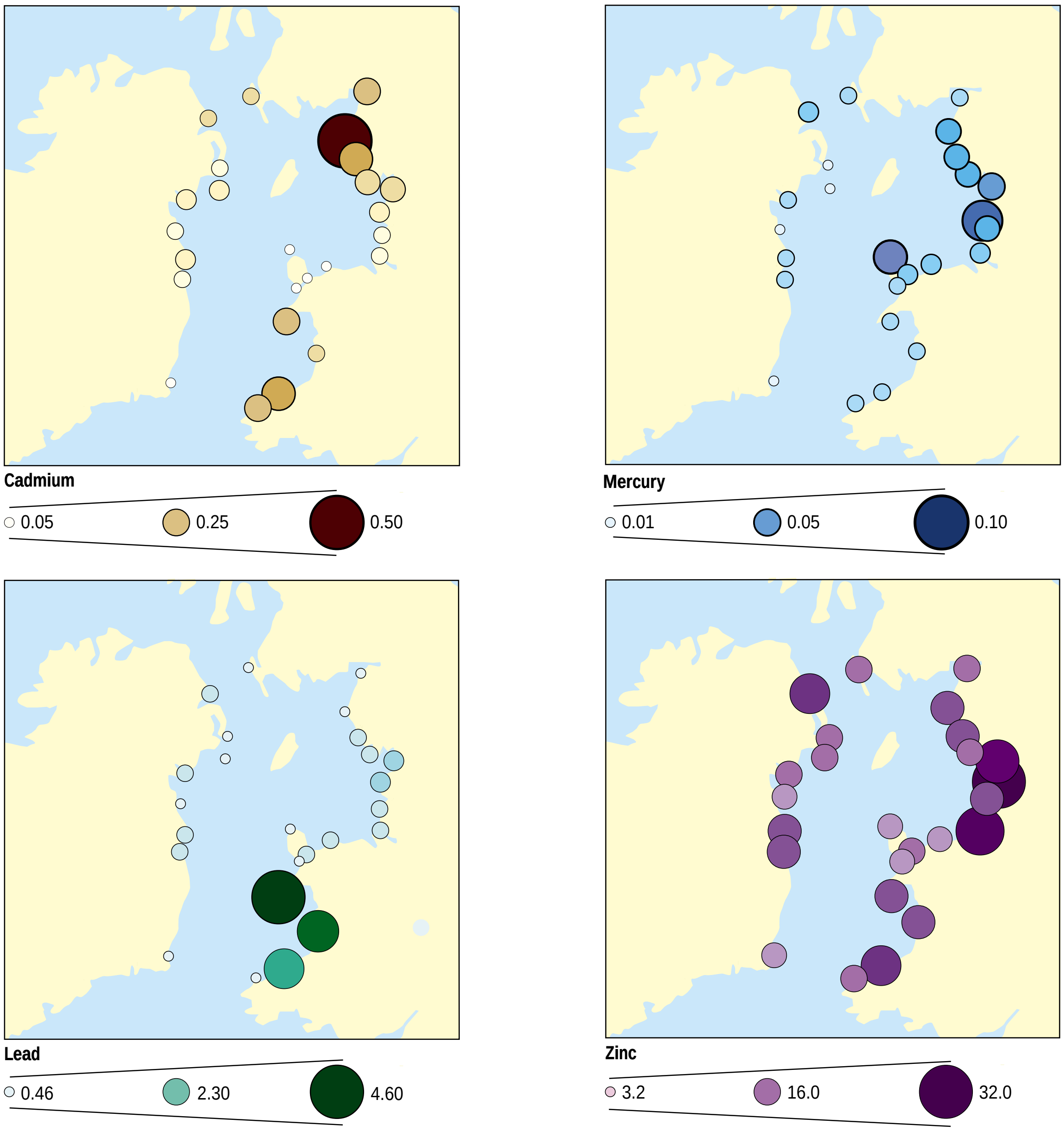


Table 4.5 **Mean metal concentrations (± 1 standard deviation) (mg/kg ww) in whole tissues of mussels from shellfish growing areas and cod muscle from the Irish commercial catch. Source of data: FRC.**

	Mussel	Cod
Cadmium	0.15 ± 0.04	0.06 ± 0.04
Mercury	0.02 ± 0.01	0.11 ± 0.07
Lead	0.15 ± 0.12	0.03 ± 0.02
Copper	1.45 ± 0.16	0.18 ± 0.05

those regarded by OSPAR as background, none exceeded UK national food safety standards and most of the higher concentrations were found in unexploited wild populations.

The history of mercury discharges from chlor-alkali plants close to the Mersey and Wyre estuaries in north-west England is well known. However, concentrations in fish flesh in the two sea areas adjacent to these two estuaries (Liverpool Bay and Morecambe Bay respectively) have been monitored consistently for many years and the Environmental Quality Standard of 0.3 mg/kg has been met since controls on the inputs were imposed. *Table 4.6* shows the data for 1982 to 1996 which indicate a fall in both areas over this period. Although these trends have low statistical confidence, data analysed specifically for trend determination purposes also suggest declining concentrations (OSPAR, 2000).

4.4.5 Distribution in marine mammals

Samples of various tissues taken from stranded and by-caught marine mammals have been analysed over a number of years. Most of the animals were from around the Irish Sea and off the Scottish coast. With the exception of cadmium, where the highest concentrations are found in the kidney, the highest concentrations of metals are generally found in the liver. High concentrations of lead and mercury were found in animals from the Liverpool Bay area, probably due to past industrial discharges; the highest concentrations, 7.0 and 430 mg/kg respectively, were found in grey seals. Marine mammals appear to have a mechanism for detoxifying the mercury as mercury selenide. The highest concentrations of cadmium (up to 11 mg/kg) were found in the livers of striped dolphin (*Stenella coeruleoalba*); this is attributed to the dominance of squid (which accumulate cadmium naturally) in their diet rather than to anthropogenic sources. Copper concentrations ranged between 2.2 and 79 mg/kg; this element is believed to be homeostatically controlled within the animals and therefore not of concern. There are few data for the Irish coast but mercury concentrations in samples from Strangford Lough in Northern Ireland were among the higher values encountered in Region III. Off the Scottish coast, samples taken from a variety of stranded marine mammal species have been analysed over a period of almost twenty-five years. In all cases the concentrations found were at the lower end of the ranges for the species concerned.

Table 4.6 **Mean mercury concentrations in fish flesh (mg/kg ww) from Liverpool Bay and Morecambe Bay 1982–96. Source of data: CEFAS.**

	Liverpool Bay	Morecambe Bay
1982/83	0.27	0.29
1984	0.31	0.27
1985	0.24	0.20
1986	0.24	0.24
1987	0.23	0.23
1988	0.22	0.23
1989	0.20	0.19
1990	0.19	0.20
1992	0.20	0.14
1994	0.17	0.18
1996	0.17	0.17

4.4.6 Summary

Mercury is the only element for which the observed concentrations in Region III give rise to concern. In the past, the mercury concentrations found in fish from Liverpool and Morecambe Bays were close to the agreed Environmental Quality Standard. This is not the case now and although concentrations in marine mammals remain high, they are not in the more toxic organic form. A number of industrialised estuaries and port areas are clearly contaminated and some metals in some estuaries exceed the EACs adopted by OSPAR. However, provided measures to control the input of mercury, and also the inputs of cadmium, lead, zinc and copper, continue to be applied it is unlikely that concentrations of these metals in Region III will present a threat to populations of marine organisms or human consumers of seafood.

4.5 Persistent organic contaminants

Sources of persistent organic contaminants are covered in Section 4.2.

Substances classed as persistent organic contaminants comprise a diverse group of compounds, many of them synthetic, that degrade very slowly in the environment, exhibit relatively high acute and/or chronic toxicities to marine life and are liable to accumulate in biological tissues. They include various pesticides, industrial chemicals and by-products of combustion. This section summarises recent information on the distribution of those persistent organic contaminants commonly included in national monitoring programmes. Most of the data relate to the major industrialised estuaries, the eastern Malin Shelf, the Irish Sea and Bristol Channel; areas that are most likely to be influenced by land-based inputs of these substances.

Tributyltin

Tributyltin is a widespread contaminant of coastal waters and sediments as a result of its use as an antifouling agent on marine structures, nets and vessel hulls. It can be very persistent in the environment and demonstrates high toxicity to marine organisms, notably endocrine disruption in gastropod molluscs. Although the use of TBT is now restricted to vessels in excess of 25 m in length, residues persist in many coastal locations. Recent surveys have shown that TBT is common in the vicinity of ports, shipping channels and smaller harbours and marinas where there are facilities for small boat maintenance.

The presence of TBT can be determined by analysis of water and sediments or inferred from the occurrence of a phenomenon known as imposex – whereby the females of certain gastropod species take on male characteristics. Investigations to establish the prevalence of imposex are increasingly used in monitoring programmes as the detectable concentrations of TBT in water (generally 1 – 2 ng/l but as high as 5 ng/l depending on the performance of the analytical measurement) and sediments (0.01 µg/g) are only marginally below the estimated thresholds for the induction of imposex. Concentrations sufficiently high to completely inhibit reproduction are estimated to be in excess of *c*. 5 ng/l. The UK has set an Environmental Quality Standard for TBT in sea water of 2 ng/l.

For Region III as a whole, there are very few data on the levels of TBT in sea water. Whereas concentrations in some busy waterways such as Milford Haven and the Mersey Estuary have exceeded the UK Environmental Quality Standard by as much as a factor of ten, concentrations in coastal and offshore waters are generally below the detection limit. Typical concentrations of TBT in sediments of estuaries on the eastern Irish Sea are in the range < 0.01 – 1.0 µg/g but higher concentrations were found in Swansea Bay (< 0.01 – 2.7 µg/g) and the Mersey Estuary (0.6 – 12.9 µg/g) in 1995. Concentrations in offshore sediments are generally < 0.01 µg/g.

Concentrations in the tissues of dogwhelks (*Nucella lapillus*) have been measured on only a few occasions but are generally very low; the highest concentration found to date (50 ng/g) was in dogwhelks from Milford Haven. Low but detectable concentrations of TBT (≤ 46 ng/g) and its metabolites were measured in the livers of by-caught or stranded harbour porpoises (*Phocoena phocoena*) collected from sites along the Welsh Coast and the north-west and south-west coast of England. Concentrations in grey seals were lower; only one value above the detection limit of 6 ng/g was recorded from the analysis of four individuals. The toxicological significance of these findings is yet to be established.

Polychlorinated biphenyls

Polychlorinated biphenyls were widely used as plasticizers and heat-transfer fluids. Because of their high toxicity release to the environment is prohibited but residues persist and significant amounts continue to enter Region III through rivers, ocean currents and the atmosphere. As commercial PCB formulations comprise a series of closely related substances (congeners), and analytical techniques applied vary with respect to the number of congeners measured, datasets from different laboratories are often not directly comparable.

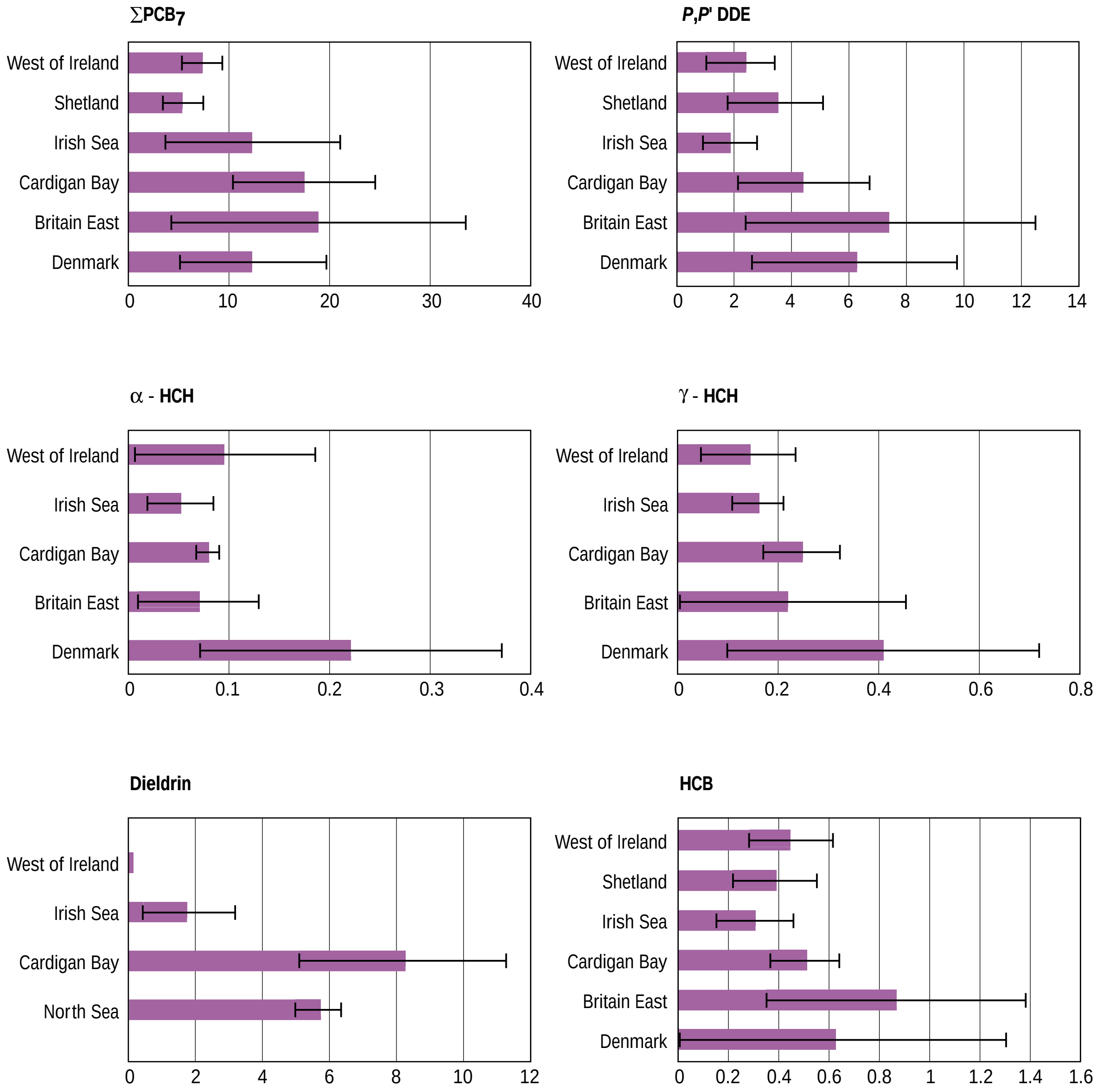
The main repositories of PCBs in the marine environment are probably fine-textured sediments but the highest concentrations are found in the fatty tissues of seabirds and marine mammals. The concentrations of PCBs in sediments tend to be closely correlated with organic carbon. Offshore, un-normalised concentrations at sandy sites are generally below the detection limits (0.2 – 0.5 µg/kg) whereas in some muddy areas, such as the north-western Irish Sea, concentrations are typically 1.0 – 10.0 µg/g dw (for the sum of ten individual chlorobiphenyl (CB) congeners). Although concentrations within this range appear to represent background, they are provisionally classed by OSPAR as concentrations indicating a potential area of concern.

In 1995/96 an extensive survey of PCBs in the sediments of sea lochs and coastal areas to the west of Scotland found that the highest concentrations for the sum of twenty CB congeners (30 – 100 µg/kg dw, un-normalised) occurred in the Clyde Estuary and its sea lochs, whereas offshore sediments generally had concentrations < 3 µg/kg dw. In sediments of the eastern Irish Sea sampled between 1990 and 1995, concentrations for the sum of eleven CB congeners were all < 2.5 µg/kg dw, whereas higher concentrations (up to 25 µg/kg for CB153 alone) occurred in the Severn Estuary and Bristol Channel. The highest values are known to be the result of a past PCB manufacturing operation at Newport. A survey of estuarine and offshore areas of Cardigan Bay in 1994, where high levels of PCBs have been found in the blubber of small cetaceans, showed that sediment concentrations were in the range < 0.2 – 12 µg/kg dw (for the sum of twenty-five CBs), with the exception of a single sample from Aberystwyth which had a concentration of 400 µg/kg dw. A subsequent and more detailed survey of the Aberystwyth area showed that elevated levels were confined to an accumulating basin off the main harbour and that most sediments in the area had concentrations in the range < 0.2 – 20 µg/kg dw.

Surveys of PCB concentrations in sediments of the western Irish Sea and Cork Harbour, conducted between 1992 and 1995, showed that elevated concentrations (i.e. not correlated with organic carbon) of a total of ten CBs occurred only in the soft sediments of Dublin port and Cork Harbour. Offshore concentrations were always < 10 µg/kg ww[2].

Information on the spatial distribution of PCBs is obtained through analyses of mussels (*Mytilus edulis*) from selected sites around the coasts. Samples collected on coasts of the Irish Sea and North Channel in 1996/97 had concentrations, expressed as the sum of seven congeners (CBs 28, 52, 101, 118, 138, 153 and 180), ranging from below the detection limit (< 0.001 mg/kg ww) to a maximum of 0.019 mg/kg ww at the mouth of the River Mersey (Liverpool Bay). The highest concentration (0.012 mg/kg ww) recorded from the Irish coast was in a sample of mussels from Cork Harbour collected in 1990. Concentrations in mussels from Irish shellfish-growing areas have been consistently low. At all sites monitored the concentrations (as the sum of seven CBs) were below the concentrations regarded by OSPAR as background (0.35 – 1.7 mg/kg ww).

Figure 4.9 **Mean concentrations (±1 standard deviation) of organochlorines in the blubber of male harbour porpoises (mg/kg lipid). Source: western Irish seaboard (Smyth, 1996); Irish Sea, Shetland, the UK North Sea coast (Kuiken *et al*. 1994); Cardigan Bay (Morris *et al*., 1989); Danish coast (Granby and Kinze, 1991).**



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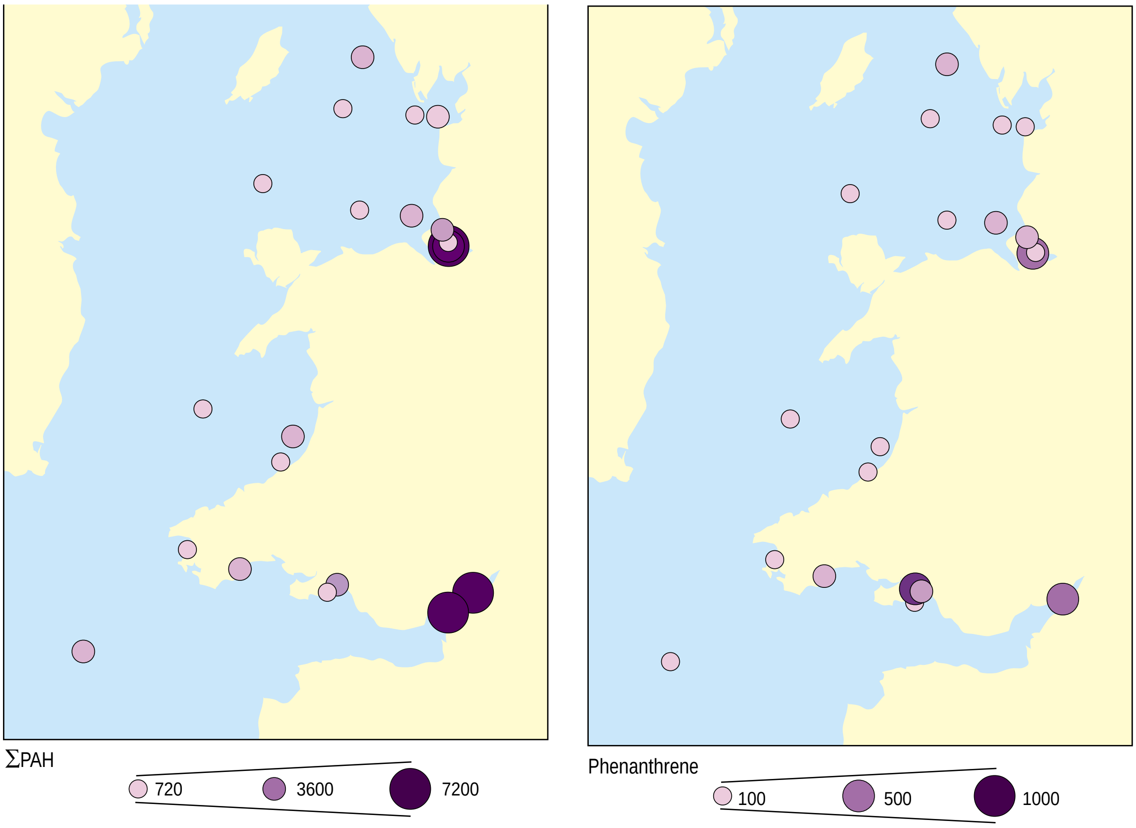
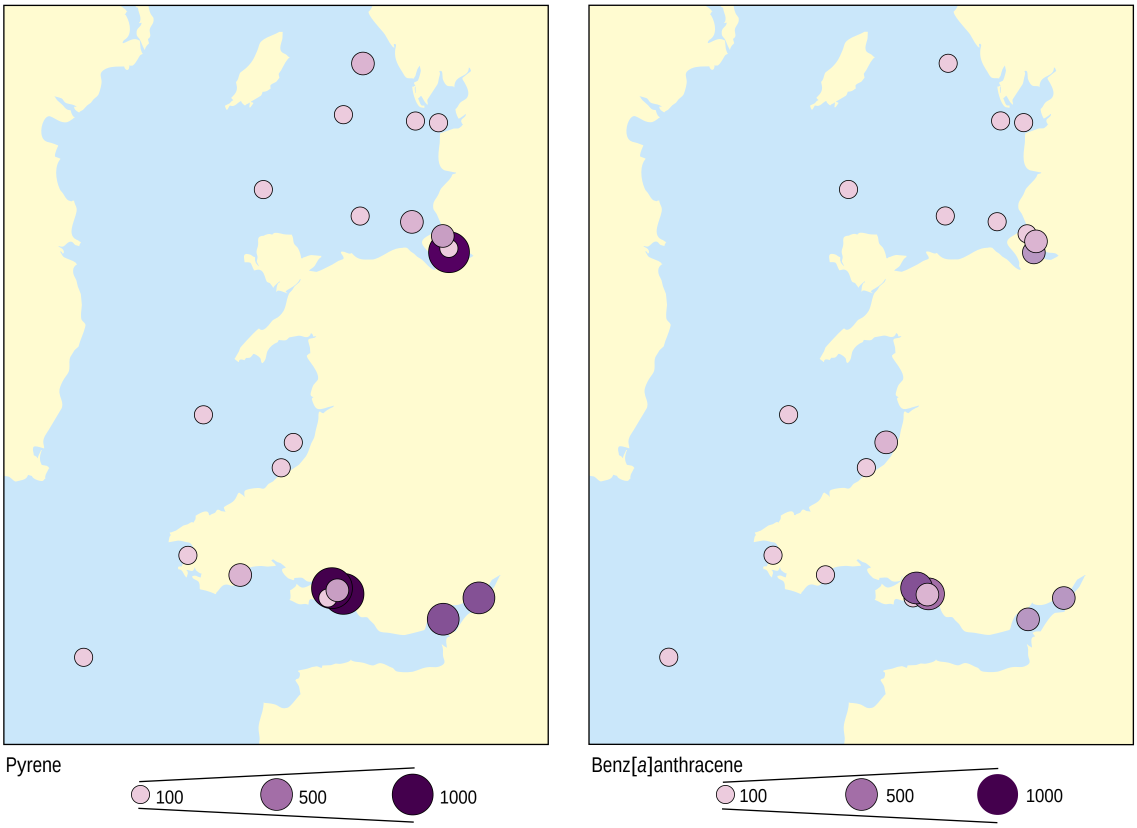
[2] On average, tissue concentrations in wet weight are approximately 30% lower than in dry weight (Fisheries Research Centre, Dublin).

Figure 4.10 **Polycyclic aromatic hydrocarbons in sediments (µg/kg) from the Irish Sea and Bristol Channel 1992–5. Source of data: CEFAS.**



ΣPAH

Phenanthrene



Pyrene

Benz[*a*]anthracene

The highest concentrations of PCBs in the tissues of fish occur in the livers of whiting from Liverpool Bay and Morecambe Bay, where the levels recorded in 1996 were 1.9 mg/kg ww and 1.7 mg/kg ww respectively for the standard set of seven CB congeners (3.0 and 2.6 mg/kg respectively when twenty-five CBs were measured; 6.3 and 5.7 mg/kg respectively when expressed as Aroclor 1254). PCB contamination in the area has been well documented and current levels of CBs in roundfish livers are within the 'upper' contamination category as specified in the old OSPAR Joint Monitoring Programme (JMP) guidelines for cod liver (applied here for roundfish generally). Concentrations of the seven CBs in the livers of Irish Sea flatfish between 1994 and 1996, including samples from Liverpool and Morecambe Bays, were in the range 0.06 – 0.6 mg/kg ww (i.e. within and below the old JMP 'medium' contamination category for flatfish: 0.50 – 1.0 mg/kg ww).

PCBs tend to occur at high concentrations in fish-eating birds and mammals. The extent of PCB contamination in these organisms is difficult to assess because of the limited availability of samples, the different congeners measured, variability between species and the dependency of concentrations on factors such as age, sex and reproductive stage.

There has been a significant decline in the PCB concentrations in seabird eggs for those colonies where concentrations were high in the early 1970s. For example, the total PCB concentrations in gannet (*Sula bassanus*) eggs from Ailsa Craig and Scar Rocks (Malin Shelf) that were > 10 mg/kg ww in the 1970s had fallen to just over 1 mg/kg by the mid-1980s. Similarly, concentrations in eggs of gannets and other species at various other localities were frequently > 5 mg/kg ww throughout the 1980s, whereas data obtained since 1994 from sites on the Isle of Man and the south coast of Ireland (Dunmore East and the Saltee Islands) suggest that concentrations are now generally well below this level. Evidence that the area surrounding the Saltee Islands had been subject to unusually high PCB contamination was obtained in the late 1970s/early 1980s when very high concentrations (i.e. > 200 mg/kg ww) were reportedly found in the adipose tissues of razorbills, shags (*Phalacrocorax aristotelis*), cormorants and guillemots; the concentrations were comparable to those known to have toxic effects. However, analysis of eggs from the same colonies in 1998 shows that the levels are now similar to those at other sites in the Irish and Celtic Seas.

The levels of PCBs (the sum of CBs 28, 52, 101, 118, 138, 153 and 180) in marine mammals are illustrated by data pertaining to the blubber of male harbour porpoises stranded on coasts of the Irish Sea, the west of Ireland and the Shetland Islands. The concentration ranges for these localities are shown in *Figure 4.9* in comparison with values for the North Sea. The concentrations of PCBs in harbour porpoises (approximately 10 – 20 mg/kg lipid) are similar to those in common porpoises (*Delphinus delphis*) but somewhat higher concentrations have been found in white-sided dolphins (*Lagenorhynchus acutus*). Anomalously high concentrations (15 – 455 mg/kg lipid) have occurred in the livers of otters from south-west Ireland. There is insufficient information to assess trends in PCB residues in marine mammals of Region III.

Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons can be formed naturally (e.g. in forest fires) although the most common source is anthropogenic emissions and the highest concentrations are generally found near urban centres. Their widespread occurrence results largely from formation and release during the incomplete combustion of coal, oil, petrol and wood, but they are also components of petroleum and its products. PAHs reach the marine environment via sewage discharges, surface run-off, industrial discharges, oil spillages and deposition from the atmosphere (see Section 4.2).

Although the lower molecular weight PAHs can be acutely toxic to aquatic organisms the major concern is that some PAHs form carcinogenically active metabolites (benzo[*a*]pyrene is the prime example). PAHs accumulate in sediments and high concentrations have been linked with liver neoplasms and other abnormalities in bottom-dwelling fish. Elevated PAH concentrations may therefore present a risk to aquatic organisms and potentially also to human consumers of fish and shellfish.

Concentrations of fifteen parent (un-alkylated) PAHs were determined in sea water from the Celtic and Irish Seas in 1993/94. In offshore waters concentrations were low or undetectable (the maximum total PAH concentration was 15 ng/l). In the Bristol Channel, concentrations of total PAHs in unfiltered water were 104 and 164 ng/l at a mid-channel site and 1150 ng/l adjacent to a steelworks. Several samples from the Mersey Estuary had total PAH concentrations of > 500 ng/l, the highest concentration being 1370 ng/l (almost an order of magnitude lower than the maximum value recorded in that particular study, i.e. 10 700 ng/l in the River Tees on the east coast of England (Region II) adjacent to a steelworks).

Very high concentrations of total PAHs in sediments were recorded during a 1995 survey of Dublin port and Cork Harbour (on the east and south coasts of Ireland respectively). The mean concentration in Dublin port sediments was 1600 µg/kg, close to the average for the twenty-two sites surveyed. The PAHs detected were mostly parent (un-alkylated) PAHs, indicating that combustion, rather than petroleum inputs, was the most likely source. Further studies to determine the origin and extent of PAH contamination in the sediments of Cork Harbour and Dublin port are warranted.

Figure 4.10a shows the distribution of total PAHs in sediment samples collected from sites in the Irish Sea and

Bristol Channel between 1992 and 1995 and *Figures 4.10b-d* illustrate the distribution of phenanthrene, pyrene and benz[*a*]anthracene respectively in these areas. Total PAH concentrations of 1 – 5 mg/kg were found at sites in the Severn Estuary. These sites also showed relatively high concentrations of individual PAH compounds (e.g. phenanthrene, pyrene and benzo[*a*]pyrene). Concentrations of total PAHs of 1 – 10 mg/kg have been measured in the sediments of Swansea Bay. Following the Sea Empress oil spill in February 1996, sediment at one site in Milford Haven yielded total PAH concentration of 93 mg/kg. Sediments from the Celtic Deep (in the north-east Celtic Sea) showed total PAH concentrations of 366 – 786 µg/kg dw.

Toxaphene

Toxaphene has been used extensively as a pesticide in North and South America, Russia and Asia but only to a minor extent in western Europe. It is not routinely included in OSPAR monitoring programmes. However, samples of fish collected between 1990 and 1992 from areas within and adjacent to Region III were found to contain toxaphene residues *(Figure 4.11)*. The highest concentrations were found west of Ireland and the UK, with lower concentrations in the North Sea. Because commercial formulations and environmental residues of toxaphene differ in composition, a subsequent study (Alder *et al*., 1995) focused on three specific toxaphene congeners (chlorobornanes). Data for herring are presented in *Table 4.7*. The data are not normalised for age and length of fish and therefore may not give a true indication of toxaphene distribution. Nevertheless, it is clear that toxaphene is a widespread contaminant in the North-east Atlantic.

Although the origin of this contamination is unknown, in view of the apparent decrease from west to east it is probable that toxaphene, along with other volatile contaminants such as mercury and PCBs, are transported from the American continents by a combination of atmospheric and oceanic processes. The use of toxaphene has been banned in the United States since 1982 but continued usage in Central and South America may contribute to residues of this pesticide in the western Atlantic. A European programme is currently underway to assess further the status of toxaphene in the waters of the North-east Atlantic.

Table 4.7 Concentrations of three chlorobornanes in herring (µg/kg lipid) from the North-east Atlantic. Source of data: Alder *et al*. (1995).

	n	Concentration
West of Ireland	3	87 – 181
Rockall Trough	1	102
West of Norway	2	102 – 170
Central North Sea	11	16 – 613
Skagerrak	3	7 – 19
Baltic	5	132 – 258

n: number of samples taken.

Other pesticides

Whereas the pesticides DDT, lindane and dieldrin are still occasionally detectable in inputs from land and the atmosphere, both inputs and environmental concentrations are low, generally stable and, in view of the restrictions placed on their use, likely to be slowly decreasing. Thus, in Region III, these substances are of lesser priority than those discussed in the preceding paragraphs and in recent years have received less attention in regional monitoring programmes.

DDT and its isomers

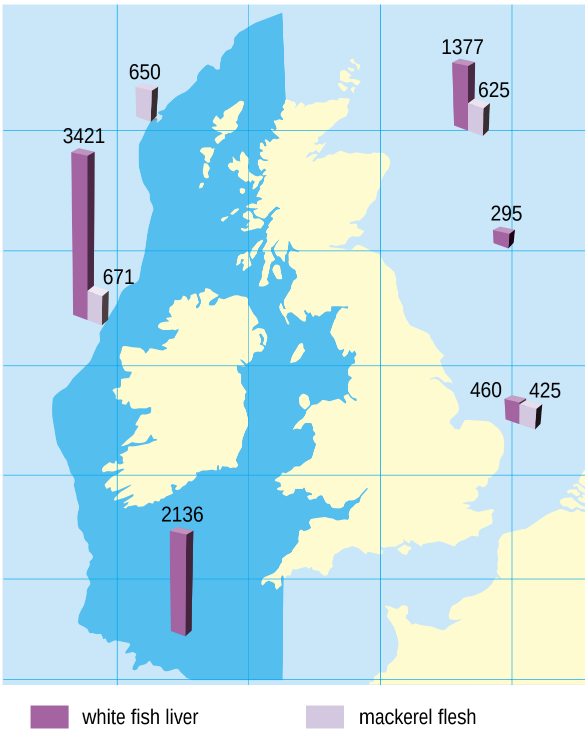
Sediments from coastal and offshore areas of the Malin Shelf, sampled in 1995/96, had absolute (un-normalised) total DDT concentrations ranging from < 1.0 µg/kg in offshore areas to 10 – 30 µg/kg in the Clyde Estuary. However, when normalised to organic carbon, the highest concentrations (300 – 1200 µg/kg) occurred in two sea lochs: Loch Fyne and Loch Goil.

Similarly, in the Irish Sea, offshore sediments had lower concentrations of DDT than estuaries. A comparative study of sediments in the western Irish Sea, Dublin port and Cork Harbour, carried out between 1992 and 1995, showed that only three sites (Dublin port, Cork Harbour and a site just north of Dublin Bay) had un-normalised concentrations of total DDT (2.5 – 5.0 µg/kg ww) that were elevated. All other sites had concentrations < 2.5 µg/kg ww.

In the period 1985 to 1996, concentrations of total DDT in the tissues of mussels from the Irish Sea, Bristol Channel and coastal areas to the south and west of Ireland were 2 – 14 µg/kg ww, whereas concentrations in the livers of flatfish were somewhat higher at 7 – 140 µg/kg ww. Levels of DDE in Irish Sea mussels were recorded as 1 – 3 µg/kg ww. The highest levels of DDT in biota were recorded in the north-eastern Irish Sea (Liverpool and Morecambe Bays). All concentrations of DDT in the commercial species tested were below the EACs adopted by OSPAR (5 – 50 µg DDE/kg ww for fish and 5 – 50 µg DDE/kg dw for shellfish) and the Codex Alimentarius Commission’s Maximum Recommended Level for food safety (5 mg/kg in meat fat).

Up to the mid-1980s the eggs of seabirds from colonies in the Malin Sea and Celtic Sea, as well as the Atlantic coast of Ireland, had concentrations of *p*,*p*’-DDE in excess of 1.0 mg/kg ww. However records from the 1990s indicate that there has been a marked decrease at most of these sites and concentrations of *p,p*’-DDE

Figure 4.11 **Total toxaphene levels in fish (µg/kg lipid) sampled around Ireland and Britain between 1990 and 1992. Source: adapted from de Boer and Wester (1993).**



in the eggs of seabirds in Region III are now generally < 0.4 mg/kg ww. Levels of *p*,*p*'-DDE in the blubber of male harbour porpoises stranded in the Irish Sea and to the west of Scotland and Ireland during the 1990s have been in the range 2 – 6 mg/kg lipid *(Figure 4.9)*.

Hexachlorocyclohexane

Concentrations of α- and γ-HCH (lindane) in sea water were determined at sites in Cardigan Bay and the Irish Sea during the period 1990 to 1993. In Cardigan Bay concentrations were low or undetectable, with maxima of about 0.3 and 0.7 ng/l for α- and γ-HCH respectively. Concentrations of α-HCH (≤ 0.2 ng/l) and γ-HCH (≤ 0.6 ng/l) were also low in unfiltered water from five locations in the Bristol Channel during 1990 to 1996. No clear gradients in concentration were observed. Higher concentrations (up to about 3 and 8 ng/l respectively) were found in sea water from the Mersey Estuary. Intermediate values were observed in Morecambe Bay, the Solway Firth and at offshore sites in the Irish Sea. The findings suggest that residues at near shore sites are introduced via rivers. Limited sampling in the north Celtic Sea indicates little difference in HCH concentrations between offshore sites in the Irish and Celtic Seas.

Concentrations of γ-HCH in sediments from coastal and offshore sites to the west of Scotland, sampled in 1995/96, were invariably < 0.3 µg/kg dw. Slightly higher (and marginally 'elevated') concentrations (0.1 – 0.5 µg/kg ww) were found occasionally in sediments of the north-western Irish Sea, Cork Harbour, Dublin Bay and Dublin port sampled between 1992 and 1995; most samples had levels < 0.05 µg/kg ww.

Concentrations of γ-HCH in the tissues of mussels around the Irish Sea, Bristol Channel, Celtic Sea and Atlantic coasts are in the range 0.2 – 2.0 µg/kg ww and, in the livers of flatfish from the Irish Sea, approximately 1 – 30 µg/kg ww. The highest levels of lindane in fish liver (up to 64 µg/kg total-HCH) occur in Liverpool Bay. These concentrations are within or above the EAC range adopted by OSPAR (0.5 – 5 µg/kg for lindane in fish), which actually relate to whole fish, and they are well below the Codex Alimentarius Commission's Maximum Recommended Level for food safety (2 mg/kg for γ-HCH in meat fat). Concentrations of α- and γ-HCH in the blubber of stranded male harbour porpoises from the Irish Sea *(Figure 4.9)* and west of Scotland during the past ten years have been approximately 0.2 to 0.4 mg/kg lipid.

Dieldrin

There are no recent data on levels of dieldrin in sea water within Region III. All sediments sampled to the west of Scotland in 1995/96 had absolute (un-normalised) dieldrin concentrations of < 6 µg/kg dw. Apart from the Clyde sea lochs, most areas had concentrations in the range 0.1 – 0.3 µg/kg dw. Similarly, in the early 1990s un-normalised concentrations of dieldrin in sediments from the north-western Irish Sea, Dublin Bay and Cork Harbour were in the range 0.1 – 0.5 µg/kg ww. Concentrations in the south-western Irish Sea (between Dublin Bay and Carnsore Point) were invariably < 0.05 µg/kg ww.

Concentrations of dieldrin in mussels from sites around the coast of Ireland decreased by an order of magnitude between 1970 and 1990. In the decade to 1994, concentrations in mussels from coasts of the Irish Sea and Bristol Channel, as well as the Celtic Sea and Atlantic coasts of Ireland, were in the range 1 – 3 µg/kg ww. Concentrations in the livers of flatfish from the Irish Sea were in the range 4 – 32 µg/kg ww. These concentrations are within the EAC range adopted by OSPAR (5 – 50 µg/kg ww for whole fish and 5 – 50 µg/kg dw for shellfish) but below the Codex Alimentarius Commission's Maximum Recommended Level for food safety (0.2 µg/kg in meat fat).

Recent data on dieldrin concentrations in seabird eggs indicate a marked decline over the 1990s and the levels are now predominantly < 0.2 mg/kg (previously 0.05 – 0.5 mg/kg) and, locally, as much as an order of magnitude less. The concentrations of dieldrin in the

Table 4.8 Concentration ranges of five phthalate esters in sea water (ng/l) from the Mersey Estuary.

DMP	DEP	DiBP	DnBP	DEHP	Source of data
n.d. – 973	n.d. – 67	65 – 709	114 – 2120	83 – 335	Preston and Al-Omran (1986)
84 – 695	68 – 243	338 – 1100	541 – 1010	125 – 693	Preston and Al-Omran (1989)
< 1	< 1 – 51	81 – 110	140 – 4800	390 – 1500	Law *et al*. (1991)

DMP dimethyl phthalate; DEP diethyl phthalate; DiBP di-*iso*-butyl phthalate; DnBP di-*n*-butyl phthalate; DEHP di-(2-ethylhexyl) phthalate; n.d.: not detectable.

blubber of harbour porpoises stranded in the Irish Sea and Scottish sectors of the Malin Shelf during the 1990s have been in the range 2 – 10 mg/kg *(Figure 4.9)*. In other species of cetacean stranded to the west of Scotland in the early 1990s concentrations were predominantly < 2 mg/kg.

Hexachlorobenzene

Hexachlorobenzene is present in sediments of the Irish Sea at very low levels (i.e. < 0.2 µg/kg). Concentrations in the livers of dab (*Limanda limanda*), sampled at sites in the Irish Sea between 1992 and 1994 were also low, generally in the range 0.001 – 0.003 mg/kg ww. Slightly higher levels (0.006 – 0.007 mg/kg ww) occurred in the livers of dab from Liverpool Bay. Concentrations in mussels were invariably < 0.001 mg/kg ww. Concentrations of HCB in the blubber of harbour porpoises stranded on the coasts of the Irish Sea and to the west of Ireland have been in the range 0.3 – 0.6 mg/kg lipid *(Figure 4.9)*.

Triazines

In a 1992 survey of the eastern Irish Sea, concentrations of atrazine and simazine in sea water were highest in samples from the Mersey Estuary where the maxima were 42 and 37 ng/l respectively. In Cardigan Bay concentrations of both herbicides were < 2 ng/l. Concentrations in samples from the Solway Firth, Morecambe Bay and offshore in the Irish Sea generally fell between these two extremes. In the Bristol Channel there was an apparent gradient decreasing seawards from maxima of about 5 and 3 ng/l for atrazine and simazine respectively, to values of < 1 ng/l offshore (in comparison, sea water from the German Bight sampled in the early 1990s had maximum concentrations of atrazine and simazine of 100 and 180 ng/l respectively).

Total hydrocarbons

Between 1984 and 1997, samples of sea water from offshore waters were collected in the Celtic Sea and Irish Sea for total hydrocarbon (THC) analysis. The Celtic Sea and Western Approaches were surveyed in 1984, and again in 1990 and 1991, and showed THC concentrations of 0.3 – 6.4 µg/l, with most samples < 2.0 µg/l. Similar concentrations were found in the Irish Sea in 1986. In the Irish Sea, THCs were highest in turbid waters (the samples were unfiltered), inshore and in areas with a high incidence of shipping activity. The lowest values were found in the central part of the eastern Irish Sea away from coastal influences. In coastal environments the highest THC concentrations were found close to harbours and coastal towns.

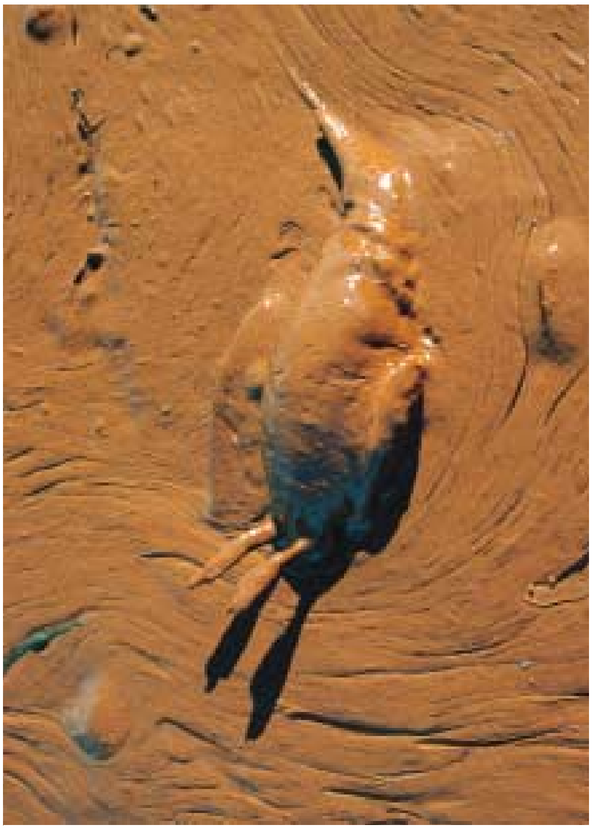
In the early 1990s, a pilot survey of total extractable hydrocarbons in sediments from Irish harbours indicated concentrations (normalised to 5% organic content) in the range < 5 – 40 mg/kg ww. Comparatively elevated concentrations were evident in the sediments of upper Cork Harbour (200 – 1000 mg/kg), in Dublin port (200 – 300 mg/kg), Dun Laoghaire Harbour (80 – 200 mg/kg) and Killybegs Harbour (80 – 200 mg/kg). These levels probably represent aliphatic hydrocarbon contamination from cargo and fishing vessels.

Phthalate esters

Concentrations of phthalate esters (esters of 1,2-benzene dicarboxylic acid) were determined in samples from the Mersey Estuary on three occasions in the late 1980s

Table 4.9 Oil pollution incidents in the Irish Sea. Source of data: ACOPS (1998).

	1980	1981	1982	1983	1984	1985	1986	1987
Open sea	2	3	3	2	4	3	7	6
Tidal river/estuary	0	2	3	0	0	0	0	0
Bay/nearshore water	0	3	0	4	1	5	1	2
Beach/shore	10	3	5	7	4	3	3	2
Port	2	22	20	3	10	19	19	13
Total	14	33	31	16	19	30	30	23
Oil spilled (t/yr)	< 250	< 150	50 – 100	< 50	100 – 150	4	263	51
Clean up costs (£000)	9	8	-	5	10	1	74	49



Guillemot killed by spilled tanker oil

(Table 4.8). Comparable, quality-controlled data are sparse, partly because of the contamination problems encountered when determining trace concentrations of phthalate esters (these concentrations are however broadly similar to those reported for the Rhine, Meuse and Ijssel in the Netherlands).

4.6 **Multiple chemical inputs**

All available data on inputs of chemicals to Region III are summarised in Section 4.2.

4.7 **Oil**

Estimates of the amounts of petroleum hydrocarbons entering Region III, from a variety of sources, are given in Section 4.2. Shipping sources are not included but ships are permitted to discharge low concentrations of oil (known as ‘operational discharges’) from bilges and engine room spaces whilst on passage. If carried out at the MARPOL 73/78 approved rates such discharges should not give rise to visible oil on the sea surface. Slicks do occur when ships fail to observe the rules concerning discharge rates and areas in which discharges are permitted. In practice however, most oil pollution in Region III arises as a result of accidents.

Statistics on oil pollution incidents in the Irish Sea were collected by the Advisory Committee on the Protection of the Sea, between 1980 and 1987 and the data are presented in *Table 4.9*. In most cases the amounts of oil involved were relatively small but the clean-up costs were not inconsiderable (see also Sections 4.2.5 and 5.13).

Other single source large inputs of oil may arise in oil-based drilling muds, but these can no longer be discharged. Such mud was only used in one well in Irish waters – in 1984. The remaining inputs, whilst substantial in terms of the total tonnes involved, occur as low concentrations in rivers and municipal and industrial discharges etc.

For the purposes of judging return to normality following the Sea Empress oil spill on the south coast of Wales in 1996, background (i.e. ubiquitous – *see Box 4.1*) concentrations of total petroleum hydrocarbons for the region were judged to be 0.2 – 0.9 µg/l in sea water, ≤ 10 mg/kg in dry sediments and 2 – 10 µg/kg in biota. Oil is a naturally occurring substance in the marine environment and concentrations in water below a few mg/l are considered unlikely to give rise to harmful effects (including sub-lethal effects) in most marine species. Such concentrations are not normally encountered in Region III and only surface slicks caused by spills or illegal discharges give rise to biological impacts.

4.8 **Radionuclides**

4.8.1 Sources

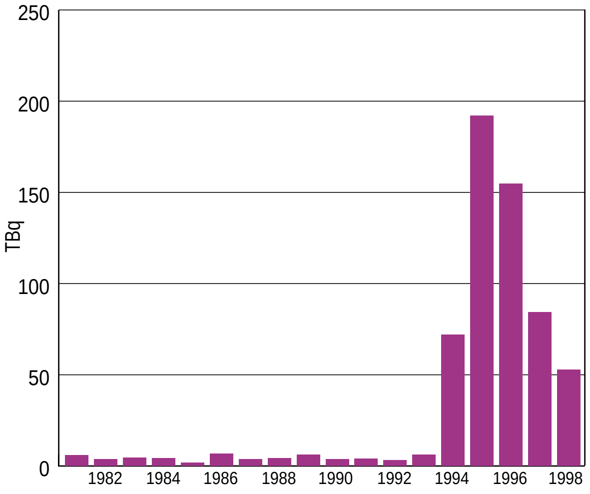
For the last forty years, inputs of artificial radionuclides to Region III have been dominated by discharges from the nuclear reprocessing facilities at Sellafield (formerly Windscale) on the Cumbrian coast. The magnitude of these releases, authorised by the UK Government, has tended to mask contributions of radionuclides from other sources such as the 1986 Chernobyl accident, the effects of which are largely terrestrial, and residues from atmospheric weapons testing. The proportion attributable to the latter is more evident in regions remote from Sellafield, such as the west coast of Ireland.

In addition to Sellafield, a number of establishments on the west coast of Great Britain are also authorised to release small amounts of radioactivity. The activities concerned include power generation, nuclear fuel production, manufacturing of medical supplies and military/naval operations. Their discharges and the adjacent environments are subject to regular monitoring. In all cases the resulting public radiation exposures are very low and difficult to distinguish from radiation due to Sellafield and nuclear fallout.

4.8.2 Trends in discharges from Sellafield

The authorised discharge limits from Sellafield are reviewed periodically and annual discharge figures are published both by the operator and the UK Department of Environment, Transport and the Regions. Discharges peaked in the 1970s, since when a number of countermeasures have been introduced and the quantities of radionuclides discharged have changed markedly as a result of changes in throughput, chemical processes, storage and waste treatment. The Site Ion Exchange Effluent Plant (SIXEP), introduced in 1986, controlled caesium-137 discharges and since 1994 the Enhanced Actinide Removal Plant (EARP) has allowed the treatment of medium-active, stored liquors. Releases of the α-emitters have declined significantly since the introduction of the EARP. For many radionuclides current discharges are at least 100 times lower than at the time of peak discharges in the 1970s. However the EARP does not remove technetium-99 and discharges of this radionuclide rose rapidly *(Figure 4.12)*, although they have subsequently declined from the peak in 1995. Discharges of iodine-129, strontium-90, carbon-14, cobalt-60 and tritium have also increased as a result of operational changes at the site, including the starting-up of the Thermal Oxide Reprocessing Plant (THORP).

Figure 4.12 **Discharges of technetium-99 from Sellafield. Source: CEFAS.**



4.8.3 Inputs of naturally-occurring radionuclides

Prior to 1992 when the operation was discontinued, the Irish Sea received about 35 t/yr of naturally-occurring uranium (and unquantified amounts of daughter products) from phosphate rock processing at Whitehaven. This resulted in elevated concentrations of radium-226 in sea water, polonium-210 in biota, and thorium-230 and lead-210 in sediments. These concentrations have now fallen substantially. About 4 t of uranium have been released annually from Sellafield, but without an equivalent loading of daughter products, and the impact has been negligible. The sediments of the Ribble Estuary can contain relatively high concentrations of thorium-234 and protactinium-234m discharged from the fuel fabrication plant at Springfields. The influence of

Figure 4.13 **Concentrations of caesium-137 in filtered sea water at Balbriggan, County Dublin, 1988–95. Source of data: Pollard *et al.* (1996).**

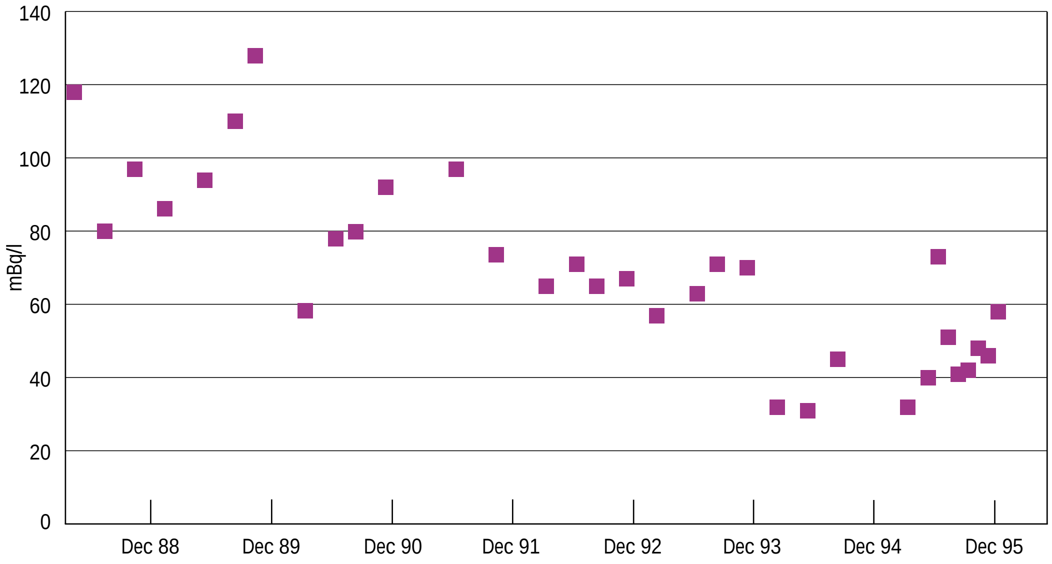
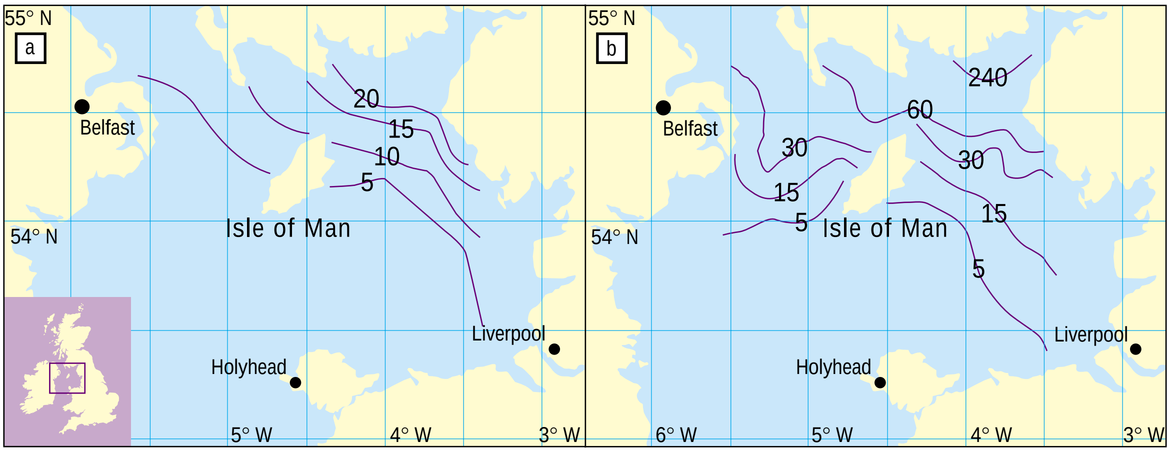


Figure 4.14 **Technetium-99 in surface waters (Bq/m^3): (a) pre-EARP release, (b) post-EARP release. Source: Leonard *et al.* (1997).**



these residues is unlikely to extend significantly beyond the estuary due to the short half-life of thorium-234 (24 days).

4.8.4 Environmental distributions

Environmental monitoring and radiological assessments are carried out both in Ireland and the UK. The results are published in annual or biennial reports. Research has established the distribution of radionuclides in sea water and subtidal and intertidal sediments, and the key processes responsible for their distribution have been investigated. Most of the input of 'soluble' radionuclides such as caesium-134, caesium-137, technetium-99, strontium-90 and iodine-129 has been transported out of the Irish Sea, whereas most of the plutonium and americium-241 resides in subtidal, muddy sediments in the eastern Irish Sea. Tides, storms, trawling and burrowing organisms mix this activity up to 1.5 m into the seabed, dilute the degree of contamination and transport sediment away from the point source, especially towards the southern Scottish coast and, to a lesser extent, to muddy sediments west of the Isle of Man. The seabed is now a source of caesium-137, remobilised as a result of the much lower sea water concentrations following the substantial decrease in the discharge. Thus, although superficially the overall distribution patterns have seemed constant with time, the redistribution of sediment-bound radionuclides is continuing.

As a result of the northerly outflow of sea water through the North Channel, Sellafield-derived radionuclides are readily detectable in the Scottish Coastal Current. The highest concentrations of caesium-137 occurred in the North Channel/Clyde Sea area in the mid- to late-1970s, but these had decreased by about two orders of magnitude by the mid-1990s. The remobilisation of caesium-137 from sediments will result in concentrations entering the Malin Sea higher than otherwise expected due to the decrease in discharges alone. Several studies have shown a tongue of water, rich in caesium-137, extending to the west of the Outer Hebrides. Increased discharges of technetium-99, due to the commissioning of the EARP in 1994, led to a five-fold increase in technetium-99 in the surface waters of the Scottish Coastal Current within about eight months. It is expected that concentrations of plutonium in the Scottish Coastal Current, which have been consistently higher than fallout levels, will continue to decrease.

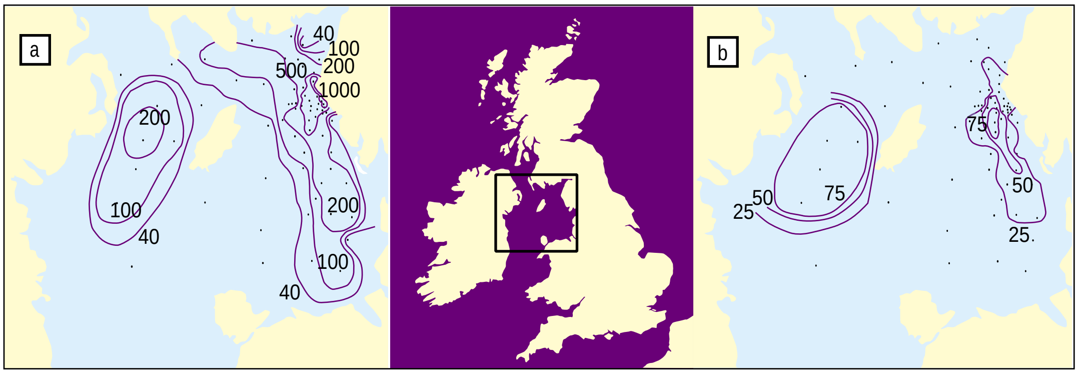
4.8.5 Levels in sea water

The general trend of decreasing concentrations of caesium-137 in sea water is illustrated by conditions off the east coast of Ireland where a slow but steady decline has been recorded since 1988 ***(Figure 4.13)***. In contrast, the significant increase in the discharge of technetium-99 in 1994, combined with the relatively rapid dispersion of this radionuclide (the transit time to the Irish coast is less than 5 months), led to a marked increase in concentrations of technetium-99 in sea water at the North Channel and in the western Irish Sea ***(Figure 4.14)***. Plutonium and americium-241 also occur in the water column but the quantities are much smaller than those in sediments. The dispersion route for plutonium is similar to caesium but concentrations are lower by several orders of magnitude.

4.8.6 Levels in sediments

The subtidal sediments of the Irish Sea contain substantial amounts (tens to hundreds of kilogrammes) of artificial radionuclides, particularly caesium, plutonium and americium. The highest concentrations in surface sediments are close to the Sellafield outfall and in a zone of muddy

Figure 4.15 **(a) caesium-137 concentrations (Bq/kg dw) and (b) silt distribution (% < 63 µm) in the surface sediments (0 – 5 cm) of the Irish Sea in 1988. Source: McCartney *et al.* (1994).**



sediments running parallel to the English coast. The area of fine-grained sediments to the west of the Isle of Man also has elevated concentrations *(Figure 4.15)*. The eastern Irish Sea sediments are now the principal source of particle-bound plutonium. The estimated total quantity of plutonium in sediments is about 200 kg. Although the subtidal sediments contain a much greater total amount of plutonium than the intertidal sediments the latter are more critical in terms of human contact.

Radionuclide concentrations in intertidal sediments have responded to the variation in discharges, the greatest changes occurring close to the source. Levels of caesium-137 in sediment have fallen steadily throughout the Irish Sea since the early 1980s, largely as a result of remobilisation and release into the water column; in some areas (e.g. the western Irish Sea) this has probably resulted in a relative enhancement of sediment concentrations. Changes in sediment-bound plutonium also reflect the slow redistribution of sediments away from the English coast to other parts of the Irish Sea, such as the large area of muddy sediments to the west of the Isle of Man. As these muddy sediments are slowly accumulating, they act as a long-term sink for plutonium and other long-lived and particle-reactive radionuclides. Accordingly, their response to decreased plutonium discharges will be considerably slower than in the case of caesium.

4.8.7 Levels in biota

Seaweeds such as the bladder wrack (*Fucus vesiculosus*) are good indicators of soluble radionuclides such as caesium and technetium in the surrounding environment. Concentrations of caesium-137 in bladder wrack diminish with increasing distance from Sellafield and have fallen in response to reductions in the discharge. On the east coast of Ireland they decreased by approximately 20% per year during the period 1983 to 1986, and although the downward trend continues it is now less pronounced. Similar changes have been measured in fish and shellfish *(Figure 4.16)*.

Concentrations of technetium-99 in seaweeds and the edible tissues of lobsters (*Homarus gammarus*) rose rapidly in response to the increased discharges after 1994. As with caesium, the concentrations decrease with increasing distance from Sellafield. Monitoring of seaweeds around Ireland during 1997 showed concentrations of technetium-99 at sites on the east coast to be almost 30 times higher than the pre-1994 level. The trends at Balbriggan and Greenore suggested that concentrations had not reached equilibrium *(Figure 4.17)* although, more recently, monitoring on the UK coast close to the discharge shows levels declining in response to lower inputs.

In general the concentrations of plutonium and americium are higher in shellfish than in fish. The most recent monitoring shows that their concentrations in fish and shellfish from routinely monitored sites in the Irish Sea are relatively stable.

Figure 4.16 **Caesium-137 concentrations in fish and prawns landed at western Irish Sea ports 1982–97. Source: Long *et al.* (1998).**

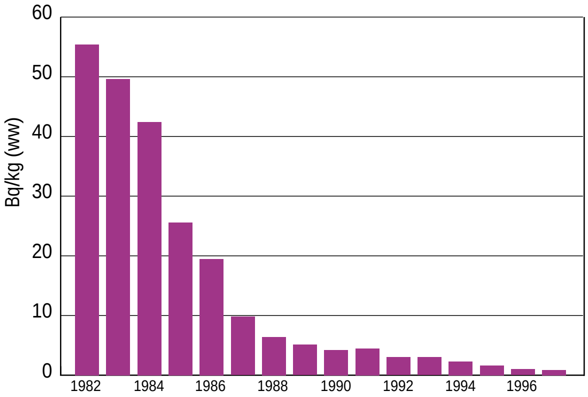
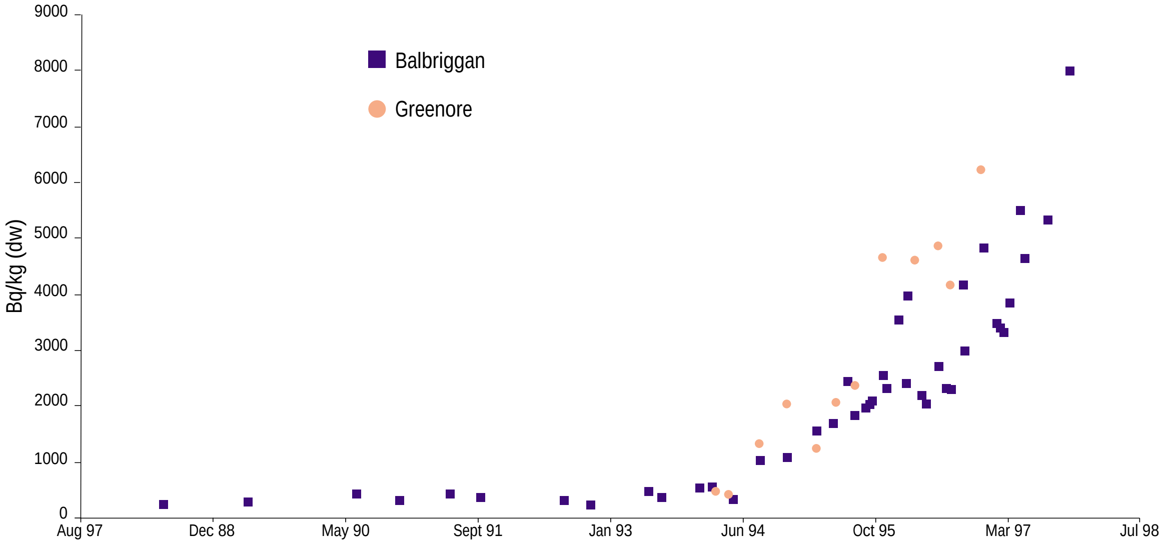


Figure 4.17 **Technetium-99 concentrations in bladder wrack from Balbriggan and Greenore 1988–97. Source: Long *et al.* (1998).**



4.8.8 Radiation exposures

Studies of the uptake of radionuclides by marine organisms have been undertaken since the early 1960s. These have included the levels of iodine-129, rubidium-106, technetium-99, plutonium and polonium-210 in a variety of fish, shellfish and seaweed. Calculation of doses to consumers of fish and shellfish has formed part of a comprehensive programme to assess the radiological impact of the Sellafield operations. Doses have varied according to the discharges and the critical groups involved. It is estimated that the highest individual doses occurred in the mid-1970s (approximately 1.9 mSv/yr) due to radiocaesium and other nuclides in fish and shellfish. This contrasts with estimated doses, due to polonium-210 and lead-210 in shellfish near the discharge point, of approximately 5 mSv/yr in the early 1980s as a result of phosphate waste discharged near Whitehaven. Collective doses *(see Box 4.2)* from all artificial sources peaked at 130 man-Sv for the UK, and 110 man-Sv for other European countries, in the 1970s. These had fallen to 3 and 20 man-Sv respectively by 1995.

The increased discharges of technetium-99 from Sellafield since 1994 have resulted in corresponding increases in the contribution of this radionuclide to the doses to seafood consumers. However, because of the low radiotoxicity of technetium-99 it contributes only about 15% of the total dose (man-made) due to radioactivity in Irish Sea fish and shellfish, still significantly less than the 65% attributable to caesium-137. In Ireland the radiation dose in 1997 to a heavy consumer of seafood (73 kg of fish; 7.3 kg of shellfish) from the north-eastern Irish Sea was estimated to be 1.4 µSv whereas the corresponding figure for the early 1980s was 70 µSv (Long *et al*., 1998). The highest dose to consumers on the Cumbrian coast in 1981 was reported to be 3450 µSv or 69% of the then recommended dose limit of 5000 µSv (using an enhanced gut transfer factor for plutonium). On the west coast of Scotland (Hunterston, Firth of Clyde), the exposure to the most exposed group of fish and shellfish consumers in 1996, including external radiation, was 23 µSv. These figures may be contrasted with average doses from all sources of radiation received by members of the public. For example, the average annual dose to a person in Ireland currently stands at about 3000 µSv (Long *et al*., 1998).

Reviews of available data on the effects of chronic radiation exposure on aquatic organisms indicate that the estimated dose rates to organisms in the north-eastern Irish Sea, and elsewhere in Region III, are unlikely to produce adverse effects at the population level. This applies even to historical dose rates that are likely to have been more than an order of magnitude greater than at present.

Box 4.2 Collective dose

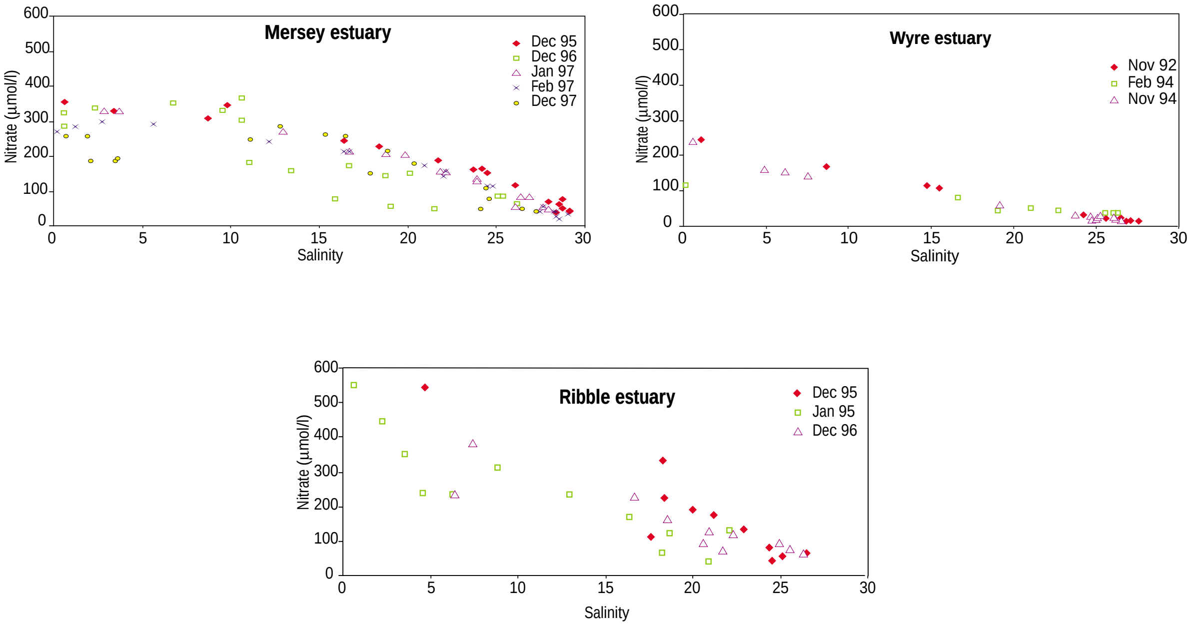
The effects of radiation from all sources on a large group of people is measured in terms of that group's **collective dose** and is expressed in man-sieverts (man-Sv), that is **the number of people within the group being considered multiplied by the average dose received by each person within that group** (this assumes uniform irradiation of the whole group).

4.9 Nutrients and oxygen

4.9.1 Introduction

The growth of plants in the sea depends upon the availability of nutrients and light. Although a number of

Figure 4.18 **Winter nitrate/salinity relationships for three major eastern Irish Sea estuaries. Source of data: EA.**



substances are recognised as being required in trace concentrations, it is normally the availability of dissolved forms of nitrogen (ammonium and nitrate), phosphorus (phosphate) and silicon (silicate) that limits plant (phytoplankton and macroalgae) growth. Although there are circumstances where the availability of silicon may limit the growth of diatoms (species that have a siliceous cell wall), nitrogen is the nutrient most likely to control growth of phytoplankton in marine waters.

In Region III, concentrations of dissolved nutrients exhibit a pronounced seasonal cycle, typical of northern temperate shelf seas. During late autumn and winter, when light is limiting, biological uptake of nutrients is low and concentrations in water increase, primarily due to the *in situ* breakdown of organic matter. In spring and summer, nutrient concentrations in the euphotic zone become depleted as phytoplankton growth resumes. This is particularly evident in areas where the water column becomes thermally stratified because this inhibits replenishment from below.

4.9.2 Sources, inputs and distributions of nutrients

In addition to the input of nutrients via oceanic water and the seasonal cycling of nutrients in the sea, nutrients are supplied to coastal waters via run-off (e.g. from agriculture and vehicle emissions), from sewage treatment plants, from certain types of industry and, over the whole area, from the atmosphere. These additional inputs can enhance the growth of phytoplankton and in extreme cases, most often in semi-enclosed coastal embayments, where there is restricted water circulation and exchange with the open sea, high levels of nutrients can produce a large phytoplankton biomass and give rise to nuisance blooms of algae. Some algal species can give rise to toxins that can be transferred to man via shellfish (see Section 5.3). As the blooms die their decomposition may lead to reduced oxygen concentrations in the water and at the seabed, thus causing mortality of indigenous animals.

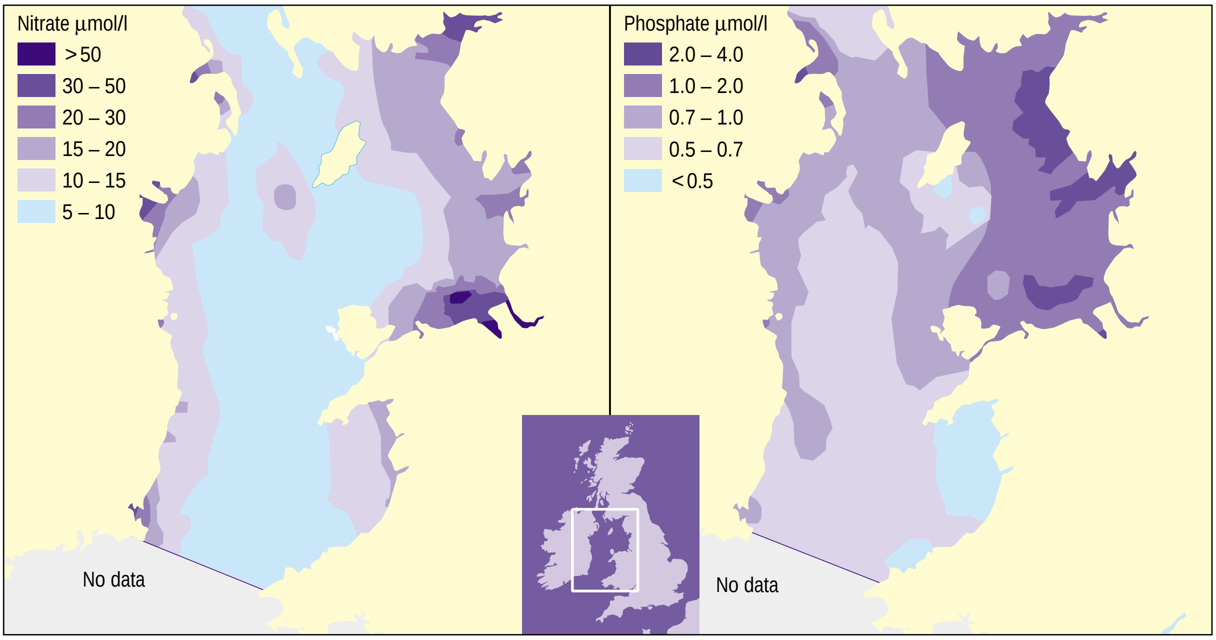
Irish Sea

Section 4.2 provides details of the various nutrient inputs to the Irish Sea area and *Table 4.10* summarises the estimates made by an Irish Sea Study Group in 1990. Since then the input of phosphate to the north-eastern Irish Sea has been substantially reduced through process changes at a phosphate rock processing plant on the Cumbrian coast and because sewage sludge disposal ceased

Table 4.10 **Nutrient inputs (t/yr) to the Irish Sea. Source of data: ISSG (1990b).**

	Nitrogen	Phosphorus
Atmospheric	43 000	2 000
Riverine	76 400	6 120
Domestic	10 700	1 900
Industrial	2 640	16 260
Sludge	3 840	720

Figure 4.19 **Nitrate and ortho-phosphate concentrations (µmol/l) in the Irish Sea January/February 1991. Source: NORSAP (1992).**



completely in 1999. The inputs from land-based sources are superimposed on natural inputs introduced by oceanic water entering the Irish Sea via the Bristol Channel, which are estimated at more than 100 million t of nitrogen and 28 million t of phosphate annually.

Although relatively small in terms of load, concentrations of nutrients in inputs from land, particularly rivers, are much higher than concentrations in Atlantic water. Nitrate : salinity plots for some major Irish Sea estuaries in winter are shown in *Figure 4.18*. Nitrate concentrations in these freshwater sources range from 200 – 350 µmol/l and for most estuaries the plots show a linear relationship, indicating the dominant process is dilution. The Mersey is an exception and shows the importance of denitrification within that estuary in substantially reducing the quantity of nitrogen exported to sea. Phosphate concentrations in freshwater range from as low as 0.2 µmol/l (i.e. lower than winter concentrations in coastal sea water) to > 20 µmol/l. The phosphate : salinity plot for most Irish Sea estuaries is not linear due to the interaction of phosphate with particulate matter. Riverine inputs exhibit marked seasonality, being higher during winter when run-off is greatest. This variability in load is most pronounced for nitrate, which originates largely from agricultural sources and flushes rapidly from land during heavy rainfall. In contrast phosphate leaches at a relatively constant rate; furthermore a large part of the phosphate load comes from sewage treatment works. As a generalisation, phosphate concentrations tend to decrease with increasing river flow, whereas nitrate concentrations increase.

Figure 4.19 shows winter concentrations of nutrients in the Irish Sea as observed in 1991, i.e. before the changes in inputs referred to in the first paragraph of this section. The influence of land-based sources is very clear for both nitrate and phosphate. The extent of coastal influence is more marked in the north-eastern Irish Sea than along the Irish coast. This is primarily due to the comparatively longer retention time of sea water in the shallow sector of the Irish Sea to the east of the Isle of Man. The nitrate distribution, in particular, closely follows the salinity contours throughout the Irish Sea and shows clearly the influence of riverine inputs such as those from the Dee and Mersey, as well as those from the River Slaney on the south-east coast of Ireland and the rivers discharging into Dundalk Bay on the north-east coast of Ireland.

Much of the Irish Sea is well mixed throughout the year and nutrients do not become seriously depleted except in the stratified north-western Irish Sea. For example, in that area, concentrations of oxidised nitrogen (nitrate plus nitrite) were reduced from 6–7 µmol/l in March 1992 to 0.5 µmol/l in July. Similarly, orthophosphate concentrations decreased from 0.9 – 0.1 µmol/l and silicate from 6.0 – < 1.0 µmol/l over the same period. The concentrations of all three nutrients recovered rapidly during autumn and winter with concentrations approaching the March concentrations by November, largely due to *in situ* remineralisation of nutrients from suspended organic matter. The seasonality noted in the Irish Sea is much less marked in the Bristol Channel where high turbidity in the middle and upper reaches severely restricts phytoplankton growth. Temporal data

Table 4.11 Mean nutrient concentrations to the west of Scotland (µmol/l) 1960–90. Source of data: FRS.

	Nitrate		Phosphate		Silicate	
	winter	summer	winter	summer	winter	summer
Clyde Sea	12.5	0.8	1.2	0.3	9.3	1.0
Inner Malin Shelf	7.3	0.6	0.6	0.1	5.2	0.9
Outer Malin Shelf	8.6	0.5	0.6	0.2	4.3	0.6
Shelf west of Hebrides	9.3	1.4	0.6	0.2	4.1	0.4
North Minch	7.0	0.1	0.6	0.3	5.1	1.2
North Channel*	8 – 13.0	-	0.5 – 1.1	-	4.6 – 10.3	-
North coast*	7.5 – 8.5	-	0.5 – 0.9	-	3.2 – 8.9	-

* data are for a sea area off Northern Ireland in 1991; -: no information.

from the 1990s on winter nutrient concentrations west of 5° 36' W, show no evidence of trends in oxidised nitrogen but there are indications that phosphate increased prior to 1994/95 and decreased thereafter.

The Celtic Sea and Atlantic Shelf west of Ireland

There are very few data on the concentrations of nutrients in near shore waters of the Atlantic Shelf west of Ireland and in the Celtic Sea but it is likely that winter nitrate and phosphate concentrations are correlated with salinity.

During the spring, major changes in nutrient concentrations occur in all shelf waters as primary production resumes. Off the west coast of Ireland the timing of the onset of spring production dictates the pattern of nutrient depletion. For example in 1990 the spring bloom was well established by mid-April with clear reductions in surface nitrate and phosphate concentrations. However, in 1992 the spring bloom was poorly developed by mid-April and the respective concentrations of nitrate and phosphate were up to 5.0 and 0.4 µmol higher than in 1990. In summer both the Celtic Sea and shelf waters to the west of Ireland become extensively nutrient depleted. Exceptions occur in the vicinity of tidal fronts such as the Ushant Front and the Celtic Sea Front. Within these localised transition zones, both nutrient levels and light are sufficient to enhance algal growth throughout the summer months. At a number of locations on the west coast of Ireland occasional upwelling events occur during the summer months. These events are associated with inshore tidal mixing and result in increased nutrient availability in stratified waters that would normally be nutrient depleted. Such events may stimulate occasional toxic algal blooms (see Section 5.7).

Malin Shelf west of Scotland

The area to the west of Scotland comprises a number of zones with distinct hydrographic features. The mean nutrient concentrations found in these five zones in winter and summer between 1960 and 1990 are summarised in *Table 4.11*. The waters in these areas are generally well mixed but nutrient depletion following the onset of the spring bloom is clear in all areas. Off the coasts of Northern Ireland and in the North Channel, winter nutrient concentrations are similar to those found off the Scottish coast (i.e. excluding the Clyde Sea area) in winter.

The west coast of Scotland is a heavily glaciated landscape with deep fjordic inlets. By far the largest estuary in terms of development is that of the Clyde. In the Clyde, nitrate tends to behave conservatively but nitrite and ammonium behave non-conservatively, probably reflecting both nutrient input and internal denitrification. Dissolved phosphate also behaves non-conservatively, responding to changes in suspended load, waste inputs and biological activity. Outside the Clyde most freshwater run-off enters the fjordic sea lochs where nitrate and phosphate concentrations (typically 6 and 0.5 µmol/l respectively) reflect the generally lower input from terrestrial sources. However, many of these sea lochs contain fish farms and these can give rise to enhanced ammonium and phosphate concentrations close to the farm sites. The significance of such inputs is discussed in Section 5.6.

4.9.3 Trends

Given the marked seasonal variations and the differences observed from year to year in the onset of phytoplankton growth it is difficult to resolve any anthropogenic influence from natural processes. Although the recently established National Marine Monitoring Programme should eventually lead to a consistent set of time series data for the area west of the UK, there is a lack of such data at present. Even in the Irish Sea there is a lack of consistent time series of data on concentrations of nutrients. However, one time series (1967 – 1994) for a site in the central Irish Sea near the Isle of Man, does suggest that both winter nitrate and phosphate concentrations have increased since sampling started at the site in 1954. This trend may be partially climate related but it is consistent with increased nutrient inputs to the Irish Sea as a result of human activities.

Table 4.12 UK guideline criteria for determining whether estuaries and coastal waters are eutrophic, or at risk of eutrophication, in the context of the EC Urban Wastewater Treatment Directive.

	Estuaries	Coastal waters	
		acceptable	requires investigation
Dissolved oxygen	≥ 7 mg/l median and not less than 6 mg/l	≥ 7 mg/l median and not less than 6.5 mg/l	< 7 mg/l median and/or values less than 6.5 mg/l
DAIN	-	< 12 µmol/l*	> 12 µmol/l*
		+	
DAIP	-	< 0.2 µmol/l	-
Chlorophyll a	-	< 10 µg/l	> 10 µg/l

DAIN dissolved available inorganic nitrogen; DAIP dissolved available inorganic phosphorus; * summer value; -: no guideline.

Support for the concept of increased nutrient concentrations over time can be discerned in the measurements of chlorophyll *a* at the Isle of Man site where, between 1967 and 1994, there was a 100% increase. Further south in the well-mixed zone, data from the Continuous Plankton Recorder programme suggest the colour index fell between 1970 and 1980 but increased thereafter. However, as this increase in the colour index was also observed throughout the Malin Shelf and Western Shelf, it is likely that the cause is macro-scale changes in the North-east Atlantic rather than land-based inputs.

4.9.4 Deoxygenation

Elevated concentrations of nitrogen and phosphorus, in the absence of similar scale increases in silicate, are generally considered to favour the growth of microflagellate and dinoflagellate species rather than diatoms. In some estuarine and coastal areas blooms of certain dinoflagellate species occasionally cause deoxygenation when the blooms collapse and decompose in summer. There is, however, no consistent pattern which might be regarded as symptomatic of eutrophication, though blooms of *Phaeocystis* spp. do occur regularly in the north-eastern Irish Sea; in Liverpool and Morecambe Bays.

Generally the offshore waters of Region III are well mixed and seriously depressed oxygen levels are unusual. The only areas where oxygen depletion is occasionally detected are the outer Clyde Estuary and Liverpool Bay at times of stratification. In both cases this is attributable to sewage sludge disposal, rather than algal blooms, and is expected to cease now that sludge disposal has stopped. Although parts of the north-western Irish Sea also stratify in summer and the bottom waters become isolated for several months, the attendant drop in oxygen concentration is small. The position rapidly reverses once stratification breaks down.

4.9.5 Eutrophication criteria

As an integral part of the OSPAR Strategy to Combat Eutrophication adopted in 1998, a classification of the eutrophication status of the maritime area is being undertaken. Within UK waters a first stage screening procedure has identified three broad areas for more detailed consideration: the Firth of Clyde, Anglesey to the Solway Firth and the Severn Estuary upstream from Bideford Bay to Carmarthan Bay. In response to the consideration of adverse eutrophication effects under the EC Directives on Urban Wastewater Treatment (91/271/EEC) and Nitrates (91/676/EEC), a special study group derived a number of guideline concentrations. These guidelines, which are not standards, are summarised in *Table 4.12*. Preliminary findings suggest that, at least for the purposes of the

Figure 4.20 **Irish estuaries and embayments for which nutrient data are available.**

Urban Wastewater Treatment Directive, the Mersey Estuary/southern Liverpool Bay area and Belfast Lough are considered to require some protection in the form of improved sewage treatment.

Similar guidelines were drawn up by Irish scientists for assessment purposes. Their conclusions are summarised in *Table 4.13* and, as with the UK figures, the numbers are guidelines rather than water quality standards. They have been used to assess the status of twenty-three major estuaries and embayments around Ireland *(Figure 4.20)*. The overall conclusions drawn are that, with the exception of locations in places such as the Malahide Estuary, Dublin Bay and Cork Harbour, eutrophication is not a problem in Irish waters.

Table 4.13 Water quality indices applied to Irish estuaries and coastal areas for assessment purposes.

		Category		
	units	low	moderate	high
BOD	mg/l	< 3.0	3.0 – 5.0	> 5.0
Oxidised nitrogen (0 – 20 psu)	mg N/l	< 1.0	1.0 – 3.0	> 3.0
Oxidised nitrogen (> 20 psu)	mg N/l	< 0.2	0.2 – 1.0	> 1.0
Orthophosphate	mg P/l	< 0.05	0.05 – 0.15	> 0.15
Total ammonia	mg N/l	< 0.2	0.2 – 1.0	> 1.0
Un-ionised ammonia	mg NH_3/l	< 0.02	0.02 – 0.05	> 0.05
Chlorophyll a	mg/m^3	< 10	10 – 25	> 25
Dissolved oxygen	% saturation	< 70	70 – 110*	> 110

* the ‘moderate’category denotes the normal concentration range for dissolved oxygen.

Sea Stacks

chapter 5

Biology

5.1 Introduction

The purpose of this chapter is first to provide a concise description of the basic biological features of the region and second to examine the changes that have occurred or are likely to occur in future. A further important aim is to assess the degree to which these changes can be attributed to human activities. Extensive descriptions of the region's ecosystems can be found in each of the subregional texts that form the basis of this quality status report. Section 5.2 therefore provides only an outline of existing knowledge but it does stress areas where more information, and better understanding, are required to ensure that the biological components of Region III can be adequately protected. As there are uncertainties about the causes of variability among plant and animal populations and it is not always possible to definitively attribute changes to human activities, sections 5.3 to 5.17 describe changes that have occurred or are occurring and assess the degree to which the changes are attributable to human activities.

Accordingly, the information presented is drawn largely from studies that measure changes in the environment that may affect marine species and studies of specific biological effects. The changes considered include physical changes (e.g. to the seabed and coastal boundaries and climate), chemical changes (e.g. nutrients or contaminant concentrations) or biological changes, for example those resulting from exploitation of fish and shellfish, cultivation of particular resources and changes in plankton communities.

Some studies have been undertaken to assess directly the biological effects of certain wastes or activities, such as disposal at sea of sewage sludge and dredged materials, many of which have been ongoing for a decade or more. Other investigations relate to the impact of particular events (e.g. oil spills) or the effect of a particular chemical. Studies of the effect of TBT on gastropod molluscs (the imposex effect) fall into this last category. In addition there are techniques such as the oyster embryo bioassay and the mussel 'Scope for Growth' test, both of which yield a picture of general water quality, while can be used for assessing general sediment quality. Results of such studies are described in the later sections of this chapter.

Waders

5.2 **Overview of the ecosystem**

5.2.1 Bacteria

Although it is known that sea water contains up to 10^9 bacteria per litre little is known about the relative importance of different communities or their detailed species composition. In very general terms however, it is known that bacteria are capable of breaking down a wide variety of organic matter. Much of this is produced by algae, but other dead marine organisms and terrestrially derived organic matter also provide food sources for marine bacteria. Bacteria can have an important role also in the degradation of many organic chemicals including many manufactured chemicals. Their role in the degradation of oil (which is an entirely natural, albeit complex, mixture) is well known and numbers of bacteria increase rapidly following an oilspill.

5.2.2 Phytoplankton

The next level in the marine food web is that of the phytoplankton (small plants) which are the source of food for zooplankton (small animals and the juvenile stages of many larger organisms). Phytoplankton range in size from $<$ 0.001 mm to about 2 mm, the larger species being those that form the most valuable food source for higher organisms. Although knowledge of phytoplankton in Region III is far from complete, certain key aspects are reasonably well established. Some of this knowledge is derived from the Continuous Plankton Recorder (CPR) surveys (see also Section 4.9.3) which have been in operation in the region since 1946. Although designed primarily to monitor zooplankton, the system gives a crude measure of phytoplankton biomass by measuring ‘greenness’, an assessment of the species present and the abundance of larger phytoplankton. Thus a reasonable record exists of the changes that have occurred in phytoplankton over the last few decades and the extent to which these changes are common to the entire OSPAR area. The records also indicate the timing and scale of the spring bloom. In the mixed waters of the Irish Sea the spring bloom is usually about a month later, and the autumn decline about two months earlier, than in the more open shelf waters to the north and south. Also in the more open waters of the Malin Shelf and Celtic Sea, there is often a small autumn bloom before the winter sets in. There have been clear changes in the relative abundance of various phytoplankton species (see also Section 4.9.3) but these are common throughout the whole of Region III and therefore probably reflect a North Atlantic-wide change, possibly related to climatic variations. Furthermore, there is considerable year to year variation in both the onset and scale of the spring bloom. Not all phytoplankton species are equally suitable as food for other trophic levels (e.g. *Phaeocystis* spp. and toxic *Alexandrium* spp. may be avoided by some grazers).

Certain species of phytoplankton are associated with effects that are readily observable and/or affect human interests. For example, *Noctiluca* spp. can form dense blooms and colour the water, while others such as *Phaeocystis* spp. are associated with foam production which can be either unsightly or smelly or both. Other species (e.g. *Alexandrium* spp.) are associated with the production of toxins that may directly affect other marine species or indirectly affect seabirds or humans through the accumulation of toxins in species they eat such as mussels. The identity of such ‘troublesome’ species is fairly well established though the fact that their presence does not always cause a problem is an aspect that is not so well understood. However, increasing attention is being paid to collecting good time series data on algal blooms and a more detailed understanding of such events is emerging.

5.2.3 Zooplankton

Generally, zooplankton growth and abundance closely reflects the phytoplankton production phase of the marine system. For offshore areas, the CPR surveys provide a good record of the presence and abundance of many species both within and between years. In Region III copepods are the most abundant form of zooplankton *(Table 5.1)* and account for up to 97% dry weight of the total zooplankton biomass. In the tidally mixed near shore environments the smaller species predominate. To a lesser extent they also predominate in the stratified regions of the Irish Sea. The larger species, mostly *Calanus finmarchicus* and *C. helgolandicus*, are more suitable as prey for fish larvae and are abundant in the Celtic Sea and Malin Shelf.

There are strong year to year variations in zooplankton abundance throughout Region III. For example *C. finmarchicus* and *C. helgolandicus* abundance in the Celtic and Irish Seas can vary by an order of magnitude between years and is more variable than that found for smaller copepod species. This variability has implications for carbon cycling generally, for example in terms of the variability in food supplies for fish larvae. In addition to the wide inter-annual variability, the CPR records also show an underlying downward trend in copepod abundance, particularly on the Malin Shelf and to the west of Ireland. This trend is also observed in other OSPAR regions, e.g. Region II (the Greater North Sea) and is believed to be climatically induced.

5.2.4 Benthos (including most shellfish)

Many of the larger benthic species are commercially important e.g. scallops, queen scallops, *Nephrops*,

Table 5.1 Zooplankton biomass and copepod species composition and abundance at selected sample sites in Region III. Source of data: adapted from Williams *et al*. (1994).

	Western Irish Sea near shore mixed conditions	Central Irish Sea stratified conditions	Central Irish Sea mixed conditions	Celtic Sea stratified conditions	Celtic Sea shelf break south-west of Ireland
Month	April/May	April/May	April/May	August	May
Number of hauls	9	9	3	5	6
Depth range (m)	28 – 73	84 – 120	60 – 85	100 – 105	76 – 116
Zooplankton biomass					
dry weight (mg/m^2)*	143 – 1 455	307 – 3 947	223 – 653	3 740 – 6 910	1 490 – 4 384
copepods as % of dry weight	72 – 97	69 – 99	78 – 81	49 – 52	90 – 97
Copepod numbers (range/m^2)					
Para/Pseudocalanus	11 433 – 92 448	16 208 – 166 258	3 366 – 10 340	10 304 – 36 389	23 527 – 92 564
Acartia spp.	610 – 134 048	164 – 164 853	15 – 42 189	1 857 – 3 351	1 854 – 17 525
Temora longicornis	1 399 – 43 751	124 – 52 153	110 – 6 545	0	0
Centropages spp.	63 – 5 870	12 – 8 011	96 – 6 913	7 943 – 28 150	0
Oithona spp.	978 – 54 103	3 906 – 75 163	100 – 3 322	599 – 1 290	13 544 – 24 229
Calanus spp.	607 – 32 076	1 417 – 93 459	25 – 2 269	13 440 – 28 707	36 415 – 72 809
TOTAL COPEPODS	25 583 – 361 512	22 576 – 399 382	3 858 – 107 000	37 927 – 91 537	83 514 – 189 613

Based on selected hauls in a 30-year time series (1960–90) of data. * copepods, euphausiids, chaetognaths, decapod larvae, coelenterates and *Limacina* spp

shrimps, crabs, lobsters, oysters, clams, mussels, cockles and whelks. Many of the smaller species provide a source of food not only for commercially important fish such as plaice and sole but also for a wide range of other predatory fish, birds and marine mammals. Because many chemical contaminants tend to be deposited onto the seabed, either through adsorption onto particulate matter or simply by precipitation, benthic species are exposed to higher concentrations (subject to bioavailability) than species in the water column. They also provide the clearest indication of the physical effects of material disposed of at sea, dredging of seabed material and disturbance by fishing gears that are dragged over the seabed.

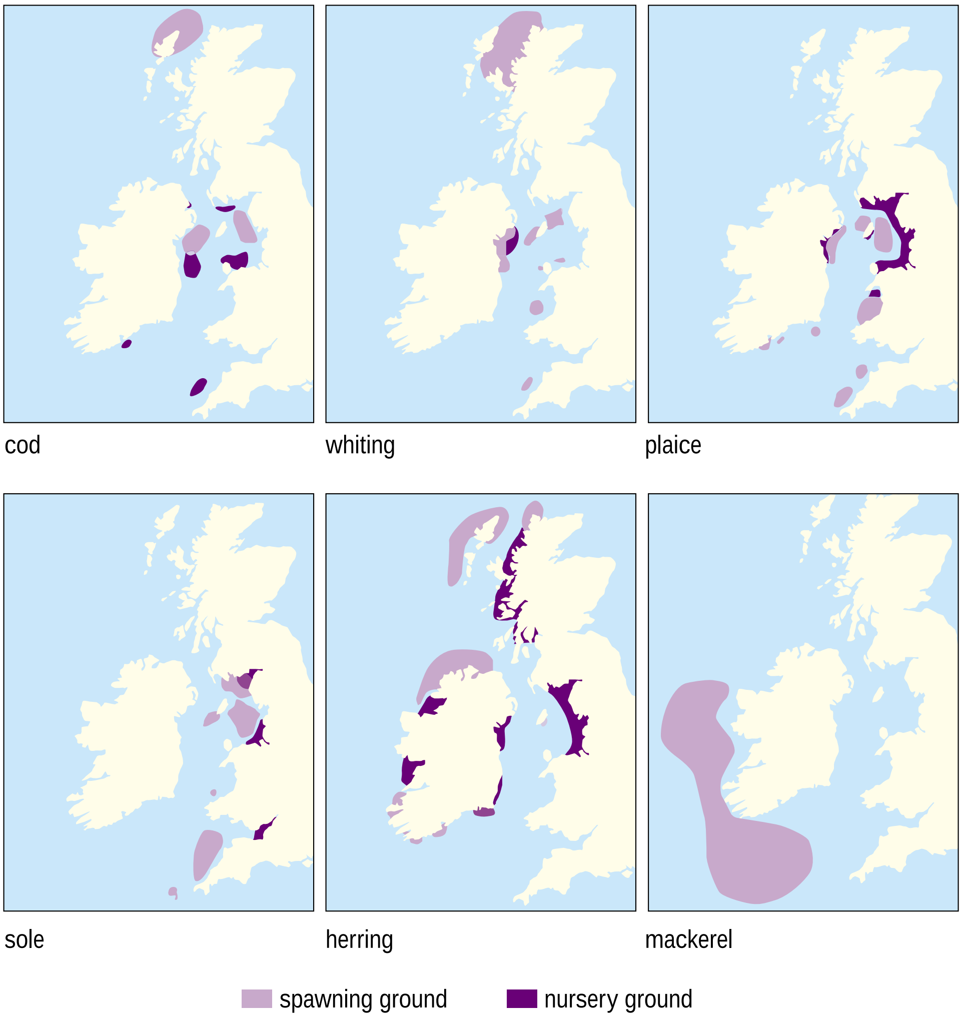
There is little information on the nature of the benthos to the west of Ireland and Scotland, although recent studies have described the infaunal and epifaunal communities in the Greater Minch area. Monitoring has been carried out at all major dredged material and sewage sludge disposal sites. There have also been a number of general surveys in the Irish and Celtic Seas to determine distributions of macrofaunal communities. As in the North Sea, these reflect the nature of the sediments, the depth of water and the latitude. This is important as it means that for a particular sediment type and depth a certain mix of species ought to be present. Major deviations from that expected composition might therefore be an indication of the influence of external factors, including human activities.

5.2.5 Fish and other shellfish

The large range of habitat and sediment types found in Region III support a diverse fish fauna including many commercially important species. In order to ensure the long-term sustainability of these species, the level of exploitation needs to be carefully managed and their habitats need to be protected. This requires a good knowledge of fish biology. Of particular importance in this respect is an understanding of the locations of spawning and nursery grounds, of migrations at different phases of the life cycle and the interaction between exploited and non-exploited species. Most of the available information on such topics is qualitative rather than quantitative.

Water temperature is a major factor limiting the overall distribution of fish. Cold water species such as cod and herring reach their southern limit in the Celtic Sea and English Channel whereas the northward penetration of warm water species such as bass, sardines (*Sardina pilchardus*) and anchovies (*Engraulis encrasicolus*) varies periodically according to sea temperature. Seasonal variations in temperature also influence the near shore distribution of many species, with cold water species moving inshore during winter and warm water species doing so in summer. Other physical factors, including depth, tidal flow and sediment characteristics, lead to considerable variation in the distribution of each species, even within its normal geographic range. Thus for example, soft muddy sediments provide a good habitat

Figure 5.1 **Spawning and nursery grounds of selected commercial fish species in Region III. Source: Hillis and Grainger (1990); Nichols *et al*. (1993).**



for gadoid species and burrowing species such as *Nephrops*, whereas species such as plaice and dab prefer sandy areas. Even within areas of similar sediment type, features such as outcrops, wrecks and gullies provide shelter and local concentrations of food, and consequently are often associated with greater densities of fish species.

With the notable exception of herring and sandeel (*Ammodytes tobianus*) which lay their eggs on well-oxygenated gravel beds, the majority of fish release their eggs into the water column and important spawning and nursery grounds occur throughout Region III. The location of the main spawning and nursery grounds for several of the commercially important species are shown in *Figure 5.1*. The spawning time for most species is late winter, spring or early summer, with the peak in early spring when the phytoplankton bloom facilitates the growth of zooplankton on which the fish larvae feed. If the timing of the spring bloom fails to coincide with the maximum density of fish larvae this may contribute to reduced recruitment. Particular hydrographic features favour recruitment (see *Box 5.1*).

Recruitment surveys of young fish are carried out jointly by countries bordering Region III. The results are summarised in *Figure 5.2* and show that whiting and haddock are by far the most widely distributed and abundant species. The distribution of older fish and adults is determined by the location of their feeding and spawning grounds, which in turn determine the location of the main fishing grounds. Catches are often highest where fish aggregate for spawning. Many of the fish species found in Region III have relatively short migration routes between feeding and spawning areas and distinct stocks of the same species are recognised

Box 5.1 The distribution of larval and juvenile fish in relation to hydrographic conditions and prey distribution

The distribution of larvae and 0-group pelagic fish in the western Irish Sea reflects the close coupling between recurrent hydrographic features and biological production. Recent work in the area, which examined the abundance of larval fish and newly metamorphosed pelagic juveniles, revealed that as with many shelf seas, fish that spawn in the coastal region do not spend all of their early life stages inshore (Dickey-Collas *et al*., 1996). The coastal region of the north-western Irish Sea is characterised by more sustained primary production, and higher zooplankton biomass, in early spring than both the offshore mixed and stratified regions. The juvenile fish utilise this biological production during the first-feeding stage. A movement or diffusion away from the coast occurs in late May, either in response to feeding conditions or by the entrainment of fish into the summer stratified region. This movement of pelagic 0-group fish ensures that they are retained in the centre of the western Irish Sea gyre, a region of high zooplankton biomass during the summer. Furthermore, the predominance of larger sized phytoplankton in stratified regions compared to mixed areas, allows a more direct and efficient transfer of energy to fish larvae via larger sizes of copepods (Coombs *et al*., 1994).

5.2.6 Birds

The distribution of seabirds (terns, gulls etc.) and waterfowl (ducks, geese, waders etc.) is well established, as are their migration patterns and numbers. Region III is widely recognised as having a large number of areas that meet the main requirements of seabirds and waterfowl i.e. safe, suitable sites for breeding, an absence of mammalian predators, a supply of food close to the breeding site and good areas for feeding during the winter. Seabird numbers are checked regularly at many of the more important breeding and overwintering sites. There has been an increase in the combined counts of the twenty-two species that breed on the shores of Ireland of around 20%. However, such figures mask variations between species. Thus for example, shag, guillemot and Arctic tern (*Sterna paradisaea*) numbers increased within the region. Although the annual migration patterns are reasonably well understood, there is evidence of recent changes in migration for some species. For example, the western stock of mackerel has undergone a northerly shift in distribution and some 'southern' species are becoming more numerous in the region.

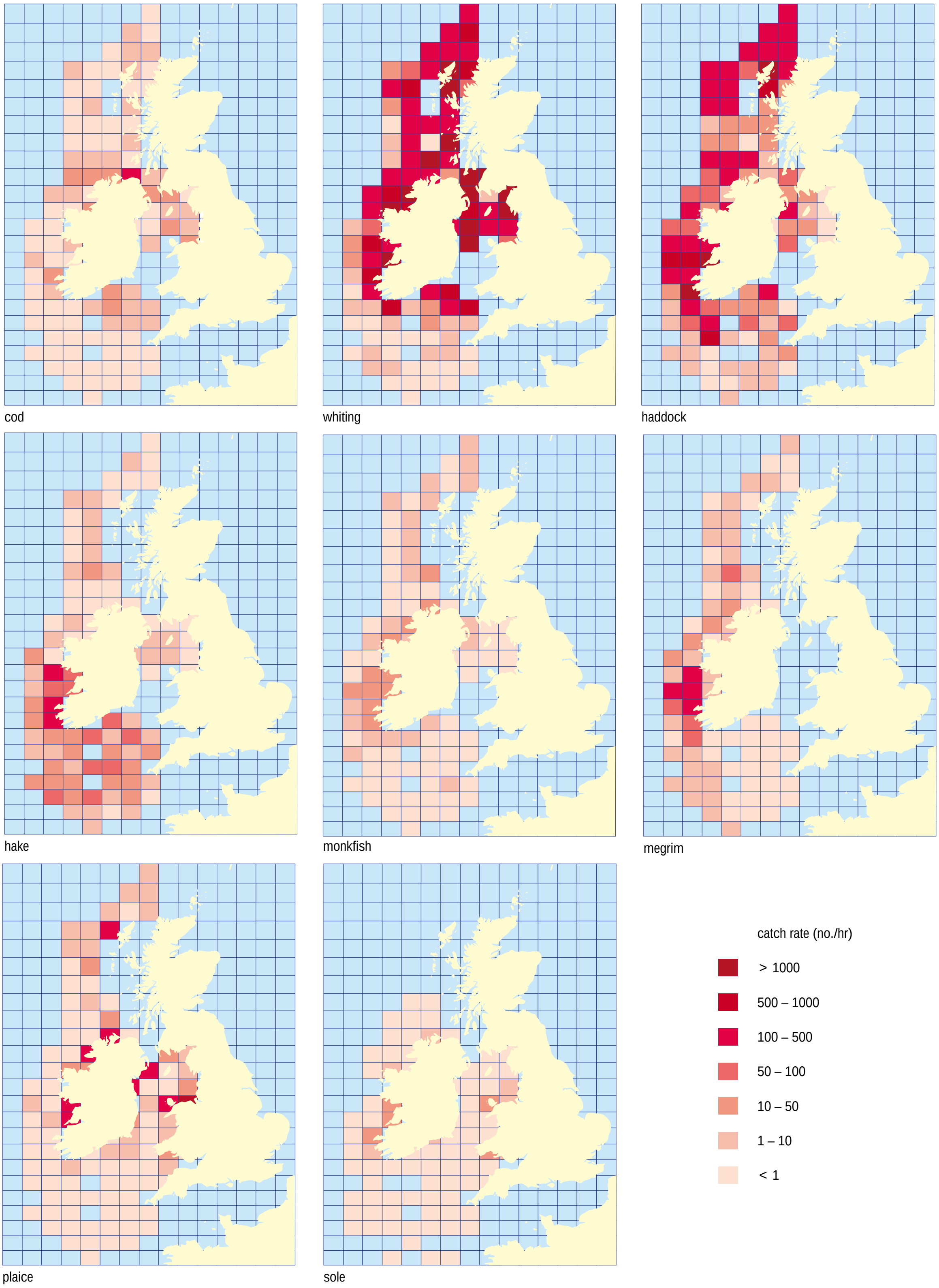
The major links between fish mortality and recruitment are summarised in *Box 5.2*. Although factors such as temperature, stratification and availability of food are important in determining the survival of fish eggs, larvae and young fish, fishing mortality is the major cause of death of older fish. In order to maintain stocks within safe biological limits information is therefore needed on both recruitment (assessed by the young fish surveys) and fishing mortality (see also Section 5.5). Apart from the need to measure mortality of the species concerned, a knowledge of species interactions is required i.e. the extent to which one species relies on another as food. Studies are underway to establish the nature of these relationships both in terms of predation on young fish and on benthic species that may be disturbed by fishing activities.

Box 5.2 Fish mortality and recruitment

Mortality: Each year a proportion of the fish alive at the beginning of the year will die from predation, disease or other natural causes (**natural mortality, M**). In addition, once fish are big enough to be taken in the fishery they are subject to high levels of **fishing mortality (F)**. Natural mortality rates differ between species and decline throughout the lifespan of a specific year-class of fish. A general rule of thumb for natural mortality is as follows: 5% per day in larvae, 40% per month in the nursery grounds, 10% per month in the first year and 10% per year in adult life. Fishing mortality is a measure of the proportion of the stock in the sea that is taken by fishing, and can be expressed as a percentage or as a 'fishing mortality rate'. Fishing mortality rates are an expression of the likelihood that a fish will die at any instant in time. A fishing mortality rate of 1.0 corresponds to a 60 – 70% reduction in stock over the course of one year. Fishing mortality is normally quoted as the average mortality for a range of age groups which are above the catchable age, for example 2 – 5 years for cod. The fishing mortality rate on each age group of a stock is determined by two factors: the proportion of that group that is big enough to be captured by the gear and the overall amount of fishing effort on the stock.

Recruitment refers to two distinct processes. The process whereby young fish, previously inaccessible to the ordinary fishing gear, become as a result of growth, change in behaviour or of movement on to the fishing grounds, potentially vulnerable to fishing. The number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable population that year. The term is also used to refer to the number of fish recruiting to the stock in a particular year, reaching a certain age (age 2 recruits are fish reaching their second year) or entering the spawning population.

Figure 5.2 **Catch rates of 1-group fish from trawl surveys carried out in Region III averaged over 1992–6. Source: unpublished data from CEFAS, DANI, FRS and FRC.**



between 1969/70 and 1985/87 by more than 100%, whereas numbers of six gull species and two tern species declined substantially.

The mechanisms that influence seabird numbers are outlined briefly in *Box 5.3*. The scope for human influence on natural variability is clearly considerable. For example, fishing can provide a food source in the form of offal and discards for certain species of birds but may reduce the supply for others. Loss or disturbance of habitat, especially of breeding sites (e.g. through coastal development) can affect seabirds and waterfowl. Chemical pollution can also be harmful. In the 1960s many species suffered reduced breeding success that was attributed to certain organochlorine compounds causing reduced egg viability through eggshell thinning and/or toxic concentrations in the egg yolk. In recent years there have been a number of mortalities of mainly herring gulls (*Larus argentatus*) and black-backed gulls (*Larus* spp.). These have been attributed, at least in part, to *Clostridium botulinum* poisoning associated with feeding on municipal refuse sites.

Box 5.3 How seabird numbers vary

Seabirds are long-lived, have high survival rates among adults and produce relatively few young each year. The proportion of non-breeding adults in a population of seabirds is large (relative to many land birds) and often varies from year to year. In a stable breeding population recruitment and immigration exactly balance mortality and emigration. The number of young produced by each pair is low and the period of immaturity long. Adult mortality rates are also relatively low. This rate must stay low for the seabird breeding population to remain stable. A series of seasons with low breeding productivity or complete breeding failure may have a relatively insignificant effect on the size of the breeding population. By contrast, a small change in adult mortality rate is enough to have a large effect on the size of a breeding population. The level of mortality among immature birds is also important, but it has a less critical effect upon population size because immature mortality is generally higher than that in adults.

Several different hypotheses have been proposed for the regulation of seabird numbers. Starvation outside the breeding season, due to density-dependent competition for food, may be an important factor (Lack, 1966). Alternatively, density-dependent mortality may occur during the breeding season through competition for food (Furness and Birkhead, 1984). Shortage of suitable nest sites may also be important. Whatever the controlling mechanisms, natural changes in the environment will alter the number of birds that can be supported. Thus seabird numbers can be expected to show both long- and short-term changes and rarely to be exactly stable.

5.2.7 Marine mammals

With the exception of otters, some of which feed along the coasts of Scotland and Ireland, marine mammals can be divided into two groups, seals and cetaceans. The common or harbour seal (*Phoca vitulina*) and the grey seal are widely distributed throughout Region III, although a number of locations are particularly favoured. For example the west coast of Scotland is home to some 10 000 common seals and the Western Isles are the birthplace of an estimated 15 000 grey seal pups annually (40% of the UK total production). Similarly, the bulk of the Irish harbour and grey seal populations are found in fourteen and seven colonies respectively on the west coast of Ireland. On Irish Sea coasts both species occur but most colonies are small; usually no more than a few tens of animals. The reasons for the smaller numbers are unclear but lack of suitable haul-out sites is probably a major factor.

The waters around Ireland, particularly those to the south and west, together with those to the west of Scotland, support a variety of cetaceans. Cetaceans are occasionally seen in the Irish Sea but, with the exception of the population of bottle-nose dolphins in Cardigan Bay, they seem only to occur as visitors. Cetaceans are frequently found stranded on the coast, sometimes alive but more often dead. The numbers stranded probably reflect the relative abundance of the different species, with harbour porpoises top of the list. An exception seems to be the bottle-nose dolphin which, although relatively common off western coasts, seems rarely to become stranded. Live strandings are most likely among animals that have become disorientated in bays or estuaries. Some strandings of dead cetaceans seem to be linked with fishing activities as many of the corpses show signs of physical damage probably caused by nets. Numbers of strandings have been recorded in both Ireland and the UK for a number of years. The Irish records show an increase in numbers stranded since the 1960s and especially since 1981. This is probably related to the greater local involvement in reporting and because past strandings of smaller cetaceans tended to be ignored. Also, at least with striped dolphins, the larger numbers involved reflect a northward shift of the species due to warmer water temperatures.

Several species of marine mammals were hunted but, with the limited exception of occasional taking of seals to control numbers or prevent excessive losses of farm fish in sea cages, this no longer takes place within Region III. Some species are believed to be at risk through the numbers caught incidentally during fishing. Residues of certain synthetic chemicals found in their tissues may also pose a risk, especially when body fat is mobilised during food shortage or lactation.

5.2.8 Particular habitats and key species

The preceding text of this section and Section 3.3 on conservation drew attention to habitats found in Region III that are regarded as unique or of particular importance. Similarly the value of particular species as key indicators of the quality of an area, or the influence of human activities, was highlighted in Section 5.2 and those that follow. By way of example, the machair habitats of Ireland and the Western Isles are regarded as special habitats. The dogwhelk is a particular indicator of the effect of TBT and certain groupings of benthic species are associated with particular types of seabed.

5.3 Impact of non-indigenous species and harmful algal blooms

Non-indigenous species

There are several ways in which non-indigenous species can threaten ecosystems if they become successfully established following introduction. They may compete with native species for food, habitat and other resources or even replace them (see also Section 5.6.1).

Harmful algal blooms

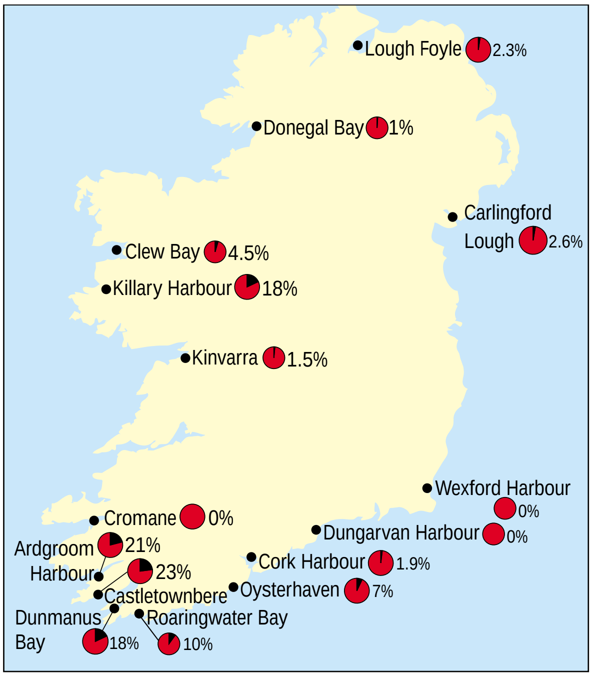
With the advent of extensive mariculture of bivalve shellfish and apparently increasing blooms of toxin-producing algae, there is concern over the possible introduction of algal species in ballast waters. There is no evidence that this has happened. Nevertheless there have certainly been more reported incidents of harmful algal blooms in recent years.

In fact the increase in recorded harmful algae events in Region III is no different to that which has been recorded worldwide. In addition, the EC Shellfish Hygiene Directive (91/492/EEC) requires member states to monitor commercial bivalve production areas for the presence of toxin-producing algae and the presence of biotoxins in bivalve molluscs. As a consequence, all major classified shellfish growing areas, and some Scottish fishing grounds, are now subject to regular algae and toxin monitoring. For this reason, and because commercial shellfish production has increased, especially in Ireland and Scotland, the number of opportunities for biotoxins to be detected has increased markedly.

The biotoxin monitoring programme in England, Wales and Scotland between April 1996 and April 1998 showed that toxin-producing species were detected in many areas and both diarrhetic shellfish poisoning (DSP) toxins and paralytic shellfish poisoning (PSP) toxins were found in some samples of shellfish. Outbreaks in England and Wales were generally of short duration, for example PSP toxins in oysters from Milford Haven caused by *Alexandrium tamarense* lasted a week in 1996 and four weeks in 1997. In Scotland, 43 areas were monitored and PSP toxins were found in bivalve shellfish from several areas, the highest levels being found at a site in Skye in June 1997. DSP toxins were found in six areas and the 1997 outbreak in the Outer Hebrides was prolonged (four weeks). In some cases the PSP toxins in mussels were associated with the presence of *Alexandrium* spp. in the water column. In Northern Ireland a biotoxin monitoring programme was started in 1993 and a total of four sites monitored; two in each of two loughs. Low numbers of several algal species associated with toxin formation have been detected in both loughs but no shellfish have tested positive for the presence of toxins. *Figure 5.3* shows the average duration of closure of shellfish growing areas in Ireland as a consequence of DSP or PSP toxins being found in the period 1991–7. There are marked annual variations. Thus, for example, the high average shown for Killary Harbour is mainly due to an isolated event in the winter of 1995/96. More typically, events last from 0 to 12 weeks each year. Although there is no evidence of temporal patterns there is clear evidence that the south-west bays are more likely to be affected by toxin-producing algal blooms. This is probably due to the unusual hydrodynamic regime of the area.

Apart from demonstrating the occurrence of biotoxins the monitoring programmes have also shown that there is no really consistent pattern of occurrence.

Figure 5.3 **Average duration of closure (as a percentage of the year) of selected shellfish growing areas in Ireland arising from the detection of DSP and/or PSP during 1991–7. Source: FRC.**



They also show that the presence of toxin-producing species does not necessarily equate with high concentrations of biotoxins in molluscs from the same area.

5.4 Impact of microbiological contaminants

Human activities are directly responsible for the input of microbiological contaminants to the sea, both directly via sewage discharges and indirectly via rivers carrying sewage discharges from upstream of the tidal limit and land run-off from animals. Animal sources can include large congregations of wild birds but are usually cattle, pig or sheep farms. Microbiological contamination can be the cause of illness in humans as a result of exposure to contaminated bathing waters or contaminated bivalve shellfish. The latter tend to accumulate bacteria and viruses as a consequence of their filter-feeding.

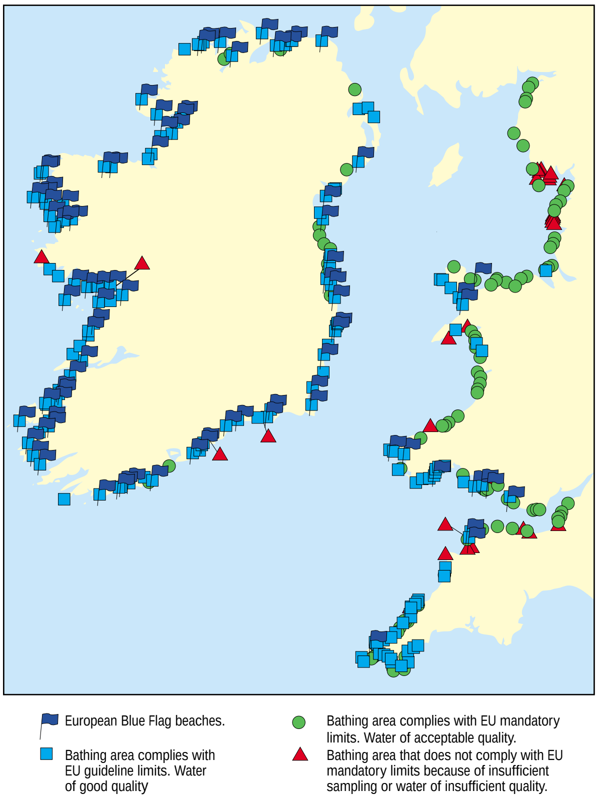
5.4.1 Bathing water quality

The EC Directive concerning the Quality of Bathing Water (76/160/EEC) lays down limits for a number of indicators of sewage pollution, among which are Mandatory Limits for total and faecal coliforms. In order for bathing water to comply with the requirements of the Directive, 95% of the samples taken during the bathing season must achieve these limits. More stringent Guideline Limits are also specified which, if achieved, mean the water is considered of good quality rather than simply acceptable. The Directive is currently under review and at present, due to variations in national systems, strict comparisons between results from different countries are not always possible, though general trends within each country over time ought to be detectable and comparable.

In addition to the EC Directive requirements, the Federation of Environmental Education in Europe seeks, with European Commission support, to promote bathing water quality through the European Blue Flag Scheme. In addition to meeting requirements for safety, provision of sanitary facilities etc., water quality must comply with the EC Guideline Limits for total and faecal coliforms and faecal streptococci. Beaches that comply with the various requirements are awarded Blue Flags when the authority concerned applies for the award and supplies the necessary compliance data.

Figure 5.4 shows the state of compliance with the EC Bathing Water Directive of beaches in the UK and Ireland during 1997–8. The figure also shows the beaches that were awarded Blue Flags in the UK and Ireland during 1998.

Figure 5.4 **Compliance with the EC Bathing Water Directive in Region III 1997–8 and European Blue Flag Beaches 1998. Source of data: EA (1999); EPA (1998); FEEE (1998).**



Bathing area data are for 1997 (Ireland) and 1998 (UK); all Blue Flag data are for 1998.

Beaches in Ireland demonstrate a very high degree of compliance with the Directive's Mandatory Limits and in 1994 all 108 designated beaches complied (in 1989 only 67 beaches were designated and 92.5% complied with the required limits). In 1996 and 1997 a further seven beaches were included and compliance with the Mandatory Limits was 95.6% and 96.5% respectively. Some of the failures related to beaches around Dublin, which has large discharges of sewage. A few other beaches have failed to comply with the Mandatory Limits but in most cases only a single breach occurred. In 1997, all 115 bathing sites were also monitored for the Guideline Limits on faecal streptococci and 91.3% were found to comply.

In the UK there has been a marked improvement in the quality of bathing waters from around 66% complying with the Directive's Mandatory Limits in 1988 to 90% in 1996. In 1996, 386 of the 433 beaches monitored in England and Wales, all sixteen of those monitored in Northern Ireland and twenty-one of the twenty-three monitored in Scotland, met the Mandatory Limits. The major problem beaches on the UK coasts of Region III are on the north-west coast of England and the Isle of Man. Major environmental improvement programmes have been launched by both the UK and Isle of Man authorities designed specifically to improve bathing water quality.

5.4.2 Shellfish quality

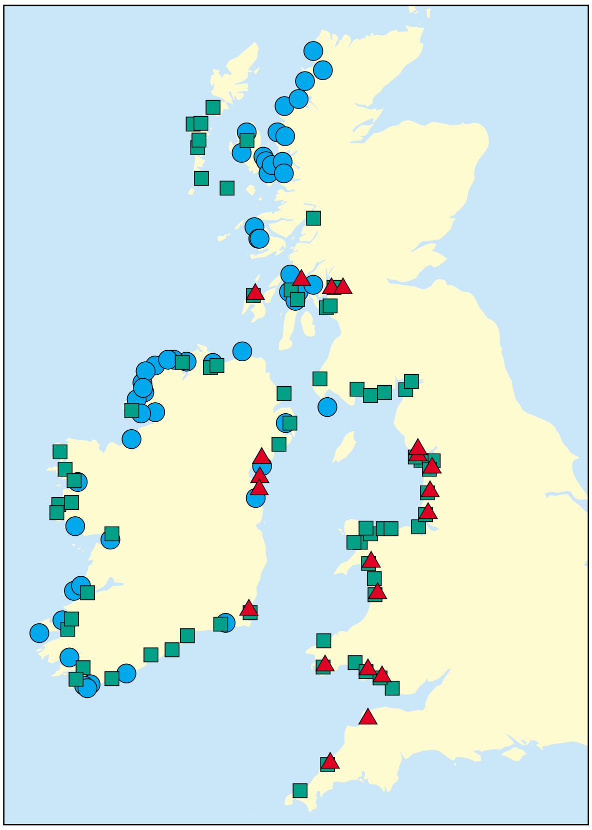
The term shellfish includes crustaceans (e.g. prawns, crabs and lobsters), bivalve molluscs (e.g. mussels, oysters, clams and scallops) and gastropods (e.g. periwinkles and whelks), all of which may be consumed. The EC Shellfish Hygiene Directive (91/492/EEC) lays down conditions for the production and placing on the market of live bivalve molluscs. These conditions effectively result in three categories of marketable shellfish depending on their content of *E. coli* and faecal coliforms. These range from Category A which can be sold for direct human consumption, through Category B which must undergo purification in an approved plant for at least 48 hr before sale, to Category C where shellfish can only be sold after being relaid for an extended period in clean water. Shellfish of poorer quality cannot be exploited.

In practice it is recognised that water quality can vary seasonally, depending on the tourist population for example, or on the amount and frequency of sewage overflow. In addition, changes result from measures introduced to comply with the EC Directives on Urban Wastewater Treatment (91/271/EEC) and Bathing Water Quality (76/160/EEC). Accordingly, national authorities are required to review classifications periodically. *Figure 5.5* shows the status of bivalve production areas in Ireland in 1995 (the latest year for which classification data were available) and the United Kingdom in 1998. In summary, 55% of Irish production areas were classified as Category A, 29% as Category B and 3.5% as Category C. The remaining 12.5% included sites with two or more classifications. There were no areas from which harvesting was prohibited. For England and Wales twenty-eight areas fell into Category B or C. Six sites failed to meet the standards for Category C due to microbiological contamination and harvesting from these areas was prohibited. As with some of the Irish areas, different sites within the same area experience different levels of contamination and thus are allocated different classifications.

Of the 156 areas in Scotland from which bivalve molluscs were harvested in 1998, 81 were classified as Category A and a further 31 as Category A or B depending on season. Of the remainder, only two are regarded as Category C. In 1997 in Northern Ireland there were eleven production sites in four areas; three classified as Category A, the remainder as Category B.

In a number of shellfish harvesting areas, such as in the Bristol Channel, some reductions in levels of microbiological contamination have resulted from improvements introduced to meet the requirements of the EC Bathing Water Directive. Others may arise as a consequence of improvements to meet the requirements of the EC Urban Wastewater Treatment Directive. However, any changes so achieved are coincidental and may not improve the classification of shellfish quality sufficiently to alter categories or to realise the full commercial potential of an area. Such changes could be brought about if the areas concerned were designated as shellfish growing waters under an earlier EC Directive (79/923/EEC) on the Quality Required of Shellfish Waters. This Directive requires member states to reduce pollution of designated shellfish growing waters to a level such that locally harvested shellfish meet Category A standards. However, at present not all waters from which shellfish are harvested are designated as shellfish growing waters. For example, in 1982 four areas were so designated in Ireland, although this had increased to fourteen by 1994. In England, 76 new shellfish waters were designated in July 1999, along with the extension of the seventeen existing designations. Such designations should encourage environmental improvements and facilitate expansion of the shellfish industry.

Figure 5.5 **Bivalve mollusc production areas in the UK (1998) and Ireland (1995) designated for harvesting under EC Directive 91/492/EEC. Source: CEFAS; Department of the Marine and Natural Resources; FRS; Lucey (1996).**



Classification of shellfish production areas

● Category A – can be sold for direct human consumption

🟩 Category B – purification required in an approved plant for 48 hours prior to sale for human consumption

▲ Category C – relaying required over a long period (at least two months) in clean sea water prior to sale for human consumption

5.5 **Impact of fishing on ecosystems**

The most obvious impact of commercial fishing is that it removes target (fish and shellfish) and non-target species (as by-catch) from the ecosystem. The species composition of the catch and by-catch varies with the type of fishing gear used. Towed gears in contact with the seabed, e.g. beam trawls, otter trawls and shellfish dredges, can cause loss, injury or mortality among benthic organisms. Physical disturbance of the seabed can also increase the amount of suspended sediment, and thus increase sediment transport, and alter the chemical equilibrium of the sediments.

5.5.1 Fishing mortality

Whilst commercial fisheries take a high proportion of the stocks of adult fish each year, catches often include immature fish which are either discarded or landed, depending on market forces. Average levels of fishing mortality during the early 1990s on those commercially exploited stocks subject to assessment are shown in *Table 5.2*.

Juvenile whiting suffer a high mortality from capture in the *Nephrops* fishery. High rates of discarding of juvenile whiting in the Irish Sea led to the mandatory use of square mesh panels in UK trawl fleets in 1992 and in Irish vessels in 1994. Juvenile haddock in the Malin Sea are also subject to high mortalities. The highest mortalities on maturing and adult fish are inflicted on cod and whiting in all areas of Region III and haddock in the Malin Sea. In the Irish Sea, where trawl surveys in the 1990s indicated a level of fishing mortality on haddock similar to that estimated for cod and whiting, that species has recently become much more abundant.

Celtic Sea herring is currently the most heavily exploited pelagic stock. Mortality among herring stocks appears to have stabilised at a relatively low level in the 1990s, though it has increased recently on the west coast of Ireland. Fishing mortality on the Western stock of mackerel increased in the 1980s following an increase in catches.

Historically, skates and rays have been a more important component of the total demersal fish catch in the Irish Sea than in other areas of Region III. The disappearance of the common skate (*Raja batis*) in the Irish Sea is attributed to fishing mortality. Studies indicate total mortality rates among ray species (Batoidei) in the Irish Sea of 30 – 50% of population numbers; most of this is attributable to fishing.

5.5.2 Discarding

Information on discarding is given in the subregional reports for the Irish Sea and the other marine areas but the figures are far from complete and are, at best, approximations. This is because only certain fleets (areas, species) have been sampled to date. Nevertheless, as an illustration of the scale of discarding within different fleets, some data are provided in the following paragraphs. Studies of methods to improve discard statistics are currently underway within the EU.

Demersal fish

It is estimated that over 15 300 t of fish (13 250 t demersal, the remainder pelagic) were discarded by the demersal fleets sampled in Region III in 1996. Approximately 65% of the demersal discards from the above fleets comprised whiting, haddock, dogfish

Table 5.2 Estimated percentage of stock caught during a year for the main fish species exploited in the Irish Sea, Celtic Sea and Malin Sea; averages for 1990–4. Source of data: ICES (1997a; 1998a,b,c).

	Age first exploited	% caught			Main age groups exploited	% caught		
		Irish Sea	Celtic Sea	Malin Sea		Irish Sea	Celtic Sea	Malin Sea
Cod	1	22	17	12	2 – 5	62	60	54
Whiting	1	38	6	27	2 – 4	67	59	44
Haddock	1	n.a.	n.a.	32	2 – 6	n.a.	n.a.	48
Hake	1	n.a.	24	24	4 – 7	n.a.	29	29
Anglerfish	2	n.a.	7	n.a.	3 – 7	n.a.	29	n.a.
Plaice	2	15	17	n.c.	3 – 6	39	44	n.c.
Sole	2	6	11	n.c.	4 – 7	33	36	n.c.
Megrim	2	n.c.	4	n.a.	3 – 6	n.c.	30	n.a.
Mackerel	2	n.c.	9	9	4 – 8	n.c.	21	21
Herring	1	1	2	2	2+	20	39	20

The age groups to which the estimates apply are that at first entry to the fishery and the main age range subject to exploitation: 1 refers to 1-group fish in their second year of life, 2 to fish in their third year of life, etc.

n.a.: no assessment of this species in this sea area during 1990–4; n.c.: negligible catch of this species in this sea area.

(*Scyliorhinus canicula*) and gurnards. Large numbers of undersized whiting and haddock are discarded in the Malin Sea and Irish Sea. During the 1990s, about half of the total quantity of whiting and haddock taken by trawlers off the west coast of Scotland, and of whiting taken by *Nephrops* trawlers in the Irish Sea, were discarded dead. In 1996, for every tonne of *Nephrops* landed in the Irish Sea by trawlers from Ireland and Northern Ireland, just under half a tonne of whiting (mostly undersized fish of age three and below) were discarded. Studies in 1992–4 indicate that 54 – 67% of plaice caught at ages 1 and 2 in the Irish Sea were discarded, whereas < 5% of fish above the minimum landing size were discarded.

Pelagic fish

Discards of mackerel and horse mackerel in the western area (ICES Sub-areas VI and VII and Divisions VIIa,b,d,e; see *Figure 3.4*) in the early-1980s ranged from 12 to 62 000 t and 1 to 8000 t, respectively. At present, only the Netherlands routinely provides information on mackerel and horse mackerel discards from their trawl fisheries in Sub-areas VI and VII *(Table 5.3)*. Estimates of discards from Spanish fleets operating in the same areas vary from 0.1 – 8.1% for mackerel and 0.2 – 25.7% for horse mackerel. Clearly, it is not possible to apply a discard rate estimated for one fleet to the entire fishery. ICES has recommended a discard sampling programme in the areas most affected.

Herring discard rates are highest in the roe fisheries, although the rates have declined in recent years due to more accurate targeting of the shoals concerned. Despite substantial catches, there are no indications that discarding has caused problems in the herring fishery in Divisions VIa and VIIb,c. The discard rate of herring in the Irish fleet fishing on spawning grounds in the Celtic Sea has been estimated at approximately 5%.

5.5.3 Non-target fish

The levels of discarding of non-target fish in most fisheries are not well recorded. An estimation of the incidental capture of elasmobranchs by the bottom-set gillnet fishery off the south coast of Ireland, extrapolated from observed capture rates and total fishing effort, was 6000 sharks (primarily tope), porbeagle and six-gill shark (*Hexanchus griseus*).

5.5.4 State of fish stocks in Region III

Stock assessment is designed to improve understanding of the dynamics of exploited species and involves the estimation of parameters such as mortality rates (due to fishing and other causes), numbers at age (including recruitment), growth and spawning stock biomass. The state of the main commercially exploited stocks of fish and shellfish in Region III is assessed annually by scientists in the bordering countries, under the co-ordination of the ICES Advisory Committee on Fisheries Management (ACFM). For a number of stock/sub-area combinations, sampling levels are too low for reliable assessments to be made.

Many of the commercial fish stocks within Region III are heavily exploited. Of the 35 stocks assessed, the spawning stocks of thirteen are low compared to their averages over the periods for which data are available. Of these, five stocks show a downward trend and the remainder have been stable over recent years. The stock size and recent trends of nine stocks are unknown. In 1997, seven stocks were considered by ICES to be ‘close to or outside safe biological limits’ (see *Box 5.4*) and, consequently, their status is a matter of concern. These were: cod in Division VIa, whiting in Divisions VIIe-k, hake (northern) in all Divisions, saithe (*Pollachius virens*) in Sub-area VI, plaice in Divisions VIIf,g and sole in Divisions VIIa and VIIf,g. Statistics from 1998 suggest the situation generally has not improved and, for some species, has deteriorated. ICES/ACFM has also recommended significant reductions in the exploitation rates of salmon stocks.

It should be noted that Sub-area VII forms only part of the area of assessment for hake, monkfish and megrim (i.e. the Bay of Biscay – Divisions VIIIa,b – is included in the assessment area) and stock status is not entirely dependent on fishing practices within Region III. Furthermore, fishing effort on demersal species in Sub-areas VI and VII since the early-1990s, particularly by French and Spanish boats, is becoming increasingly focused on areas off the shelf, and thus outside Region III, and it has become difficult to monitor the distribution of effort.

Poor catch statistics and a lack of biological data severely hamper assessment of the horse mackerel stock and there are uncertainties about its current status. Under-reporting and mis-reporting in Division VIa, whereby fish caught in the assessment area are reported as being

Table 5.3 Discard rates for mackerel and horse mackerel in the Dutch trawl fisheries in 1996. Source of data: ICES (1998c).

	Landings (t)	Discards (t)	Total catch (t)	Discard rate (%)
Mackerel*	34 203	10 028	44 231	22.7
Horse mackerel†	115 264	16 870	132 134	12.8

* for ICES Sub-areas VI and VII and Divisions VIIa,b,d,e; † discards are for the western stock of horse mackerel (ICES IIa, IVa, VIa, VIIe,g,h and VIIIa). Landings are from ICES Sub-areas VI and VII (it is assumed that this accounts for majority of Dutch horse mackerel landings).

caught in another, affects the reliability of assessments of the cod fishery.

5.5.5 Benthos

Whilst there is evidence that fishing has immediate effects on benthic communities, there is a general lack of time series data to enable distinctions between the long-term impacts of fishing and those caused by factors such as nutrient enrichment, climatic fluctuations and/or pollution. The influence of natural disturbances such as occasional winter storms must also be considered. The establishment of protected areas, undisturbed by fishing, would assist research into factors regulating benthos communities.

The impact of fishing disturbances on benthic communities and the seabed is very much dependent on fishing intensity, design of the gear and sediment type. It is well known that trawls and dredges towed along the seabed can displace, kill or injure animals that live on the seabed or in the sediment. Large numbers of invertebrates are caught in bottom trawls and discarded. The survival of these discards varies considerably and dead or injured animals provide a food source for benthic scavengers. Repeated disturbance by fishing gear alters benthic communities, causing a reduction in the abundance of long-lived species and an increase in the abundance of short-lived and faster growing species, especially in more stable sediments. In Region III, research into the impacts of fishing on benthos has been carried out mainly in the Irish Sea.

In 1994, up to 25%, 22% and 8% of the total area of the Irish Sea seabed was disturbed by otter trawling, beam trawling and shellfish dredging respectively. More recent statistics suggest that fishing intensity may be even greater in the Irish Sea *Nephrops* grounds which can receive up to five sweeps per year from otter trawls deployed by the Irish fleet alone. This results in a general flattening of the sediment surface due to the collapse and burial of *Nephrops* burrows and filling in of the openings. In deep soft muds, the deep tracks (up to 14 cm) left by the trawl doors can persist for prolonged periods, whereas in fine sediments exposed to tidal currents the marks tend to disappear within 2 – 3 days.

In trials using commercial beam trawls in the North Sea and Irish Sea discard mortality ranged from < 10% for starfish (*Asterias rubens*) and brittlestars (*Ophidtrix fragilis*) to 90% for the bivalve *Arctica atlantica*. Most crustacean species and echinoderms with a hard outer shell suffered intermediate levels of mortality. The greater penetration depth of beam trawls compared to otter trawls can result in higher numbers of discarded, non-target invertebrates. However, differences in the total direct mortality due to otter and beam trawling are apparent only in silty areas where the otter trawl penetrates less deeply. Non-target invertebrates, principally crustaceans and molluscs, comprise only 5% of the total catch in *Nephrops* trawls in the Irish Sea.

In a comparison of the effects of beam trawls and scallop dredges to the south-west of the Isle of Man, both gears modified the benthic community in a similar manner, causing a reduction in the abundance of most epifaunal species. Beam trawls clearly caught and retained a larger biomass and number of species per unit area than the scallop dredge. Over the same type of ground scallop dredges killed a smaller proportion of the by-catch than beam trawls. However, scallop dredging has seriously affected *Modiolus* beds in Strangford Lough. In both deep and shallow parts of the Irish Sea *Nephrops* ground that remain unfished due to the proximity of wrecks, the diversity and biomass of benthic communities is greater than in areas subject to regular disturbance by otter trawls. In these intensively-fished grounds the echinoderm *Brissopsis lyrifera* is now seldom found, although the area was once classified as a *Brissopsis* community. At a previously unfished site in the upper reaches of the Firth of Clyde experimental trawling increased the number of opportunistic species (e.g. small polychaetes) and decreased diversity.

Box 5.4 Safe Biological Limits

Consistent with a precautionary approach, ICES/ACFM establishes limits (reference points) for fishing mortality rates and spawning stock biomass, beyond which the stock is considered to be outside **Safe Biological Limits** and the fishery to be unsustainable. One such reference point is the Minimum Biologically Acceptable Level (MBAL); this is the level of spawning stock below which the probability of poor recruitment increases as spawning stock decreases. MBAL is not a target for management but rather an indicator of a situation which may threaten the future sustainability of the stock. The most recent approach adopted by ICES is based on the precautionary approach and sets precautionary levels for biomass and fishing mortality (B_{pa} and F_{pa}) at which action must be taken to protect the stock. Other criteria which indicate when a stock is outside safe biological limits include the age structure and distribution of the stock (a decrease in stock size may be accompanied by a decrease in the area occupied by the stock) and exploitation rates. A fishery which maintains stock size within a precautionary range (a range within which the probability of reaching any limit is very small) would be expected to be sustainable. It should be noted that the numerical values of the reference points used to define safe biological limits may change as biological characteristics of the stock change, or as new information becomes available.

5.5.6 Birds

Although seabirds can become entangled in nets, there is very little information on the incidence of this phenomenon in Region III. The use of monofilament nets is considered to be the principal cause of death among auks, especially in the seas around Great Britain and Iberia. In the 1970s, drift netting for salmon was implicated in the trapping of large numbers of guillemots and razorbills (mainly juveniles) in Galway Bay (on the Atlantic seaboard). There has been no recent assessment of the nature or extent of this problem. Despite evidence of bird entanglement in drift nets and gillnets on a local scale, over the last twenty-five years there have been population increases in bird species most likely to be affected (i.e. diving birds such as auks, shags and cormorants). In summary, the impact of this source of mortality may not be as important as other controlling factors.

Discards and offal from commercial fishing provide a significant food source for scavenging seabirds. The 7500 t of discards and offal generated by fleets sampled in the Irish Sea alone during 1996 could potentially support an estimated 50 000 birds. Changes in fish stock structure resulting from commercial fishing may have altered the food supply of certain seabirds leading to changes in the composition of some seabird colonies.

5.5.7 Marine mammals

Most reports concerning the entanglement of seals and cetaceans in fishing gears have been anecdotal and the data have been collected opportunistically. Without accurate information on population dynamics and true by-catch levels it is difficult to determine whether this mortality is sustainable by the populations concerned.

A study of Irish trawlers targeting herring in the inshore spawning grounds of the Celtic Sea during the 1994/95 season estimated an annual catch of 60 grey seals. Fixed nets used near major seal colonies are believed to pose a greater threat than towed gears. A total of 51 seals (predominantly juveniles) were taken as by-catch by vessels participating in a seal-fishery interaction study off the west coast of Ireland from 1994 to 1996. Most gillnetting in shallow coastal waters goes unreported because it is carried out by boats < 10 m in length which are not covered by fishing logbook regulations. Thus, extrapolating seal mortality rates from reported fishing effort is extremely difficult. Surveys are currently being carried out to assess the level of seal by-catch to the north-west and south-east of Ireland.

The harbour porpoise appears to be particularly vulnerable to capture in fishing nets. A 1988 IUCN action plan identified the incidental killing of harbour porpoises in gillnets in the eastern North Atlantic as a priority for monitoring.

A programme to assess the marine mammal by-catch of the Irish and UK bottom-set gillnet fisheries (primarily targeting hake) on the Celtic Shelf to the south-west of Great Britain and Ireland was conducted from 1992 to 1994. Forty-three harbour porpoises and four common dolphins (*Delphinus delphis*) were caught, of which 63% were caught in static nets, 29% in tangle nets and the remainder in nets set over wrecks. The total annual by-catch was estimated to be 2200 harbour porpoises (95% confidence interval 900 – 3500) and 200 common dolphins (95% confidence interval 0 – 500). These by-catch estimates represent 6.2% and 0.3% of the estimated Celtic Sea populations of harbour porpoises and common dolphins respectively. Such estimates should be interpreted with caution due to the difficulty in weighting the sample data in relation to the overall distribution of fishing effort. Nevertheless, there is concern about the ability of the harbour porpoise population in the Celtic Sea to sustain an annual by-catch of the magnitude suggested.

Striped and common dolphins, among others, have been taken as by-catch in the albacore tuna (*Thunnus alalunga*) drift net fishery which operates in deep waters of the south-west Celtic Sea. Prior to EC legislation that restricts the total length of gillnet to 2.5 km per vessel, it was estimated that the combined French, UK and Irish fleets caught 1700 common and 2900 striped dolphins annually. It is not possible to determine what percentage of the respective populations these estimates represent as the animals caught may reside and/or breed, at least temporarily, outside Region III. Fishing effort has dropped sharply since then and by-catch rates are also likely to have declined. Nevertheless, EC fisheries ministers voted in June 1998 to introduce a ban on drift net fishing for tuna to come into effect in January 2002.

Post-mortem examinations of 234 harbour porpoises, 138 common dolphins and 50 individuals of ten other species of dolphin and whale stranded on the coasts of England and Wales from 1990 to 1995 identified the cause of death in 76% of the animals. Thirty-eight per cent of the harbour porpoises were killed by entrapment in fishing gear; neonatal starvation, pneumonia and generalised infection accounted for a further 31% of harbour porpoise mortalities. Although there is circumstantial evidence from stranding records of the entanglement of common and white-sided dolphins in pelagic trawl nets, a survey of Irish boats targeting Celtic Sea herring reported no by-catch of cetaceans. Large pelagic trawlers targeting horse mackerel along the shelf edge to the south-west of Ireland do catch small cetaceans – primarily white-sided and common dolphins and long-fin pilot whales (*Globicephala melaena*). The number varies considerably from year to year (eleven in 1992 to 117 in 1994) and the catch rate has been estimated at 1.1 dolphins per 100 hours of towing. However, it is not possible to determine an annual mortality rate due to this fishery. The by-catch of dolphins in the mackerel fisheries to the west of Ireland has not been assessed.

Improved estimates of population sizes and knowledge of stock identity and migration are required to enable more accurate assessments of the impact of by-catches on cetacean populations. The effectiveness of acoustic deterrents in reducing harbour porpoise by-catch in the bottom-set gillnet fishery for hake is currently being investigated.

5.6 Impact of mariculture

The environmental implications of mariculture potentially include:

- effects on the local environment from organic waste and nutrients;
- toxicity and bioaccumulation of persistent chemotherapeutant residues;
- the introduction of pests and diseases through the importation of bivalve molluscs;
- ecological interactions between mariculture operations and co-occurring wild species;
- genetic interaction between escaped farmed salmon and wild salmon populations;
- the transfer of diseases and parasites from farmed to wild fish or *vice versa*; and
- interactions between birds and the large-scale intertidal culture and harvesting of bivalve molluscs.

Accumulation of organic waste beneath salmon farm cages is a common consequence of the salmon farming operations carried out in Region III. The scale of these accumulations, as well as the scale of effects on sediment structure and benthic communities, depends on farm size and local hydrographic conditions (e.g. water exchange and current exposure). Stratified, semi-enclosed water bodies with poor water exchange are most at risk from the adverse effects of mariculture inputs.

At some mariculture sites in Ireland, such as parts of Mulroy Bay (on the Malin Shelf) and Lettercallow Bay (on the Atlantic seaboard), impacts on benthic communities during the 1980s were clearly attributable to mariculture wastes. During this period, a survey of Lettercallow Bay found that the area of enriched sediment in the bay was extensive and that the benthic environment had been considerably altered by intensive mariculture activities. Measures have since been introduced to minimise the impacts of farming in the area. A review of conditions in Mulroy Bay in 1990 showed that sediment impacts around salmon cages were not extensive, although the organic content of the sediments was high (10 – 30%). Finfish farming in the more sheltered parts of Mulroy Bay has been reduced considerably since 1996.

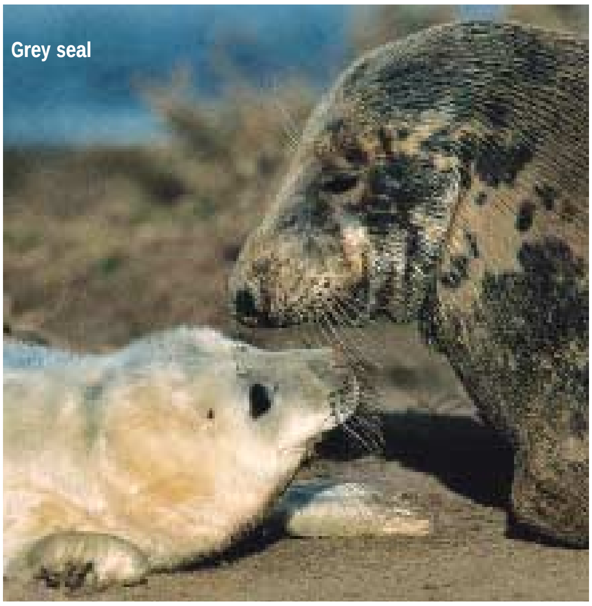

Arctic tern

In some areas with poor flushing characteristics, the deposition of organic detritus beneath suspended mussels has resulted in benthic enrichment. In Bantry Bay mussel longlines have caused significant benthic enrichment in sections of the bay subject to poor water exchange. The impacts include increased organic content of sediments, decreased faunal diversity and the prominence of opportunistic polychaetes. In Glengarriff Harbour, deposits of pseudo-faeces beneath longlines are also prevalent and it is likely that continued expansion of mussel farming in any part of Bantry Bay will lead to further deterioration of the benthic environment. In Killary Harbour (a fjordic inlet), benthic enrichment under mussel rafts is minimal, due to the depth of the site allied to good dispersion, but a large increase in the numbers of starfish has been recorded. This is probably due to accumulations of detached mussels upon which this species feeds.

High intensity shellfish cultivation has potential to alter the nutrient flow within embayments. For example, it has been estimated that in Killary Harbour an annual harvest in excess of 3000 t (live weight of mussels) would result in over 50% of primary production being diverted to mussel production, with possible consequences for the food chain. This warrants further investigation. Clearly, the potential impacts of bivalve culture in poorly flushed embayments subject to high stocking densities need to be carefully assessed prior to developing new installations.

5.6.1 Introduction of non-indigenous species

A literature review conducted by the UK JNCC (Eno, 1996) concluded that some 50 species now known to be present in UK waters ought to be regarded as non-indigenous. Most were introduced accidentally either via shipping or through movements of shellfish for cultivation purposes. The Pacific oyster was a deliberate introduction for aquaculture development purposes and the hard-shelled clam (*Mya arenaria*) may have been deliberately



introduced. Of the 50 species classed as non-indigenous, seventeen are found in waters off the west of Scotland and of these only seven are animal species (the review excluded species < 20 µm in size). Some of the introduced species are now common, for example *Spartina anglica* or common cord grass.

The introduction of other non-indigenous marine molluscs (e.g. abalone and Manila clam (*Ruditapes semidecussata*)), as well as the transfer of molluscs from one area to another, for mariculture purposes includes a risk of transporting competitors, predators, parasites, pests and diseases. Of the total of 126 species imported into the North-east Atlantic region, thirty have been recorded in Irish waters. Whilst some of these species were intentionally introduced for mariculture, the vector of introduction for many is unknown but may have been shipping. Others are known to have been incidental species associated with importations of bivalve molluscs for mariculture.

Until about 1920, American oysters (*Crassostrea virginica*) were regularly imported into Region III. One species introduced in this way is the slipper limpet, *Crepidula fornicata*. Any populations that became temporarily established in Ireland have not survived but it still persists in some UK waters. In the 1920s to 1950s, native oysters from France were imported to restock certain Irish bays and may have been the source of Chinese hat shell (*Calyptraea chinensis*) on the west coast of Ireland.

Following the implementation of EC Directive 91/67/EEC in January 1993, the movement of shellfish species between member countries is, in principle, free of restrictions. The trade in half-grown Pacific oysters from France has resulted in the oyster-gut parasite *Mytilicola orientalis* being introduced to Ireland. In 1993, samples taken in Carlingford Lough on the North Channel, and Dungarvan, Cork Harbour and Oysterhaven on the Celtic Sea, revealed the presence of this organism. As far as is known, it has become established only in Dungarvan harbour. *M. orientalis* may harm Pacific oysters and other molluscan species in areas where it becomes abundant. Finally, a number of phytoplankton species have been recorded in importations of Pacific oyster, including cysts of toxin-producing dinoflagellates.

One of the best documented cases of damage to native species through international transfers is that caused by a protistan *Bonamia ostrea*. Bonamiasis is a disease of flat oysters which was first described in Brittany (France) in 1979 where it caused a high level of mortality. It is believed that the disease was originally introduced through an illegal consignment of oysters to the south-west of Ireland in the early 1980s; it was first diagnosed in oysters in Cork Harbour in 1987 and subsequently in Clew Bay and Galway Bay. It has now become widespread in flat oyster populations. Losses due to the disease may be 80% or more.

The ICES Code of Practice for the Introductions and Transfers of Marine Organisms, issued in 1995, has been implemented with a view to preventing problems resulting from species introductions.

5.6.2 Interactions with birds

Little information is currently available on the extent to which mariculture operations in Region III have interfered with the feeding or breeding of seabirds and waterfowl; however, predation by eiders (*Somateria mollissima*) is a very significant problem in subtidal rope cultivation of mussels. The feeding and roosting grounds for birds could be disturbed and the amount and type of their food supply altered by, for example, the growing and harvesting of clams and oysters in intertidal areas of bays and estuaries. Mariculture zoning policies that will effectively protect important intertidal bird habitats are necessary.

5.6.3 Genetic interactions

Concerns associated with genetic interactions between wild and reared salmon include potential for gradual replacement of wild stocks by farmed salmon, genetic alteration of native populations, possible reduction in local adaptation and reduction in fitness. Occasionally, commercial catches in salmon farming areas on the Scottish west coast have contained up to 20% or more of escapees. In contrast, reared salmon are infrequent (generally < 1%) in east coast Scottish fisheries distant from salmon farming sites. At least 7% of spawnings in certain Scottish rivers are attributed to farmed female salmon.

Examination of 52% of the declared Irish salmon catch between 1991 and 1997 showed that escapees ranged from 0.06% of total catch in the mid-west to 0.47% in the south-west. Many of these fish do not enter rivers and even less will breed. In two rivers in the north-west adjacent to sea cages from which escapes occurred in 1992, farm salmon have been shown to breed with wild salmon. Only a small proportion of adults bred successfully in these rivers but up to 18% of juveniles sampled in the rivers were of maternal farm parentage and these survived to at least the 1+ summer stage. As survival at sea and homing to the natal river of hybrid fish may be impaired, the long-term change in the genetic make-up of the associated wild populations is uncertain. As many incidents go unreported the full extent of the problem is unknown but, in one reported incident in 1997, approximately 40 000 fish escaped.

5.6.4 Diseases and parasites

The occurrence and spread of infectious diseases in farmed fish is due to the high densities at which the fish are held. The agents (bacteria, viruses and parasites) causing these diseases are ubiquitous in the environment and are capable of creating serious diseases in both farmed and wild fish. Disease transmission between farmed fish and wild fish is most likely to occur at farm sites or by the escape of farmed fish. No information on the trends or current incidences of diseases in mariculture within Region III was available for this assessment.

The greatest controversy regarding possible disease interactions between farmed and wild fish currently concerns sea lice. Sea lice are copepod ectoparasites of fish of which the principal species associated with salmonid culture is *Lepeophtheirus salmonis*, a salmonid-specific species common on both wild and farmed fish. Most marine salmon farms are liable to infestation, relayed initially from local wild salmon. The greatest problem arises from the reinfection which often occurs within farm stocks. Heavy infection on farmed salmon may result, leading to tissue damage and secondary infection which, if uncontrolled, will cause heavy losses. Since the late 1980s, it has been suggested that infection of post-smolt sea trout (*Salmo trutta*) by sea lice from fish farms has caused serious disease problems in the west of Ireland, Scotland and Norway, leading to the death of sea trout at sea and the early return of post-smolts to freshwater. The collapse of sea trout populations in the west of Ireland (Galway Bay to Clew Bay) and the north-west of Scotland coincide with areas of intensive marine salmon farming and there is a widespread perception that increased infection by sea lice from salmon farms is an important factor. Despite considerable research, there are still many uncertainties regarding the transmission of sea lice between farmed and wild salmonids and studies to resolve the issue are ongoing. Meanwhile, improved husbandry, farm and area management, combined with the use of chemical treatments, are being used to reduce sea lice infections among farmed stocks.

5.6.5 Chemical residues

Chemicals are used only in finfish cultivation and can be grouped into three broad categories: antibiotics which are administered orally or by injection, pesticides such as dichlorvos which are applied externally in bath form, and structural antifoulants such as copper and, in the past, TBT. A priority is to avoid residues in the tissues of harvested fish.

Broad spectrum antibiotics such as oxytetracycline and oxolinic acid have been fed to cultured salmonids for the treatment of furunculosis and vibriosis. The introduction of effective vaccines has reduced amounts used to only a few per cent of the usage a decade ago. These two antibiotics have relatively short tissue residence times and residues in harvested fish are generally avoided through use of a suitable withdrawal period prior to harvesting. Whilst there has been speculation that persistence of oxytetracycline residues in sediments beneath farm cages might promote antibiotic resistance in bacteria, the evidence suggests that any such residues or resistance are most likely to be confined to the area impacted by waste from the cages.

Although not currently licensed for use in mariculture, the pesticide ivermectin (22,23-dihydroavermectin B1a) is incorporated into the feed as a treatment against sea lice at some farms; in Scotland this is done under veterinary prescription. Monitoring of ivermectin in the flesh of Irish farmed salmon in 1995/96 showed that of 150 samples tested 94% contained levels below detection (< 2 µg/kg ww) and the remaining 6% had residues of 2 – 14 µg/kg ww. The latter figure is marginally less than the Maximum Residue Limit of 15 µg/kg applied to the fatty tissues of farmed animals. This suggests that the withdrawal period applied in Ireland is sufficient to avoid unacceptable residues in the flesh of harvested salmon. Only a small proportion (3%) of UK farmed salmon tested in 1995 showed detectable concentrations of ivermectin and none of the 415 and 279 samples tested in 1996 and 1997 respectively had detectable concentrations.

The organophosphate dichlorvos (DDVP) (licensed for example as Nuvan or Aquaguard), a therapeutic agent once commonly applied by bath to control sea lice infestations, is less used since preparations containing hydrogen peroxide, azamethiphos (another organophosphate) and cypermethrin (a synthetic pyrethroid) have become available. Dichlorvos is categorised as a List 1 substance under the Dangerous Substances Directive (76/464/EEC). Although there are few studies on DDVP accumulation in salmonids, significant dichlorvos residues are not expected in the flesh of treated fish because organophosphates do not tend to bioaccumulate. Residues may, however, occur in sea water. In 1998, only one sample of sea water (out of 38) from the vicinity of farms in Beirtreach Buí Bay (on the Atlantic seaboard) actively using DDVP was found to have concentrations above the detection limit (20 ng/l). On the other hand studies in Scottish sea lochs have found depression of acetylcholinesterase activity in wild organisms (lobsters and mussels) up to several hundred metres from cages where dichlorvos was used. The potential environmental effects of the solvent, i.e. di-*n*-butyl phthalate (DBP), which makes up 50% of commercial dichlorvos formulations has received less attention. It is listed as a priority pollutant in the United States and Canada and as a suspected oestrogen-mimicking compound. Although it is reported that DBP is readily metabolised by fish, should use of dichlorvos continue confirmatory evidence of its effects would be advisable.

Based on its physico-chemical properties ivermectin has potential to persist in sediments, particularly fine-grained sediments at sheltered sites. Recent data from a farm in Galway Bay indicate that ivermectin is detectable in sediments adjacent to the farm at concentrations up to 6.8 µg/kg and to a depth of 9 cm. Ivermectin demonstrates relatively high toxicity to polychaetes and crustaceans and there is a possibility of adverse effects to biota which ingest waste food pellets or faeces containing this compound. Infaunal polychaetes have been affected by deposition rates of 78 – 780 mg ivermectin/m^2. More information is required to adequately assess the risks to biota that may be in contact with sediments, or indeed sea water, contaminated with ivermectin.

The use of copper, alone or in combination with other biocides, is the preferred antifouling agent for marine cages since the use of TBT-based paints was prohibited. Although copper poses less of an environmental hazard than TBT, cultured salmon within treated cages and adjacent wild organisms must be subject to a degree of copper exposure. Data from salmonid farms in Scotland show that copper accumulates to very high concentrations in fine sediments in the vicinity of farms using copper-based paints. Concentrations were consistently in breach of the sediment quality criteria proposed by the Scottish Environmental Protection Agency. Elevated concentrations of zinc were also found at the sites and these were linked to the large amounts of this metal used in galvanised cage structures and fish feed. Shellfish collected at Irish sites shared by salmon farms, i.e. Kilkieran Bay, Clew Bay, Killary Harbour and Mulroy Bay, have not shown increases in tissue concentrations of copper. In general there are insufficient data to assess residues of, and exposures to, copper resulting from the use of copper-based antifoulants.

5.7 Impact of nutrient enrichment

Elevated concentrations of nutrients in fresh and marine waters can result in increased productivity, and associated changes in nutrient ratios, and this can be associated with changes in community structure. When such changes occur, especially when they are persistent, the term eutrophication is used to describe the full sequence of events. Although an increase in nutrient concentrations is regarded by some as a symptom of eutrophication, in this report such a change is regarded only as a warning of potential eutrophication; the key issue is whether there are also persistent, undesirable biological changes.

The development of nuisance levels of algae may also be regarded as a product of anthropogenic activity. The most commonly cited examples are the periodic development of blooms of flagellate *Phaeocystis* spp. which secrete a mucus-like substance that leads to foam on the sea surface, seasonal increases in macro-algae or incidence of shellfish poisoning due to the presence of toxin-producing dinoflagelletes. However, in most cases such events are a normal feature of marine production. For example, blooms of toxin-producing dinoflagellates are a regular occurrence in bays in the south-west of Ireland and can cause shellfisheries to be closed for extended periods. Research has shown that the incidence of dinoflagellates is related entirely to the unusual hydrodynamics of the area.

The assessment of nutrient data in Section 4.9 concludes that eutrophication, i.e. anthropogenically induced increases in nutrient concentrations associated with undesirable biological changes, is not a feature of the open waters off Ireland or Scotland (i.e. on the Malin Shelf and Celtic Sea). The assessment further concludes that it is not a feature of most of the Irish Sea. The potential for marine eutrophication nevertheless exists and detailed studies are being conducted to assess whether any local areas actually suffer eutrophication or indeed are at risk of becoming eutrophic. So far as the UK is concerned, no definitive conclusions have yet been reached but the early indications are that the Mersey Estuary/Liverpool Bay area and Belfast Lough may be showing signs of eutrophication and reductions in nutrient inputs are probably required.

Formal assessment of the situation in Ireland is ongoing and *Table 5.4* summarises the conclusions reached thus far. Even in the areas listed, where eutrophic conditions are considered to occur, only part of the area is generally affected and the effects occur only for limited periods.

The situation in Cork Harbour provides a good example of the difficulties that are often faced in distinguishing between the effects of organic carbon inputs and the effects of increased organic carbon in the form of decaying algal growth. There is no doubt that water and sediment quality in inner Cork Harbour is impaired. High BOD levels, impoverished benthic fauna and depressed oxygen concentrations in bottom waters are readily discernible. The area is affected by increasing organic

Table 5.4 Irish estuaries and bays currently considered to display evidence of eutrophic conditions.

Occasional	Regular	Persistent
Upper Boyne Estuary	Upper Slaney Estuary	Broadmeadow Estuary
Castletown Estuary	Upper Bandon Estuary	Upper Cork Harbour
Lower Cork Harbour	Upper Suir Estuary	
Upper Barrow Estuary	Lady's Island Lake	
Inner Dublin Bay		

loads discharged in the harbour, but high nutrient inputs are also evident. Recent surveys show that algal production may be significantly light-limited and available nutrients may not always be efficiently converted into algal biomass. However, observations suggest that under certain conditions high chlorophyll levels can develop in the upper harbour. Wide variations recorded in the daytime levels of dissolved oxygen, from significant deoxygenation to supersaturated conditions, suggest that inner Cork Harbour is subject to eutrophication. In parts of inner Dublin Bay, which receives substantial discharges of sewage, large amounts of macro-algae have developed in recent years. This is the only non-estuarine area in Ireland showing signs of localised eutrophication.

5.8 Impacts of tourism and recreation

Tourism has many advantages for the economies of coastal communities in Region III, particularly in the more remote areas where employment opportunities are limited. However, in some coastal areas, large seasonal influxes of visitors, together with construction and development to provide accommodation, recreational facilities and improved access to the shore, are increasing pressures on coastal ecosystems. In some of the more picturesque areas, physical development is changing coastal landscapes and eroding the aesthetic values that are most influential in attracting visitors from home and abroad (see also Section 3.4).

There are still many kilometres of undeveloped coastline with little or no impact from recreational activities although these tend to occur in more remote areas, such as the west coasts of Scotland and Ireland. Elsewhere numerous habitats have been damaged or disturbed by an excessive throughput of visitors (e.g. Colwyn Bay to Corsewall Point), motorcycles and four-wheel drive vehicles and the construction of access roads, car parks and other visitor facilities. In many localities heavy pedestrian traffic is eroding footpaths (the north coast of Cornwall in particular) and dune systems, causing loss of vegetation, reductions in biodiversity and disturbance to breeding birds.

Among the Areas of Scientific Interest recently surveyed in four Irish coastal counties, 37% had been significantly damaged and a further 16% were under immediate threat; the most frequently cited cause was recreation pressure. Recreational activity also gives rise to an estimated 18% of the litter deposited on Ireland's beaches. In some parts of Ireland recreational developments such as golf courses have resulted in ecological damage to sites of international conservation value and the cumulative pressures from vehicles, pedestrians and caravan use have caused serious deterioration of vegetation and increased risk to the stability of dune systems.

On more easily accessible and frequented shores, human presence and recreational activities have disturbed roosting and nesting seabirds. In Bannow Bay (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. On the Isle of Man, disturbance by dog-walkers is considered to be a significant factor in reducing breeding success in a nationally important colony of little terns.

In response to the pressures of coastal tourism, policies and measures to improve protection of coastal environments are being introduced in a number of areas. Much of the coastline of south-west England between Land's End and Kenfig has been designated as a Tourist Protection Area. More sustainable forms of tourism, such as the extension of farm businesses to include holiday accommodation and the staging of events at inland locations, are actively encouraged. On coasts of the north-eastern Irish Sea, policies to promote sustainable recreation and to redevelop facilities within existing resorts and urban areas have been introduced. The policies discourage new developments on the open coast and in undeveloped estuarine areas. On the west coast of Scotland, codes of practice are being developed to reduce disturbances to birds, seals and cetaceans caused by the growing number of animal watchers. In Ireland the government is working with local authorities to introduce more integrated forms of coastal zone management and a number of coastal counties have prepared management plans that impose tighter restrictions on coastal development.

5.9 Impact of sand and gravel extraction

The main areas from which seabed aggregates have recently been extracted within Region III are the Bristol Channel, north-eastern Irish Sea and sandbanks off the south-east and south-west coasts of Ireland. Maërl is also licensed for extraction in Bantry Bay in the south-west of Ireland (Section 3.9). No information is currently available on the environmental effects of extraction at these specific sites.

Aggregate extraction commonly involves the use of suction dredgers which physically alter the seabed leaving long shallow tracks or large depressions up to several meters deep. The impacts on marine flora and fauna depend on the characteristics of the individual area. If an area is used by spawning fish, which require a stable bed, then disruption of egg laying can occur. Short- or long-term changes in sediment deposition can occur as well as changes in the composition and abundance of benthic species. Studies carried out after aggregate extraction at a site off the east coast of England showed an immediate reduction of $> 40\%$ in the number of benthic species and an 85% reduction in abundance. However, a limited increase in the number of species during the seven month post-dredging period indicated some recolonisation had occurred.

In Ireland, occasional conflicts between aggregate extraction and fishing interests have prompted an EU-funded study to update the inventory of sand, gravel and maërl resources and to examine the implications of extraction for coastal erosion and fisheries. The findings will guide future decisions on expansion of the industry. In the UK, from mid-1999 new aggregate extraction operations will be subject to a formal statutory process.

5.10 Impact of dredging

The effects of the disposal of dredged material are usually confined to the smothering of indigenous sediments and benthos. However, if the material has been contaminated by inputs to the harbours or navigation channels dredged, it may adversely affect animals that survive the smothering effect as well as surrounding communities. In order to guard against this, the national authorities require dredged materials to be analysed for contaminants prior to disposal. In the rare event that contaminant levels are considered excessive, deposition at sea is not allowed and alternative disposal means must be sought. Although many dredged sediments contain measurable concentrations (generally < 1 mg/kg dw) of TBT (see Section 5.14.4) in the surface layer, there have been few instances where sea disposal has been prohibited for this reason alone. Both in Ireland and the UK it is common practice to require applications for dredged material disposal licences to explain what alternative disposal means have been considered. This has led to the ‘beneficial’ use of dredged material for beach recharge, land claim and reclaim, sometimes with additional nature conservation benefits.

Investigations are carried out by the appropriate national authorities to ensure that disposal sites are selected to minimise adverse effects and to confirm the effects of disposal are within acceptable limits. As a consequence most large disposal operations are subject to some form of monitoring. In Ireland only two disposal sites are considered to merit investigation; the Dublin port disposal site and a site off Cork Harbour. The Dublin port disposal site is adjacent to the now disused Howth sewage sludge disposal site. It is therefore difficult to establish which source contributes what, but in any event there is little evidence of significant metal contamination. At the other site off Cork Harbour the seabed is characterised by mobile sediment, rippled sands and accumulation of either sediment or contaminants is considered unlikely. In Scotland the only site found to show elevated contaminant levels, probably in part related to disposal of sediments influenced by past industrial activity, is one used for the disposal of Clyde Estuary dredgings. The level of contamination in dredged materials from the Mersey Estuary and certain south Wales’ ports also presents disposal difficulties. The effects of dispersed fine material on benthic habitats can be an issue and at least one disposal site (the Skomer Island site near Milford Haven) has been changed as a result.

5.11 Impact of coastal protection and land reclamation

The creation of artificial structures to prevent flooding alters the habitat of the immediate coastline. Substantial lengths of coast in both Ireland and the UK are protected by some form of sea defence works. The area inland of the sea wall is often significantly altered. It may for example cease to be a wetland suitable for wildfowl or seabirds and may be used for agricultural purposes or be developed for industrial or housing purposes. Large areas along the Clyde, Ribble and Mersey estuaries, the Belfast and Strangford loughs and the Liffey Estuary have been affected in this way.

Structures such as groynes, which are designed to minimise erosion, often provide shelter to which intertidal marine species can attach themselves and in this limited sense can be regarded as beneficial. However, unless very carefully engineered and sited they are often the indirect cause of enhanced erosion at unprotected adjacent sites. Recently trials have been made to reinforce the existing natural environment using geotextiles, specially planted vegetation and even fences to slow the movement of sand dunes. Some of these have been very successful and account now needs to be taken of the factors that promote this success.

Almost by definition coastal erosion is most likely to affect areas that are inherently unstable and exhibit impoverished fauna. It is also a process that is likely to be exacerbated by climate change and sea level rise. The need to protect areas liable to erosion should therefore take account of the cost-effectiveness of the proposed measure as well as the need to protect the habitat at risk and human interests, including those in the immediate landward area.

5.12 **Impact of offshore activities**

The discovery of offshore deposits of oil and gas in Region II (the Greater North Sea) prompted the search for similar deposits in Region III. The seismic surveys undertaken use airguns to generate the acoustic energy required. These reduce the impact on fish and the low frequency sound range is thought to be beyond the hearing range of seals. Studies of the possible effects on cetaceans have thus far proved inconclusive.

Exploratory drilling to establish the presence of commercial oil or gas deposits has taken place in many parts of Region III (see Section 3.11) and is strictly controlled especially in areas considered to be at particular risk. Legislation in response to EC Directive 97/11/EC requires an Environmental Case to be made for each stage of any development and in particularly sensitive areas surveys are required after each stage.

Exploitation drilling is essentially the same as exploratory drilling and is subject to the same controls, the main difference being that more wells are usually drilled at a single site. Oil-based drilling muds have not been extensively used for wells drilled within Region III. Once operational, production facilities are subject to national authority controls which, in common with those applied to drilling operations, accord with OSPAR guidelines. Monitoring, also following OSPAR guidelines, is undertaken to check for adverse effects. To date detailed results are not available. Although there are fears over the consequences of accidental releases of oil, thus far most discoveries have been of gas and no blow-outs have occurred. The accidental release of chemicals used operationally or of produced oil or gas condensate have also, thus far, been marginal and have had no significant consequences.

5.13 **Impact of shipping**

Some of the environmental impacts related to shipping are referred to elsewhere in this report. These include contamination by TBT-based antifoulants (Sections 4.5, 5.6.5 and 5.14.4) and the disposal of dredged material (Section 3.10). Sediments in a number of the larger ports (e.g. Dublin and Port Talbot) are contaminated with mineral ores lost during loading and unloading operations. In addition, a proportion of the petroleum hydrocarbons associated with a reduction of Scope for Growth in mussels (Section 5.14.5) is likely to be derived from operational losses of fuels and oils by commercial vessels, including fishing vessels. On some beaches, particularly those exposed to the prevailing westerly winds, a significant fraction of the debris and litter, including plastics and netting, is related to shipping and fishing (Section 5.15). The introduction of non-indigenous marine species by ships, in ballast waters or by hull-fouling (Section 5.3) could have serious ecological, and possibly human health, implications. Eight of the twenty-four non-indigenous species found in Cork Harbour are believed to have been introduced in this way. None of the above impacts attracts the degree of publicity, or generates the level of public concern, that accompanies major shipping accidents involving loss of cargoes, especially oil. Considering the heavy shipping traffic through Region III (Section 3.12), the frequency of such incidents is extremely low (Section 3.13). Despite the immediate effects of oil spills on seabirds and impacted shores, and the high costs of oil removal, in most cases the damage is relatively short-lived.

By far the most serious oil spill in Region III occurred in Milford Haven (Bristol Channel) in February 1996 when the Sea Empress released more than half of its 131 000 t of crude oil and 480 t of heavy fuel oil. This spill, despite being very large, had remarkably little lasting effect on species other than birds. Aerial spraying of dispersants (446 t) during ebb tides ensured that much of the dispersed oil was prevented from reaching the shore. The dispersed oil did not accumulate in offshore sediments. Nevertheless the spill caused extensive oiling of seabirds, especially scoter ducks (*Melanitta nigra*), and heavy mortalities of bivalve molluscs and other invertebrates in Carmarthen Bay. There were marked reductions in the distribution and abundance of subtidal crustaceans associated with the oiling of sediments around Skomer Island and within Milford Haven. No effects were detected among benthic fauna or adult fish further offshore and the major commercial shellfish beds in the Burry Inlet and Three Rivers area were unaffected. The use of dispersants is thought to have prevented further ecological damage and to have expedited recovery. Although fishing in the affected area was prohibited immediately to protect consumers, conditions improved sooner than expected and it was possible to reopen the finfisheries within three months; all fishery restrictions were removed within about nineteen months.

5.14 **Impact of contaminants**

5.14.1 Introduction

This section summarises existing information on the actual or potential effects of contaminants, other than nutrients, on organisms inhabiting coastal and offshore areas of Region III. Only in a few cases have biological effects been measured directly, i.e. in terms of responses by individuals, populations or communities, and with the possible exception of imposex (see Section 5.14.4) it is difficult to provide incontrovertible evidence that one or more specific contaminant is responsible for the effects observed. Thus, in many cases only the existence of effects and their probable causes can be noted, highlighting the need for management action to further reduce inputs and/or additional research.

5.14.2 Metals

Recent monitoring programmes, conducted in accordance with guidelines developed under the OSPAR Joint Assessment and Monitoring Programme, focus on a small group of heavy metals i.e. cadmium, mercury, lead, copper and zinc, selected for their intrinsic toxicities and/or potential to accumulate in biological tissues. All metals occur naturally and are transported, redistributed and recycled by natural processes. Their status as contaminants stems from their widespread use in industry, their occurrence in waste materials and the tendency of activities such as mining, smelting and construction to augment releases of these metals to water and the atmosphere.

Available information on the current (until around 1997) environmental distributions of the five metals is summarised in Section 4.4. This shows that, in general, the main repositories of metal contaminants are fine-grained sediments, particularly in bays and estuaries close to densely populated and industrialised areas.

The biological significance of metals can be assessed either by comparing existing concentrations to existing standards of environmental quality (EQSs) or food safety, or to the expected ‘background’ levels, as appropriate. Where standards do not exist, concentrations have been assessed in relation to relevant toxicological data. The concentrations of cadmium, mercury, lead, copper and zinc in both sea water and sediments sampled in Region III during the 1990s are well within existing relevant standards and below concentrations likely to be harmful to marine life. At most locations the concentrations are within the expected ‘background’ ranges, i.e. those related to the normal geochemistry of the areas concerned. Concentrations in fish and shellfish for human consumption are within existing food safety standards.

In the past, concentrations of mercury in fish from Liverpool and Morecambe Bays were close to the agreed EQS limit but have now declined. Mercury is bioaccumulated in marine food chains and high concentrations have been found in marine mammals worldwide. Although much of this mercury is bound in a non-toxic complex with selenium, it has been estimated that the limit of tolerance for mercury in mammalian hepatic tissue is within the range 100 – 400 mg/kg ww. The levels of mercury in the livers of seals, porpoises and dolphins in the northern Irish Sea sometimes exceed 100 mg/kg ww and the toxicological significance of this should be established.

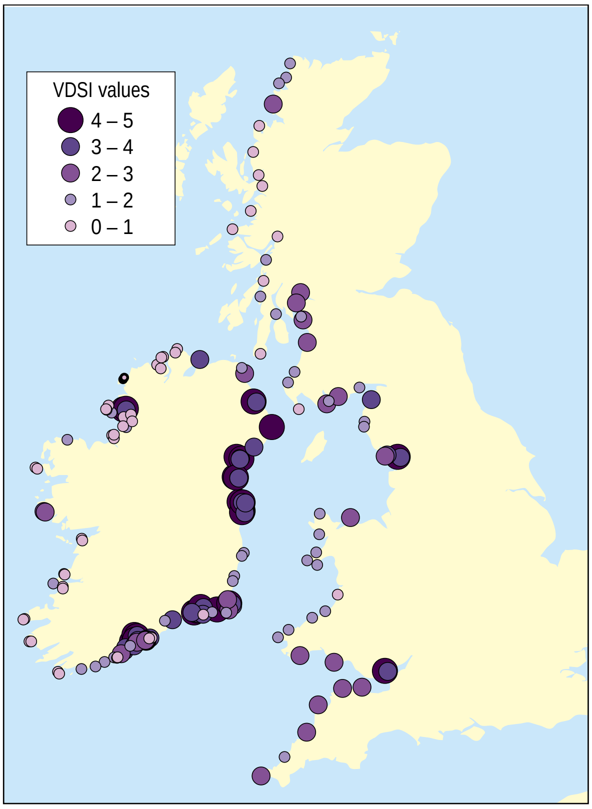
5.14.3 Polychlorinated biphenyls

The environmental concentrations of PCBs in Region III are reviewed in Section 4.5. These organochlorine compounds are ubiquitous in the marine environment but concentrations measured in sea water and sediments at coastal and offshore sites are, with a few localised exceptions, very low and within the ranges found throughout the North-east Atlantic. Various organic contaminants may induce production of the enzyme ethoxyresorufin-*O*-deethylase (EROD) in fish liver and the extent of this activity can be used to measure the degree of exposure to a range of compounds including PCBs. EROD activity has been measured in the livers of plaice collected along a transect extending from the inner Clyde Sea to the Solway Firth (south-west Scotland). The greatest activity was found in plaice from the sewage sludge disposal site at Garroch Head and near to industrial centres at Hunterston and Irvine Bay. High EROD activity generally coincided with high PCB levels in the sediments. However, separate studies using tissue culture techniques concluded that most of the toxicity associated with Clyde Sea sediments is due to PAHs.

Polychlorinated biphenyls are accumulated by marine organisms, especially within the fatty tissues of piscivorous birds and marine mammals, in which concentrations may occasionally achieve levels of potential toxicological significance. During the 1980s, abnormally high concentrations of PCBs were found in the eggs and adipose tissues of seabirds at colonies on the south Malin Shelf and to the south of the Irish Sea. It was surmised that the concentrations were sufficiently high in some cases to reduce hatching success and that occasional mass mortalities of seabirds, such as occurred in the Irish sea in 1969, may have resulted from a combination of food shortages and PCB poisoning. However, PCB levels in seabirds at the previously most contaminated colonies have now fallen substantially and there has been no long-term effect on populations of the species concerned.

In contrast, anomalously high concentrations of PCBs were found during the early 1990s in cetaceans from Cardigan Bay in the southern Irish Sea and in otters from south-west Ireland. The origins and toxicological significance of these residues are unknown. However, prior to death some of the otters with high PCB body burdens were reported to have behaved in a manner suggestive of organochlorine poisoning. Thus, it is possible that in these areas PCBs are more available than elsewhere, perhaps from reservoirs stored in sediments, recycling in the food

Figure 5.6 **VDSI values for dogwhelks sampled in coastal waters of Region III. Source of data: Harding *et al*. (1998).**



chain or from localised inputs from land or the atmosphere. Further investigation is necessary to isolate the sources and processes involved.

5.14.4 Tributyltin

Surveys conducted around Ireland and the western coasts of Great Britain during 1997 indicate that ten years after the introduction of TBT restrictions biological effects are still evident at all but the most remote coastal sites, although often at a lower level. The effect most frequently encountered is the acquisition of male characteristics by females of certain gastropod molluscs – a phenomenon known as Imposex. Two indices of imposex in dogwhelks, the relative penis size index (RPSI) and the vas deferens sequence index (VDSI), have been used. The VDSI is thought to give a better indication of the status of dogwhelk populations because it reflects the number of sterile females present. *Figure 5.6* shows VDSI values from an extensive survey around the coasts of the region in 1997. Values > 4 are considered sufficiently high to threaten reproductive output.

In the early 1980s, a significant reduction in the settlement of flame shell (*Limaria hians*) larvae in Mulroy Bay (south Malin Shelf) was associated with mean VDSI values in dogwhelks of 4.4. The use of TBT by the local mariculture industry ceased in 1985 and by 1990 there was no longer any evidence of effects on flame shells *(Figure 5.7)*.

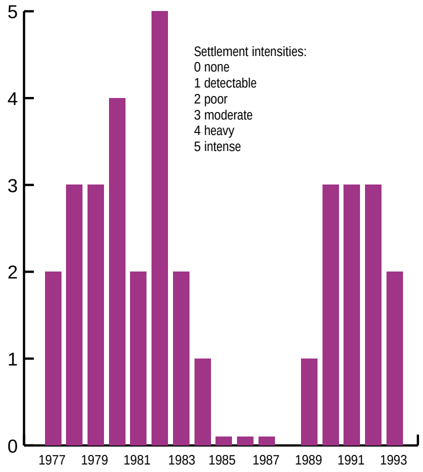
Concentrations of organotins (22 – 209 µg/kg) have also been found in the fatty tissues of marine mammals in Region III but the biological significance of these residues is unknown.

5.14.5 Combined effects of contaminants

Scope for Growth (SFG) in mussels is a sensitive indicator of general water quality and contaminant concentrations. It quantifies the extent to which growth potential is reduced in surveyed areas compared to clean reference sites. Substances contributing to reduced SFG can be identified through a quantitative toxicological interpretation of tissue contaminant levels. Spatial differences in SFG at sites around the Irish Sea, remote from sewage and industrial discharges, were assessed in summer 1996 and 1997 in comparison with reference sites off the coasts of Scotland and Cornwall.

Whereas high SFG values were recorded along the coasts of Wales and Scotland, they were significantly depressed in the Mersey/Liverpool Bay area, around the Lancashire coast and along the east coast of Ireland south of Belfast Lough. This suggests a pattern of reduced water quality consistent with the prevailing hydrodynamics of the Irish Sea and centres of urban and industrial development around Liverpool Bay and Dublin Bay. The concentrations of petroleum hydrocarbons in mussel tissues were sufficiently high to explain much of the decline in SFG. However, on both sides of the Irish Sea the decline was also associated with a general increase in tissue levels of contaminants including PAHs,

Figure 5.7 **Relative settlement intensities of flame shells in Mulroy Bay. Source of data: Minchin (1995).**



TBT, total DDT, dieldrin, γ-HCH, PCBs and certain metals (cadmium, selenium, silver and lead). Some of these contaminants were particularly elevated (i.e. > 10 times higher than background or detection limits) in the coastal margins of Liverpool Bay, Morecambe Bay and Dublin Bay. Nevertheless, the total reduction in SFG at many sites could not be explained only by the presence of contaminants, suggesting 'unknown toxicants' may be implicated. The reduced SFG in mussels from Llanddwyn Bay on Anglesey may be related to locally elevated levels of dieldrin and HCH of unknown origin.

5.14.6 Other substances

There has been some speculation that concentrations of toxaphene in fish (see Section 4.5) might have consequences for the health of consumers who regularly eat fish from these waters. However, there is doubt concerning the applicability and reliability of the food safety standards that gave rise to this concern and standards for toxaphene in fish are presently under review within the EU. In view of the potentially adverse effects of certain PAHs on marine organisms the high concentrations of total PAHs reported in sediments in Dublin and Cork harbours warrant further study, including elucidation of the specific compounds present and their sources.

5.15 Impact of marine litter

Marine litter is derived from both land-based and marine sources and it has been estimated that 50 – 80% is derived from land. Marine sources include offshore structures, shipping and the fishing industry including mariculture operations. Land-based sources include refuse disposal sites on or close to shorelines, sewage-derived debris plus items discarded by tourists on beaches and the coastline generally. The presence of litter is unsightly and the material may impact upon several areas before reaching its final sink. Although there are many different forms of litter much is plastic and drink containers are a growing component. There have been a number of attempts to quantify the scale of the litter problem in UK waters and on the coastlines of both Ireland and the UK. One such study was undertaken recently in the Minch off the Scottish west coast. The results are summarised in *Table 5.5* and suggest that quantities of litter on beaches in the area have increased over the last ten years and that the main sources were fishing, shipping, aquaculture and tipping. The MARPOL 73/78 Convention prohibits the disposal of garbage by shipping within three miles of the coast and plastic items anywhere, but its efficacy is unknown.

There has apparently not been any concerted attempt to quantify the ecological impact of litter in Region III. Thus, the effects of marine litter can only be considered in terms of the occasional positive recorded incident from within the area and known effects as reported from other areas.

Seabirds are particularly susceptible to the ingestion of litter and may pass it on to their chicks by regurgitation. As a consequence the birds may suffer acute physical injury or obstruction of their alimentary canal systems. Larger pieces of marine litter may entangle marine mammals, seabirds and some species of fish and mobile shellfish such as crabs. The consequence may be drowning or slow starvation or simply impaired foraging ability due to the material affecting the animal's ability to move. In areas where large amounts of marine litter are deposited smothering of the native species may occur, although unless anoxic conditions develop the material itself may form a substrate suitable for more tolerant species.

In some cases the deposition of marine litter on beaches may be of a sufficient problem that the local authorities find it necessary to remove it in order to maintain high visual or olfactory beach standards. Where mechanical removal methods are used this process will disturb the beach material and all plants and animals. The financial cost is considerable; for example the cost of keeping the two beaches clear of litter at Weston-super-Mare on the south coast of the Bristol Channel is put at around £100 000 annually.

5.16 Impact of munitions disposal

A site in the Firth of Clyde was used for the disposal of industrial wastes associated with explosive manufacture but this practice ceased in 1989 following the OSPAR Decision to ban the disposal of industrial wastes at sea.

Three other sites in Region III were used for the disposal of military munitions mainly during or immediately after the two World Wars. The Inner Sound and Sound of Mull were both used for disposal of small arms and conventional munitions. A grab sampler and underwater TV survey in the Sound of Mull found no traces of any munitions.

The area known as the Beaufort's Dyke was used to dispose of a variety of munitions including phosphorus flares and smoke bombs and rockets containing phosgene gas (see also Section 4.2.2). The majority of the material was dumped by UK military authorities but the area was also used to dispose of some munitions from Ireland. Although the UK and Irish authorities have agreed to draw up as comprehensive a list as possible, given that much of the material was dumped soon after the two World Wars and that many records were routinely destroyed, the list is unlikely ever to be complete.

The Beaufort's Dyke is more than 50 km long and 3.5 km wide at its broadest point. It is over 200 m deep, with the deepest parts exceeding 300 m, and provided the materials dumped are left undisturbed they should not present a hazard to either marine life or human health. There have, however, been instances of phosphorus devices being trawled up by fishing vessels and in 1995 considerable numbers of incendiary devices were found on the Scottish coastline with smaller numbers on the coast of Northern Ireland and Ireland. This led to surveys to determine the distribution and densities of munitions within and adjacent to the disposal site. The bulk of the dumped material is located within, or immediately adjacent to, the north-eastern sector of the disposal site but smaller quantities were also observed to the west and south-west of the charted boundary of the site. Small numbers of phosphorus devices continue to be washed up in the area.

Analyses for metals and for explosive and propellant residues indicated no chemical contamination of either surface sediments or commercially exploited fish and shellfish species collected from within and adjacent to the disposal site. The risk to human health, therefore, would appear to be confined to instances where the materials could come into direct contact with people after being disturbed from their original resting place. Given the depth of water this is likely to occur only during fishing, pipelaying or other operations that disturb the seabed.

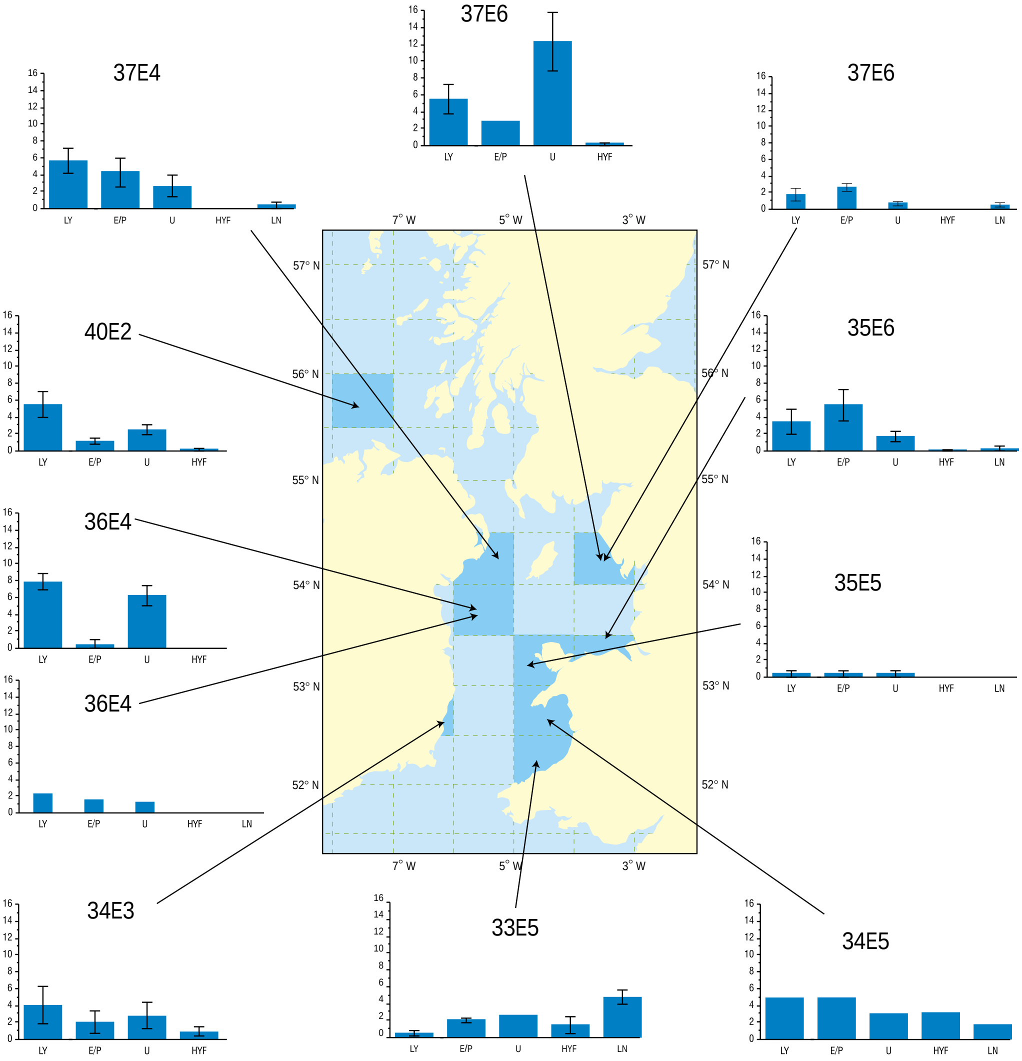
Table 5.5 Marine litter (%) attributed to source categories/activities at selected sites in the Minch. Source of data: FRS.

	Fishing	Shipping	Aquaculture	Fly-tipping	Tourism	Farming	Hunting	Unknown
Lewis								
Laxay (Loch Erisort)	15	9	8	15	-	2	-	51
North Tolsta (NE Lewis)	27	28	-	14	-	-	-	31
Carloway (W Lewis*)	31	12	14	10	-	-	-	33
Nr. Shader (NW Lewis*)	17	36	2	4	-	5	3	33
Harris								
Tarbart (E Harris)	17	14	21	8	3	3	4	30
Rubha Romagi (W Harris*)	32	22	-	6	2	4	7	27
Uist								
N. Rubha Ardvule (SW Uist)	20	28	4	1	-	5	2	40
Hougharry (NW Uist)	25	18	2	-	-	3	1	51
Lochmaddy (NE Uist)	31	26	13	7	4	-	-	19
Lochskipport (SE Uist)	26	15	10	2	-	2	-	45
Sutherland								
Oldshoremore (Kinlochbervie*)	41	14	13	4	-	-	-	28
Scourie	36	16	10	6	-	-	-	32
Lochinver	43	10	8	6	-	-	-	33
Ross and Cromarty								
Ullapool*	42	15	16	11	2	-	4	10
Gairloch	36	14	9	3	6	-	-	32
Applecross	31	18	21	2	-	2	-	26
Skye and Lochaish								
Balmacara*	29	12	32	12	3	2	-	10
Struan	24	25	12	3	-	-	-	36
Uig	31	15	9	5	2	-	-	38
Lochaber								
Mallaig*	46	15	18	10	2	-	-	9
Sanna Ardmurchan	27	32	7	2	6	-	1	25

The sample size at each site is 300.

* denotes sites considered as ‘hot spots’ during the survey; -: no information.

Figure 5.8 **Disease prevalence (%) in dab (mean (±1 standard error) in 1994–6. Source of data: CEFAS (1999); Boelens *et al*. (1999) after Dethlefsen.**



LY lymphocystis E/P epidermal papilloma U epidermal ulceration HYP hyperpigmentation LN liver nodules (histologically confirmed only)

5.17 **Combined effects**

5.17.1 Fish diseases

During the last twenty-five years, various studies have suggested links between the prevalence of fish diseases and environmental contamination. However, many of the macroscopic external diseases recorded in marine fish are the result of infectious or parasitic aetiologies and are subject to spatial, temporal and biological variations that may have natural or as yet unknown origins. Nevertheless, international guidelines (ICES, 1996) have been developed for recording long-term trends in the prevalence of external macroscopic diseases in populations of flatfish. In conjunction with specific biomarkers for contaminant exposure, disease data can be used as a possible indicator of contaminant effects. There is evidence to suggest, for instance, that liver cancers in selected flatfish species may possibly be linked with PAHs and polychlorinated hydrocarbons in sediments.

Studies carried out in the Irish Sea during the 1970s and 1980s recorded the presence of external disease conditions in flatfish, such as lymphocystis, ulcers and fin rot. Although spatial differences in prevalence were recorded, their significance cannot be assessed because the studies took place prior to the standardisation of disease monitoring techniques.

Since 1994, studies in the Irish Sea carried out by UK and German scientists, conducted according to ICES guidelines, have examined the prevalence of lymphocystis, ulceration, epidermal hyperplasia, hyperpigmentation and macroscopic liver nodules, mainly in dab and cod. Prevalences of the principal external diseases recorded in dab during these surveys are shown in *Figure 5.8*. Seasonal variation may account for the higher prevalences of diseases recorded by the German surveys compared to the UK surveys. The low levels of hyperpigmentation in dab from locations in the Irish Sea is noteworthy since the condition appears to be an increasing feature of North Sea dab stocks. Its aetiology is unknown.

Although there is growing evidence demonstrating a link between anthropogenic pollution and the formation of liver pathology in flatfish, the inter-relationships of environmental and biological variables affecting the development of liver tumours remain poorly understood. In comparison to the North Sea, where confirmed hepatocellular tumours (adenomas, pre-neoplastic lesions) are particularly prevalent in dab from the Dogger Bank, liver tumours in Irish Sea dab are generally at low levels. Whereas none of the fish collected in Liverpool Bay and Red Wharf Bay from 1995 to 1997 showed gross lesions, 21.6% of dab livers exhibited pre-neoplastic lesions.

Although the general disease prevalence (i.e. ulceration and skeletal deformities) in cod was low, in the UK surveys 7.3% of cod examined were infected with the pathogenic copepod parasite *Lernaeocera branchialis* and metacercariae of the metazoan parasite *Cryptocotyle* sp. were encysted in the skin of cod at various locations. Examination of other fish species also revealed generally low levels of disease prevalence.

Since 1993, cases of pigment anomalies and blindness in commercial catches of anglerfish (*Lophius piscatorius* and *L. budegassa*) have been reported from areas in the vicinity of the Celtic Deep. Both normal and affected fish examined were heavily infected with the microsporean parasite *Spraguea lophii*. However, there was no evidence that the effect of this parasite would result in pigment anomalies or blindness. No unusual contaminant burdens were detected in affected fish and the aetiology of these changes remains unknown.

In summary, there are no indications from recent studies of changing spatial or temporal trends in disease prevalence among fish populations in the Irish Sea. Disease prevalence in Irish Sea dab has remained at relatively low levels when compared to that recorded in North Sea dab, but rates are higher than in English Channel stocks.

5.17.2 Endocrine disruption

There is clear evidence that a diverse range of natural and synthetic substances, including PCBs, dioxins, TBT and various other organo-metallic compounds, pesticides, pharmaceuticals and industrial chemicals, have potential to impair reproduction in aquatic organisms through interference with their endocrine (i.e. hormonal) systems. Studies in freshwater environments have shown that these 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 chemicals or combinations of chemicals are responsible for the observed effects (i.e. feminisation in male fish) but ethynylestradiol (contraceptive agent), PCBs and alkylphenol-ethoxylate (derived from industrial detergents) have been positively implicated. Although TBT-induced imposex (see Section 5.14.4) is the only confirmed instance of this phenomenon in Region III at present, many other endocrine-disrupting substances are known to be present in effluents and river water discharged to the area. Feminisation similar to that observed in freshwater environments has been found in flounder (*Platichthys flesus*) from Red Wharf Bay (Anglesey), Liverpool Bay and especially in the Mersey Estuary. Pending clarification of the likely impact of endocrine disruption on populations, as opposed to individual organisms and the establishment of causative agents, it may be necessary to further reduce inputs of these substances in discharges to the region.

chapter 6

Overall assessment

6.1 Introduction

The purpose of this final chapter is to focus attention on the impact of human activities upon Region III and to highlight instances where remedial actions at both national and international level are leading to improvement; including those resulting from the OSPAR strategies on hazardous substances, radioactive substances, eutrophication, ecosystems and biological diversity, and offshore activities. Attention is also drawn to other issues, not necessarily within the OSPAR field of influence, where improvements in knowledge or measures to mitigate clearly identified and adverse impacts are necessary. Among the former are improvements in the way data are gathered so as to facilitate their interpretation and assessment for decision-making purposes.

The issues identified have been prioritised subjectively according to their geographic scale, their broad ecological implications and the extent of their impact on economically important resources or amenities. In assigning priorities to particular conditions, account has been taken of the nature of the change or hazard in question, whether it is of natural or anthropogenic origin, the adequacy of existing scientific knowledge and the measures currently in place that should serve to mitigate the condition. In most cases suggestions are made as to what could be done to remedy the situation, based primarily on an assessment of scientific and technical feasibility.

A number of issues are included because they are considered to be of importance either in some parts of Region III or in other areas of the North-east Atlantic. However, because the science indicates that, in Region III at least, the scale and ecological significance of the impacts are currently small, all are ranked lower in terms of priority. This does not mean that no action is required. Rather, it indicates that, provided the measures currently in place to control the sources and activities responsible for the impacts are maintained, it is reasonable to assume the impacts will be reduced in line with both OSPAR and EC objectives.

This report is based on three subregional reports prepared in relation to pre-selected areas of Region III. The lead government departments in Ireland and the UK are making separate arrangements for their publication. The reports reflect the different states of knowledge and past methodologies used to gather data in the subregions. As a consequence, comparisons across the entire region are sometimes difficult. Some possible solutions to such problems are given in Sections 6.2 and 6.3 and a brief summary of the overall status of Region III is provided in Section 6.4.

6.2 Assessment of human impacts

6.2.1 Issues of high importance

The following issues are considered to be of high importance because of their effects across the whole of Region III and beyond.

Fishing

Although certain areas are subject to more intense activity than others, for example certain *Nephrops* grounds are trawled over five times a year, fishing is a long-established practice throughout Region III and almost by definition has one of the biggest impacts on marine life. By its very nature and scale, fishing has an impact on target stocks. However, the precise extent of that impact can be difficult to assess, partly due to incomplete data on discards and recorded fish landings which, in turn, are partly due to the present system of setting landing quotas for each catch region. Together these mean it is often difficult to obtain accurate data with which to estimate fishing mortality and population size and without such data it is not possible to define a level of fishing effort that will ensure the protection of stocks. However, the setting of precautionary thresholds for stock biomass and fishing mortality seeks to allow for such uncertainty. As it is, stocks of several species i.e. cod, hake, saithe, whiting, plaice and sole are considered to be outside safe biological limits in parts of the region while for several other species e.g. skates and rays, the data do not at present allow an appropriate assessment.

Fishing also has an impact on non-target stocks of fish, and on birds and marine mammals, through their incidental catch in fishing gear. Data on which to assess scale and significance are limited but there is concern that mortality rates of porpoises in the Celtic Sea bottom-set gillnet fishery, aimed primarily at hake, are unsustainable. The long-term impact of fishing disturbance on benthic communities and the seabed is dependent on fishing intensity, design of the gear and sediment type. Certain gears, in particular beam trawls and scallop dredges, do have an impact on the seabed due to physical disturbance; this in turn affects the benthic communities and possibly also the transport of seabed material and contaminants. Although some research has been done on this issue (mainly in the Irish Sea), there is currently no conclusive evidence to show that either effect has serious consequences in Region III. Although most of the evidence suggests that the effects of physical disturbance are short-term and reversible, present efforts to clarify the position should be maintained.

Endocrine disrupters

Endocrine disruption caused by TBT is a well-established phenomenon in Region III. However, less obvious interference with the reproductive capability of fish has been detected in freshwater species downstream of particular industrial sites and sewage discharges and similar effects have now been shown to occur in some marine invertebrates and fish. The effect on individuals is, in most cases, fairly obvious but the impact at species and population level needs to be clarified. If shown to be of significance in terms of reproductive potential, efforts to identify and control the causative agents will need to be increased. At present it is suspected that many compounds are involved, of which PCBs, certain industrial detergents and chemicals used as human contraceptive agents are but three of the groups.

Tributyltin

The endocrine disruption effect of TBT used in antifouling preparations led in the UK and Ireland to the prohibition in 1987 of TBT in antifouling paints used on small boats (< 25 m) and on equipment used in mariculture. There is clear evidence that these measures have been effective in Region III. In areas close to concentrations of small boats and mariculture operations a reduction in TBT concentrations in the water and a recovery in populations of dogwhelks and other affected species is evident. However, TBT-related responses are still very obvious where illegal use persists (e.g. on fishing vessels) and in areas affected by run-off from boat yards. They are also apparent in the vicinity of ports, harbours and major shipping lanes due to the permitted use of TBT on the hulls of larger vessels. The IMO has recommended measures to prohibit the new treatment of ships with organotin compounds which act as biocides with effect from 1 January 2003, with a total ban coming into force on 1 January 2008. If adopted this would apply to all vessels within the region.

Coastal development

Except for the sparsely populated west coasts of Scotland and Ireland there is considerable pressure for more extensive use of coastal land for industry, housing and resort areas such as campsites, but at the same time the number of areas recognised as important from a conservation standpoint is increasing. Many of these are being designated as special areas of conservation, nature reserves and/or sites of special scientific interest etc. with various levels of legal protection accompanying the designations. Careful consideration should be given to resolving the complex social, legal and administrative issues involved as there are likely to be serious conflicts of interest between the needs to protect designated conservation areas and the pressure of human requirements for housing, leisure etc.

Climate change

There is evidence of an increase in both frequency, and perhaps severity, of storms and also of an increase in temperature. Whilst a definite trend is difficult to assess against known natural variability, the expectation of continued change will have to be allowed for in planning coastal defences and coastal development generally. It will also have to be taken into account when considering what measures can be taken to protect species and habitats. In this context, as climate change is likely to be accompanied by changes within ecosystems, it will also complicate the identification and assessment of other changes attributable to human activities.

6.2.2 Issues of medium importance

The following issues are considered to be of medium importance because although they also have ecological implications and/or impacts on economically important resources, their impact is generally considered to be contained within Region III.

Sewage

Most of the inhabitants of Ireland and the UK live close to the coast and the sewage from most coastal towns, and indeed many settlements well inland, is discharged to the sea. Until fairly recently, many of the sewage discharges received either no treatment or only primary treatment (i.e. settlement) to remove solids. Consequently a great deal of undegraded organic matter entered the sea and, where screening was inadequate, sewage-derived debris added to the litter problem in beach areas. As a consequence of the EC Directive on Urban Wastewater Treatment (91/271/EEC) many sewage discharges are now receiving, or will soon receive, secondary treatment and this will help to reduce both the litter problem and the potential for organic enrichment and deoxygenation in coastal waters. It will not always adequately reduce either nutrient or microbiological contaminant inputs. Accordingly, where the receiving environment is showing signs of eutrophication, further treatment may be necessary to remove either nitrogen or phosphate or both. If sewage discharges adversely affect bathing waters or shellfish growing waters further treatment in the form of disinfection and/or alterations to the discharge location may be required.

Litter

Litter clearly has an impact on aesthetic values and the cost of clearance from amenity beaches in particular can be considerable. It also has an impact on certain marine species but the scale to which this occurs within Region III is unclear. Much of the problem can be shown to be of local or regional origin and controls of local sources would go a long way towards solving the problem. To achieve this will, however, require a major effort to educate the public and those involved in the tourism, fishing and shipping industries.

Microbiological contamination

As a consequence of the EC Bathing Water Directive (76/160/EEC) a high proportion of bathing beaches in Region III now meet the mandatory standards. There are, however, some notable exceptions, particularly along the north-west coast of England, and further improvements are needed in this area. Many of the necessary improvements are planned. In England, the designation in July 1999 of a further 76 new shellfish waters under EC Directive 79/923/EEC, and the extension of the seventeen existing designations, should lead to further improvements in water quality around coasts and estuaries and should help improve nearby bathing waters.

Mariculture

Mariculture is now a major industry in Ireland and Scotland. The main species cultivated is Atlantic salmon, but large numbers of mussels and oysters are also reared, especially in Ireland. Inappropriate siting of fish and shellfish farms has, in some cases, given rise to organic enrichment of the sediments beneath the cages or rafts and also, in the case of fish cultivation, to nutrient enrichment through surplus food and excreta. Interactions between intensive finfish farming and the surrounding environments are of concern in a number of areas, especially in western Scotland where the industry has grown rapidly.

The development of serious infestations of caged salmon by sea lice could lead to the spread of lice to wild stocks of salmonids and some sea trout stocks may be adversely affected by this route. The solution is better farm management and fish husbandry but, where this involves the use of chemicals for parasite and disease control, concerns have been expressed about the impact on other species due to the toxicity and persistence of the chemicals used. However, the evidence offers little support to these concerns, or to worries about the development of antibiotic resistant bacteria. The impact of escaped stock in terms of interbreeding with wild stock is at present unclear but it is feared this could lead to an impaired homing instinct and a general deterioration of genetic diversity. This is mainly an issue for salmon at present but could involve other species in the future as the range of species cultivated is extended.

There are concerns over the introduction of certain cultivated shellfish species because ecological problems could develop if temperature increase allowed them to breed more readily and thus to become widely distributed. At present under EC rules there is, in principle, free movement of shellfish between all EU countries. There have already been several cases where disease (e.g. *Bonamia*) and parasites (e.g. *Mytilicola*) have been spread as a result of inadequate control of stock movements. Such problems can affect wild as well as cultured stock and better controls appear necessary.

Biotoxins

All major shellfish growing areas in the region are now subject to regular monitoring both for the presence of toxin-producing algae and toxins in shellfish products. This, coupled with expansion of commercial shellfish production, has greatly increased the probability that biotoxins will be detected. There has indeed been an increase in the number of harmful bloom events but there is no clear indication of the cause. Whilst the involvement of nutrient inputs as a consequence of land run-off and sewage discharges etc. cannot be ruled out in every case there are many instances, for example off the south coast of Ireland and the west coast of Scotland, where it is unlikely to be a contributory factor in large-scale algal blooms. It is also apparent that the presence of toxin-producing species does not always lead to biotoxins in shellfish. Further work is required to understand the causes of toxin production. Meanwhile continued monitoring is necessary to ensure human health protection.

Metallic contaminants

Metals are naturally present in sea water and run-off from land is part of the natural geological weathering process. Inputs are, however, increased as a consequence of mining and industrial activities and through use of metals and their salts in various applications. In sea water, dissolved metals rarely achieve concentrations that are directly toxic to marine biota but, through bioaccumulation, some metals can occasionally achieve tissue concentrations that are toxic to organisms and their predators, including humans. Within Region III, the concentrations of cadmium, mercury, lead, chromium, nickel, arsenic, silver etc. in sea water are well below the levels likely to give rise to toxicity, as indicated by reference to the ecotoxicological assessment criteria adopted by OSPAR. However, in some heavily contaminated estuaries, such as the Mersey, the northern coast of the Bristol Channel between Swansea and Cardiff and the Avoca river on Ireland’s east coast, Environmental Quality Standards set for the protection of marine species are exceeded for copper and zinc and this could account for some of the effects seen in bioassay results. The concentrations of mercury in the flesh of fish from Liverpool and Morecambe Bays did in the past give rise to concern but, following reductions in inputs from the chlor-alkali industry, there are clear indications of a downward trend and the concentrations are now considered acceptable. However, the concentrations of mercury in the livers of seals, porpoises and dolphins in the northern Irish Sea occasionally exceed 100 mg/kg, a level that may have some toxicological significance. This needs to be clarified and there should be no relaxation over present controls on discharges of mercury.

In the few estuaries contaminated with high levels of copper and zinc, and in the Liverpool/Morecambe Bay areas where the mercury level was high, monitoring ought to continue. Elsewhere, however, given that prevailing concentrations of metals in water, sediments and harvested species do not give rise to concern, and because the changes that can be expected are very small, there seems little benefit in continuing extensive monitoring of metal distributions or trends in most parts of Region III, where selective monitoring on a precautionary basis would be adequate.

Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons reach the marine environment via sewage discharges, surface run-off, industrial discharges, oil spillages and deposition from the atmosphere, and result largely from incomplete combustion of fossil fuels. Lower molecular weight PAHs can be acutely toxic to aquatic organisms and some form carcinogenically-active metabolites. Residues in sediments have been linked with liver neoplasms and other abnormalities in bottom-dwelling fish. Elevated PAH concentrations may therefore present a risk to aquatic organisms and potentially also to human consumers of fish and shellfish. There are indications that sediments in a number of the region’s industrialised coastal inlets contain significantly elevated PAH concentrations and that concentrations in sea water adjacent to Irish Sea coasts, although in the ng/l range, may affect the growth of mussels and possibly other organisms. Further research into the speciation, sources, biological implications, sinks and trends in environmental concentrations of PAHs appears warranted.

Oil spills

Oil as a pollutant of the marine environment arises from two main sources, accidental spillages and illegal operational discharges from ships. Although the latter are believed to be infrequent, the localised occurrence of oil or tar on beaches is often noted during shoreline surveys. Large-scale oil spills are much more significant and Region III has not escaped their impact. The most recent spill came from the Sea Empress in early 1996. However, despite the images of destruction and the loss of seabirds in particular, large spills generally have only a transient effect on most impacted species and amenities. The economic impact of an oil spill, in terms of the cost of clean-up to protect tourist and wildlife interests, is often substantial and may be additionally so if fixed fishery resources (e.g. mariculture and shellfisheries) are affected. The solution to chronic oil pollution from illegal discharges is better observation of the rules by ship operators and stricter enforcement by the authorities. Occasional accidental spillages are probably inevitable but the risk of their occurrence can be reduced by measures such as the traffic separation schemes already in operation and by supervising navigation to ensure that ships avoid the more hazardous inshore routes whenever weather permits.

Ballast waters

The discharge of ballast waters can lead to the introduction of non-indigenous species but the scale of the problem in Region III is unclear. Various means of preventing such introductions have been under review by a joint ICES/IMO working group. Pending the conclusions of that group, there seems little that can be done apart from monitoring areas adjacent to the most likely points of entry and preventing, where possible, the establishment of breeding populations. Once established, removal is almost certainly impractical.

Ships on passage

Although there are a number of traffic separation schemes in operation in the region which are intended to reduce the chance of ship collisions, the risk of other forms of accidents e.g. loss of cargo or the ship through mechanical failure or storm damage, remains. Thus far within Region III loss of deck cargo and/or chemical spillages have presented few serious problems. Nevertheless, the potential for damage exists if certain hazardous materials are lost close to mariculture sites, spawning grounds or centres of human population. At present it is clear that the number of shipping movements in the region is increasing but data on the type of shipping movement and the cargoes involved are difficult to access. It is therefore impossible to assess the potential for accidents (through collisions, loss of cargo or ship) and thus the potential for damage or the requirements for emergency response. A solution to the problem of data accessibility ought to be found prior to the next quality status report.

6.2.3 Other important issues

The issues assigned to this group fall into four categories:

- those affecting very few areas in Region III;
- those which are generally under control within Region III;
- those perceived to be problems by the public but where the scientific evidence does not support these concerns; and
- those which warrant further scientific research to clarify their potential for environmental degradation.

Organochlorine pesticides

The use of most organochlorine pesticides has been in decline since the 1960s and none of the substances routinely monitored are now present in concentrations that present a significant risk to either marine species or human health. In the past, DDT residues were suspected of being a partial cause of eggshell thinning in some seabird species but this is no longer the case. Monitoring for organochlorine pesticides in the marine environment, especially for trend determination purposes, is both a complex and expensive undertaking. Considering the present concentrations of the suite of pesticides currently monitored the justification for continuing extensive monitoring of these substances is questionable. However, in view of the recent identification of elevated toxaphene residues in species from the area, clarification of the safe level of toxaphene for human consumers is necessary. Further work to establish more accurately the concentrations of individual chemicals within this group of compounds may also be necessary. Toxaphene is not used in north-west Europe and its presence in marine organisms caught in Region III is almost certainly a result of long-range transport from North and South America.

Polychlorinated biphenyls

In the past concentrations of PCBs have been implicated in the death of seabirds (coupled with starvation through storms and shortage of food) and possibly eggshell thinning. The available evidence suggests that residues in fish and seabirds are decreasing but the rates of decay and dissipation of PCBs already in the environment is a slow process. Residue levels of PCBs in marine mammals may be high enough to cause harm, especially when the animals suffer a shortage of food or illness and their contaminant body burden is mobilised along with their fat reserves. Similar fears relate to the well-being of young bottle-nose dolphins in Cardigan Bay (through mobilisation of the mother’s body burden during lactation) as this population has unusually high PCB concentrations in body fat. As it is impractical to protect marine mammals from natural stress, the need to continue present controls on use and especially disposal of PCBs remains a priority.

Eutrophication

For the purposes of this report eutrophication has been examined with respect to the existence of persistent (or recurrent) ‘undesirable’ biological changes associated with increased nutrient concentrations in the environment. It is clear that within the Irish Sea and many estuaries concentrations of both nitrate and phosphate have been anthropogenically enhanced. However, very few areas are considered to be eutrophic within the terms of the definition outlined above. In UK waters only the Mersey Estuary/Liverpool Bay area and Belfast Lough are considered to be showing signs of eutrophication and in Ireland only inner Cork Harbour is considered to be showing signs of eutrophication, with parts of Dublin Bay (and a few estuaries to the north of Dublin Bay) being affected for limited periods. In no case does the degree of eutrophication cause serious biological damage and in all cases it is anticipated that remedial measures in the form of amended agricultural practices and improved sewage treatment will improve the situation.

Deoxygenation

Sags in oxygen concentration exist in a number of Irish estuaries, in the heavily urbanised Mersey Estuary and in Belfast Lough and occasionally, at times of stratification, in Liverpool Bay. In addition, a limited area of seabed around the Garroch Head sewage sludge disposal ground is affected as a consequence of high concentrations of organic matter arising from the sludge disposal operation. In the two sludge disposal areas, Liverpool Bay and Garroch Head, oxygen depletion is associated with the (former) sludge dumping, rather than decaying algal blooms. In no case is the spatial scale of the impact or its biological effect of ecological concern. Nevertheless, it is anticipated that further treatment of industrial effluent and sewage will lead to improvements in the quality of the affected estuaries and this, coupled with the cessation of sewage sludge disposal, should lead to elimination of oxygen sags in the Liverpool Bay and Garroch Head disposal grounds.

Radioactivity

The question of radioactive contamination, particularly that arising from the Sellafield nuclear fuel reprocessing plant, is a matter of concern to the public. This concern stems from the higher levels of radioactivity discharged in the past, that sophisticated systems can detect the signal far from the source and recent increases in the discharge of certain radionuclides, particularly technetium-99. However, technetium is of low radiological significance and there have been substantial net reductions in the levels of many other more harmful radionuclides over the last decade. Recent OSPAR commitments indicate this process (including reductions in technetium) is likely to continue and that radioactivity levels will continue to decline. In terms of exposure to the public, the incremental risks to health due to present discharges from Sellafield are extremely small. For example, in Ireland a heavy consumer of fish and shellfish from the Irish Sea in 1997 would have received an estimated dose of 1.4 µSv compared to the current dose limit which is set at 1000 µSv. This would amount to an addition of 0.05% to the average dose of 3000 µSv received from all other sources of radiation. In the UK the highest reported dose was received by consumers on the Cumbrian coast in 1981, amounting to 3450 µSv or 69% of the then recommended dose limit of 5000 µSv (using an enhanced gut transfer factor for plutonium). Exposure levels to marine species are also well below those known to cause adverse effects.

Munitions

In the past, quantities of surplus and out of date munitions have been disposed of at sea, usually at sites some distance from land. An exception was the use of the deep trough known as Beaufort’s Dyke in the North Channel between Northern Ireland and Scotland. From time to time items are washed up on beaches along the east coast of Ireland, the Isle of Man and the west coast of Scotland. The munitions most commonly found are phosphorus incendiary devices; these present a hazard to beach users and are a source of public concern. It is no longer possible to establish exactly what materials and what quantities were deposited in the Beaufort’s Dyke or in the general vicinity of the designated disposal area. Detailed surveys of the seabed have clearly established that some material was dumped outside the disposal area as originally marked on the charts; the charts have now been amended. Provided the munitions remain undisturbed on the seabed they do not present a hazard. This applies to both incendiary devices, which only ignite on contact with the air, and those containing phosgene gas, which if it does seep out will be hydrolysed into harmless substances on contact with the water.

Military activities

Military activities can lead to disturbance of wildlife and interfere with other uses of the areas involved. In most cases, however, animals appear to get used to noise and many areas used by the military are regarded as wildlife havens and, in some cases, are designated as conservation areas largely because they are not subject to other forms of human interference. There has, in the past, been a number of incidents involving submarines and fishing vessels and more than 50 lives were lost in this way. The frequency of such incidents has been lower in recent years.

Dredged material

Although some dredged material is contaminated with metals and other substances in most cases its disposal is not a significant source of contaminants. Disposal sites are now carefully selected to ensure that the physical impacts of disposal are of little consequence for surrounding ecosystems. In a few cases contamination levels have been sufficiently high that release has contributed to contaminant residues in sediments and biota outside the disposal area. However, improved control over land-based sources of contaminants is expected to reduce the contaminant burden in dredged material. Furthermore, the regulatory requirements now governing the disposal of any highly contaminated dredged materials preclude their disposal at sea.

Sand, gravel and maërl extraction

Removal of marine sediments for building or other purposes is currently not a major activity in Region III. In the past, extraction of sand from near shore banks has led to beach erosion but the dangers of this are recognised and extraction is now only permitted after careful assessment of such issues. The process of removal of seabed material inevitably involves some disturbance of the benthos and alteration of the seabed profile. This can lead to major local changes. The planning regimes now being introduced by the Irish and UK authorities should preclude unacceptable changes (e.g. large-scale habitat alteration and interference with fish spawning) should demand for marine aggregates increase.

Offshore developments

Although the downturn in oil prices has meant the scale of exploration for, and exploitation of, oil and gas deposits is low in Region III at present, there is believed to be considerable scope for expansion in the future. Changes to benthic communities have been identified over relatively large areas surrounding established oil production platforms in other parts of the OSPAR area, e.g. the North Sea where oil-based drilling muds were used and discharged. Whereas such muds have been used in Region III, their discharge to the sea has been prohibited for some time. All operations are now subject to strict national legislation in line with OSPAR requirements and any impact should be minor and localised. There are plans for more land-based wind power generators at a number of coastal sites and for both wind- and wave-power generation systems offshore. Precautions are needed to ensure these do not interfere with other users of the sea, particularly fishing and shipping, and to safeguard habitats.

6.3 Adequacy of knowledge and availability of data

The process of producing this report, and particularly the three more extensive subregional reports on which it is based, has revealed a remarkable amount of information, much of which has not previously been compiled or assessed for management purposes. Nevertheless, there are a number of topics about which our understanding is relatively poor. Some of these have been mentioned in the previous section on prioritisation of issues, for example:

- the effects of fishing on benthic species and marine mammals;
- factors causing the development of toxin-producing species of algae and why the presence of such species is not always associated with the formation of toxins, or at least the occurrence of such toxins in shellfish;
- the risks of introducing non-indigenous species via ballast waters;
- data on fishing discards, of both target species and non-target species, and more accurate fish catch statistics;
- the scale and causes of endocrine disruption in marine species; and
- data on the passage of ships carrying cargoes of hazardous materials.

Other needs include better understanding of the implications of, and reasons for, reduced SFG in mussels. There is a lack of consistent, good quality, time series data sets (e.g. on nutrients) and it is difficult to establish trends in contaminant concentrations. There is also a need to compile data on human activities (e.g. tourism and construction) that are specifically relevant to the coastal zone. More fundamental, perhaps, is the lack of understanding concerning the relationships between trends in climate and changes in physical hydrography and how this might influence patterns of water movement and biological production. There is also a lack of understanding of the role of fronts in affecting the abundance and distribution of fish, fish eggs and larvae and as sinks for contaminants attached to suspended particulate material.

Inputs

The efficacy of input reduction measures can only be assessed with confidence if the data relating to input measurements are reliable. Transport, agricultural, industrial, residential and recreational activities have substantially altered and added to the flux of contaminants reaching the marine environment and in recent years measures have been taken to reduce some of these inputs. Some of the data available for inputs to Region III are questionable, largely because of the number of inputs for each pathway (rivers and industrial and municipal discharges), seasonal variability and differences in sampling strategies used by different agencies. Furthermore, estimates of atmospheric inputs to the region (which for some contaminants constitute a high proportion of the total input) are very tentative due to the scarcity of stations for sampling atmospheric deposition. As a result, it is not possible to determine what proportion of the actual input the current data represent or that the load estimates for different parts of Region III are comparable. A particular difficulty centres on those data reported on the basis of concentrations below a specified detection level. This applies particularly to riverine inputs where the volumes are large and detection levels used by different agencies differ widely. For some catchments the problem is exacerbated because measurements are too infrequent to account for the high seasonal variability of river discharges. Clearly, improvements are necessary if the effectiveness of the various input reduction measures is to be assessed. Harmonisation of sampling methodologies and the use of more realistic detection limits will be required. For the purpose of assessing trends in the inputs of many substances it might be more cost-effective to refocus sampling as close as possible to the main known sources.

Intra-regional comparability of data

Apart from the instances identified, the data assessed in this report were generally considered reliable and, as far as could be ascertained, comparable. One of the reasons for this has been the introduction of schemes for data quality assurance at national and international level. At national level, the UK’s quality assurance schemes for chemical and benthic monitoring, and also for some bioassay techniques, have been particularly successful. The Quality Assurance of Information for Marine Environmental Monitoring in Europe (QUASIMEME) system of chemical analytical quality control has also improved the situation. Nevertheless, there are some notable disparities between the concentrations of PAHs reported by laboratories in Ireland and the UK and this raises questions as to whether the methods used by the two parties are actually measuring the same substances or categories thereof.

More serious differences arise in the comparability of data on metals in sediments where several laboratories supplying data did so using normalisation procedures that were not in line with ICES/OSPAR recommendations. In another case an important data set on metals in sediments was reported as ‘wet weight’ rather than the standard ‘dry weight’. The other major problem arose over disparate and often inadequate procedures for measuring input loads. The adoption of detection limits suited to input measurement rather than compliance with quality standards, and closer harmonisation of sampling frequencies, would help to improve this situation.

6.4 Overall assessment and conclusions

The coasts and seas of Region III exhibit marked differences in both natural characteristics and human pressures as well as the degree to which human activities are changing the environment. Generally the waters off the west coasts of Ireland and Scotland are relatively unimpacted by contamination arising from within the region. The main needs in these areas are to ensure that exploitation of their mariculture potential does not result in serious contamination and disruption of natural ecosystems and that recreational activities, and associated developments, do not cause long-term damage to valuable habitats and landscapes.

Ecosystem effects due to pollution are, for the most part, confined to urbanised estuaries such as inner Cork Harbour, the Liffey Estuary and inner Dublin Bay, Belfast Lough, the upper reaches of the Bristol Channel, the Mersey Estuary and Liverpool Bay, and the upper Clyde Estuary. Less obviously, much of the Irish Sea is subject to elevated levels of contaminants ranging from nutrients to metals, organochlorine pesticides, PCBs and radionuclides. Environmental levels of most contaminants routinely monitored appear to be either stable or decreasing. Apart from TBT, there is little scientific evidence to indicate that present concentrations of these contaminants, either alone or in combination, have been harmful to populations or communities of marine biota. Nevertheless, in the absence of more extensive biological effects monitoring, the possibility of some localised effects (e.g. reduced Scope for Growth, endocrine disruption, changes in community structure, loss of biodiversity) on marine biota due to chronic exposure to contaminants cannot be ruled out. Monitoring of commercial species from the Irish Sea and elsewhere in Region III has shown that seafood from the area is of good quality and safe to eat.

Certain other human activities are having an appreciable impact on the marine and coastal environment. Most notably fishing, where recent exploitation rates of some species in some areas have resulted in stock sizes that are considered to be below safe biological limits and where the impact on non-target species is often either unclear or clearly detrimental. The ecological significance of the constant removal by fishing of large amounts of biomass from the middle ranks of the food web, although largely unknown, could be considerable and warrants greater research.

Many environmental impacts, both at sea and on shore, are associated with the operation of commercial ships including ferries, cargo and fishing vessels. These include the dredging of ports and harbours, operational and accidental discharges of oil, vessel-derived litter and netting, the importation of non-indigenous species in ballast water and the effects of antifoulant paints. Although such effects are generally localised, and in some cases intermittent, any trend towards increase in traffic, vessel size or port expansion ought to be associated with attention to environment protection measures.

In a number of areas the loss or modification of coastal habitats due to construction for housing, infrastructure and recreational developments is at odds with the move towards better conservation of wildlife, scenic landscapes and sites of ecological or archaeological importance. This provides a strong argument for a more integrated approach to coastal zone management that includes the preparation of long-term plans for the use, development and conservation of coastal areas. Such plans are being developed in some areas.

SPECIES

Reference list of species mentioned in this report (sorted by common (English) name within categories)

Common (English) name	Scientific name
Mammals	
Bottle-nose dolphin	*Tursiops truncatus*
Common dolphin	*Delphinus delphis*
Common harbour seal	*Phoca vitulina*
Grey seal	*Halichoerus grypus*
Harbour porpoise	*Phocoena phocoena*
Long-fin pilot whale	*Globicephala melaena*
Striped dolphin	*Stenella coeruleoalba*
White-sided dolphin	*Lagenorhynchus acutus*
Birds	
Arctic tern	*Sterna paradisaea*
Black backed gull	*Larus* sp.
Common tern	*Sterna hirundo*
Cormorant	*Phalacrocorax carbo*
Eider	*Somateria mollissima*
Gannet	*Sula bassanus*
Guillemot	*Uria aalge*
Herring gull	*Larus argentatus*
Kittiwake	*Rissa tridactyla*
Little auk	*Alle alle*
Manx shearwater	*Puffinus puffinus*
Puffin	*Fratercula arctica*
Razorbill	*Alca torda*
Roseate tern	*Sterna dougallii*
Sandwich tern	*Sterna sandvicensis*
Scoter duck	*Melanitta nigra*
Shag	*Phalacrocorax aristotelis*
Slavonian grebe	*Podiceps auritus*
Fish	
Anchovy	*Engraulis encrasicolus*
Anglerfish	*Lophius budegassa*
Anglerfish	*Lophius piscatorius*
Atlantic salmon	*Salmo salar*
Blue whiting	*Micromesistius poutassou*
Cod	*Gadus morhua*
Common skate	*Raja batis*
Dab	*Limanda limanda*
Dogfish	*Scyliorhinus canicula*
Flounder	*Platichthys flesus*
Gurnards	*Triglidae* sp.
Haddock	*Melanogrammus aeglefinus*
Hake	*Merluccius merluccius*
Halibut	*Hippoglossus hippoglossus*
Herring	*Clupea harengus*
Horse mackerel	*Trachurus trachurus*
John Dory	*Zeus faber*
Lemon sole	*Microstomus kitt*
Long-finned tuna (albacore)	*Thunnus alalunga*
Mackerel	*Scomber scombrus*
Megrim	*Lepidorhombus whiffiagonis*
Norway pout	*Trisopterus esmarki*
Plaice	*Pleuronectes platessa*
Pouting	*Trisopterus luscus*
Rainbow trout	*Oncorhynchus mykiss*
Saithe	*Pollachius virens*
Sandeel	*Ammodytes tobianus*

Common (English) name	Scientific name
Seabass	*Dicentrarchus labrax*
Sea trout	*Salmo trutta*
Sardine (pilchard)	*Sardina pilchardus*
Six-gill shark	*Hexanchus griseus*
Sole	*Solea solea*
Sprat	*Sprattus sprattus*
Spurdog	*Squalus acanthias*
Turbot	*Psetta maxima*
Whiting	*Merlangius merlangus*
Lower animals	
American oyster	*Crassostrea virginica*
Amphipod	*Corophium volutator*
Bivalve mollusc	*Arctica atlantica*
Blue mussel	*Mytilus edulis*
Brittle star	*Ophidtrix fragilis*
Chinese hat shell	*Calyptraea chinensis*
Common whelk	*Buccinum undatum*
Copepod	*Acartia* sp.
Copepod	*Calanus finmarchicus*
Copepod	*Calanus helgolandicus*
Copepod	*Centropages* sp.
Copepod	*Lernaeocera branchialis*
Copepod	*Oithona* sp.
Copepod	*Para/pseudocalanus* sp.
Copepod	*Temora longicornis*
Dogwhelk	*Nucella lapillus*
European abalone	*Haliotis tuberculata*
Flame shell	*Limaria hians*
Hard-shelled clam	*Mya arenaria*
Lobster	*Homarus gammarus*
Manila clam	*Ruditapes semidecussata*
Mussel	*Modiolus modiolus*
Native/flat oyster	*Ostrea edulis*
Norway lobster (Dublin Bay prawn)	*Nephrops norvegicus*
Pacific oyster	*Crassostrea gigas*
Parasitic copepod	*Mytilicola orientalis*
Parasitic worm	*Cryptocotyle* sp.
Queen scallop	*Chlamys opercularis*
Sea louse	*Lepeophtheirus salmonis*
Sea Urchin	*Brissopsis lyrifera*
Slipper limpet	*Crepidula fornicata*
Starfish	*Asterias rubens*
Plants	
Bladder wrack	*Fucus vesiculosus*
Common cord grass	*Spartina anglica*
Dulse	*Rhodymenia palmata*
Micro alga	*Alexandrium* sp.
Micro alga	*Alexandrium tamarense*
Micro alga	*Noctiluca* sp.
Micro alga	*Phaeocystis* sp.
Other organisms	
Parasitic protozoan	*Bonamia ostrea*
Parasitic microsporean	*Spraguea lophii*
Bacteria	*Escherichia coli*
Fungus	*Clostridium botulinum*

ABBREVIATIONS

μ (prefix)	micro, 10^{-6}
ΣPCB	Sum of concentrations for individual chlorinated biphenyl congeners
Σ (prefix)	Sum (of concentrations)
°C	Degrees Celsius
ACFM	Advisory Committee on Fisheries Management (ICES)
ACG	Assessment Coordination Group (OSPAR)
ACOPS	Advisory Committee on Protection of the Sea
AMAP	Arctic Monitoring and Assessment Programme
ASCOBANS	Agreement on Small Cetaceans of the Baltic and North Sea
ASMO	Environmental Assessment and Monitoring Committee (OSPAR)
atm	1 atmosphere = 1.013 x 10^5 Pascal
BC	Before Christ
BGS	British Geological Survey
BOD	Biochemical Oxygen Demand
Bq	Becquerel (1 disintegration per second)
BRC	Background / Reference Concentration
CB	Chlorinated Biphenyl
CEFAS	Centre for Environment, Fisheries and Aquaculture Science (UK)
CFC	Chlorofluorocarbon
cm	Centimetre
CPR	Continuous Plankton Recorder
CPUE	Catch Per Unit Effort
d	Day
DAIN	Dissolved available inorganic nitrogen
DAIP	Dissolved available inorganic phosphorus
DANI	Department of Agriculture for Northern Ireland
DBP	Di-*n*-butyl phthalate
DDE	1,1-dichloro-2-(2-chlorophenyl)-2-(4-chlorophenyl)ethene
DDT	4,4'-dichlorodiphenyl-1,1,1-trichloroethane
DDVP	Dichlorvos (an organophosphate)
DEHP	Di(2-ethylhexyl)phthalate
DEP	Diethyl phthalate
DiBP	Diisobutyl phthalate
DMP	Dimethyl phthalate
DnBP	Di-*n*-butyl phtlalate
DSP	Diarrhetic Shellfish Poisoning
dw	Dry weight
EA	Environment Agency (England and Wales)
EAC	Ecotoxicological Assessment Criteria
EARP	Enhanced Actinide Removal Plant
EC	European Commission
EEA	European Environment Agency
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency (Ireland)
EQS	Environmental Quality Standard
EROD	Ethoxyresorufin-O-deethylase
EU	European Union
FRC	Fisheries Research Centre (Marine Institute, Ireland)
FRS	Fisheries Research Service (Ireland)
fw	Fat weight
G (prefix)	Giga, 10^9
GOOS	Global Ocean Observation System
GRT	Gross Registered Tonnage
HCB	Hexachlorobenzene
HCH	Hexachlorocyclohexane
ICCAT	International Commission for the Conservation of Atlantic Tuna
ICES	International Council for the Exploration of the Sea
IMES	Irish Marine Emergency Service
IMO	International Maritime Organization
IMPACT	Working Group on Impacts on the Marine Environment (OSPAR)
INPUT	Working Group on Inputs to the Marine Environment (OSPAR)
ISSG	Irish Sea Study Group
IUCN	International Union for Conservation and Natural Resources
JAMP	Joint Assessment and Monitoring Programme (OSPAR)
JNCC	Joint Nature Conservation Committee (UK)
kg	kilogramme

km	Kilometre
km^2	Square kilometre
km^3	Cubic kilometre
lw	Lipid weight
M	Molar mass
M (prefix)	Mega, 10^6
MAGP	Multi-Annual Guidance Programme (for Fisheries)
MAIB	Marine Accident Investigation Branch (UK)
MARPOL	International Convention for the Prevention of Pollution from Ships (1973/1978)
MBAL	Minimum Biologically Acceptable Level
mm	millimetre
MNR	Marine Nature Reserve
MON	Ad Hoc Working Group on Monitoring (OSPAR)
MW	Molecular Weight
n (prefix)	nano, 10^{-9}
NAO	North Atlantic Oscillation
NERC	Natural Environment Research Council (UK)
NHA	Natural Heritage Area
nm	nautical mile
NMP	National Monitoring Programme (UK)
NORSAP	Northern Seas Action Programme (EU)
NOx, NO$_x$	Oxidised Nitrogen
OSPAR Commission	The term 'OSPAR Commission' is used in this report to refer to both the OSPAR Commission and the former Oslo and Paris Commissions. The 1972 Oslo Convention and the 1974 Paris Convention were replaced by the 1992 OSPAR Convention when it entered into force on 25 March 1998
p (in pCO$_2$)	partial pressure
p (prefix)	pico, 10^{-12}
PAHs	Polycylic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PSP	Paralytic Shellfish Poisoning
PSU	Practical Salinity Unit (replaces 'parts per thousand' – ppt)
QSR	Quality Status Report
QSR 2000	Quality Status Report for the entire OSPAR maritime area published by OSPAR in 2000.
QUASIMEME	Quality Assurance of Information for Marine Environmental Monitoring in Europe
RFV	Research and Fishery Vessel
RPII	Radiological Protection Institute of Ireland
RPSI	Relative Penis Size Index
RTT	Regional Task Team (OSPAR)
s	second (time)
SEPA	Scottish Environmental Protection Agency
SFG	Scope for Growth
SIME	Working Group on Concentrations, Trends and Effects of Substances in the Marine Environment (OSPAR)
SIXEP	The Site Ion Exchange Effluent Plant
SOC	Southampton Oceanography Centre
SPA	Special Protection Area
SPM	Suspended Particulate Matter
SSSI	Site of Special Scientific Interest
Sv	Sievert (1 J kg^{-1} x (modifying factors))
t	Tonne
T (prefix)	Tera, 10^{12}
TAC	Total Allowable Catch
TBT	Tributyltin
THC	Total Hydrocarbons
THORP	Thermal Oxide Reprocessing Plant
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNESCO	UN Educational Scientific and Cultural Organization
VDSI	Vas Deference Sequence Index
W	Watt
ww	Wet weight
yr	Year

GLOSSARY

Amphidrome	A point in the sea where there is no vertical tidal movement
Anoxia	A complete absence of oxygen
Anthropogenic	Caused or produced by human activities
Background concentrations of natural compounds	The concentration of a natural compound that would be found in the environment in the absence of human activity. Natural compounds are those produced by biosynthesis from natural precursors or by geochemical, photochemical or chemical processes.
Background/Reference Concentrations (BRCs)	The following operational definitions have been used by OSPAR to determine Background/Reference Concentrations (BRCs): concentrations reflecting geological times (obtained from layers of buried marine sediments) or concentrations reflecting historical times (obtained from measurements carried out prior to significant anthropogenic inputs of the respective substance; relevant for nutrients only) or concentrations from pristine areas (preferably areas far from known sources and normally having very low concentrations).
Baroclinic	Referring to a condition and type of motion in which the pressure is not constant on the surfaces of constant density, e.g. due to internal tides and other internal waves
Benthos	Those organisms attached to, living on, in the seabed. Benthos is categorised by its diameter into: - nanobenthos: passes through 63 µm mesh - microbenthos: passes through 100 µm mesh - meiobenthos: within the 100 – 500 µm range - macrobenthos: passes through 1 cm mesh but is retained on 1000 – 500 µm mesh - megabenthos: visible, sampled using trawls and sieves
Bioaccumulation	The accumulation of a substance within the tissues of an organism. This includes 'bioconcentration' and uptake via the food chain
Bioassay	The use of an organism for assay purposes. Generally referring to a technique by which the presence of a chemical is quantified using living organisms, rather than chemical analyses
Bioavailability	The extent to which a substance can be absorbed into the tissues of organisms. Possibly the most important factor determining the extent to which a contaminant will enter the food chain and accumulate in biological tissues
Biomass	The total mass of organisms in a given place at a given time
Biosynthesis	The production of organic compounds by living organisms
Biota	Living organisms
Bloom	An abundant growth of phytoplankton, typically triggered by sudden favourable environmental conditions (e.g. excess nutrients, light availability, reduced grazing pressure)
By-catch	Non-target organisms caught in fishing gear
Climate	The long-term average conditions of the atmosphere and/or ocean
Contaminant	Any substance detected in a location where it is not normally found
Continental margin	The ocean floor between the shoreline and the abyssal plain, including the continental shelf, the continental slope and the continental rise
Discards	Fish and other organisms caught by fishing gear and then thrown back into the sea
Diversity	The genetic, taxonomic and ecosystem variety in organisms in a given marine area
DSP biotoxins	A group of toxins produced by some marine dinoflagellates that, if transmitted through the food web, cause a syndrome known as Diarrhetic Shellfish Poisoning (DSP) because it is mainly caused after the ingestion of shellfish and with diarrhoea being the main symptom
Dumping	The deliberate disposal in the maritime area of wastes or other matter from vessels or aircraft, from offshore installations, and any deliberate disposal in the maritime area of vessels or aircraft, offshore installations and offshore pipelines. The term does not include disposal in accordance with MARPOL 73/78 or other applicable international law of wastes or matter incidental to, or derived from, the normal operations of vessels or aircraft or offshore installations (other than wastes or other matter transported by or to vessels of offshore installations for the purpose of disposal of such wastes or other matter or derived from the treatment of such wastes or other matter on such vessels or aircraft of offshore installations)
Ecotoxicological assessment criteria (EAC)	The concentrations that, according to existing scientific knowledge, approximate to concentrations below which the potential for adverse effects is minimal
Ecosystem	A community of organisms and their physical environment interacting as an ecological unit
Emission	A release into air
Endocrine disrupter	An exogenous substance that causes adverse health effects in an intact organism, or its progeny, consequent to changes in endocrine function. In applying this definition to the marine environment it will be necessary to consider substances that are likely directly or indirectly to affect the hormonal regulation in whole organisms by the mimicking of hormones or by affecting enzyme systems responsible for hormone equilibria.
Euphotic zone	The upper layers of the sea with sufficient light penetration for net photosynthesis to occur
Eutrophication	The enrichment of water by nutrients causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned, and therefore refers to the undesirable effects resulting from anthropogenic enrichment by nutrients
Feldspars	A group of rock-forming minerals consisting of aluminium silicates
Fisheries management	In adopting Annex V to the 1992 OSPAR Convention, on the Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area, OSPAR agreed that references to 'questions relating to the management of fisheries' are references to the questions on which action can be taken under such instruments as those constituting: - the Common Fisheries Policy of the European Community; - the corresponding legislation of Contracting Parties which are not Member States of the European Union; - the corresponding legislation in force in the Faroe Islands, Greenland, the Channel Islands and the Isle of Man; or - the North East Atlantic Fisheries Commission and the North Atlantic Salmon Commission; whether or not such action has been taken. For the avoidance of doubt, in the context of the OSPAR Convention, the management of fisheries includes the management of marine mammals
Focus areas	An area of special attention in the QSRs. They may consist of a typical and valuable habitat for marine life, may be under (anthropogenic) stress, may be of strategic or economic importance, or scientific research may have resulted in a relatively large amount of information on the area
Food web	The network of interconnected food chains along which organic matter flows within an ecosystem or community
Fossil fuel	Mineral fuels (coal and hydrocarbons) rich in fossilised organic materials which are burnt to provide energy
Fronts	The boundary zone between two water masses differing in properties, such as temperature and salinity. Fronts can be either convergent or divergent
Geochemical	Relating to the natural chemistry of the Earth
Glacial deposit	Sediment deposits resulting from large-scale movements of glaciers and ice-rafting during glacial periods
Glacial periods	Cool to cold climatic periods, characterised by advancing ice sheets and caps, within the Quaternary Period
Gyre	Large-scale ocean circulation pattern generated by the interaction of winds and the rotation of the earth
Harmful Algal Blooms (HAB)	Blooms of phytoplankton that result in harmful effects such as the production of toxins that can affect human health, oxygen depletion and kills of fish and invertebrates and harm to fish and invertebrates e.g. by damaging or clogging gills
Hazardous substances	Substances which fall into one of the following categories: (i) substances or groups of substances that are toxic, persistent and liable to bioaccumulate; or (ii) other substances or groups of substances which are assessed by OSPAR as requiring a similar approach as substances referred to in (i), even if they do not meet all the criteria for toxicity, persistence and bioaccumulation, but which give rise to an equivalent level of concern
Hydrography	The study of water characteristics and movements
Imposex	A condition in which the gender of an organism has become indeterminate as a result of hormonal imbalances or disruption, as in the case of the effect of tributyltin on gastropods
Inshore waters	Shallow waters on the continental shelf, a term usually applied to territorial waters within 6 miles of the coasts
Interglacial periods	Warm to temperate periods between glaciations within the Quaternary Period
Internal waves	Waves occurring on density surfaces within the ocean and most commonly generated by the interaction between tidal currents and the sea bed structure
Intrusion	Water that is intermediate in density between two contiguous water masses and so flows between them
Isohaline	A line connecting points of equal salinity
Isotope	A form of an element chemically identical to another but with a different atomic weight
Key species	A species whose loss would have a detrimental or disproportionate effect on the structure, function and/or biological diversity of the ecosystem to which it belongs

Kinetic	Relating to, characterised by, or caused by motion
London Convention	The 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter. The Convention is administered by the International Maritime Organization
Machair	A relatively smooth, shell-rich, blown sand surface stabilised by vegetation forming a continuous short grass and herb rich sward
Marine biotoxins	Toxins produced by phytoplankton species (e.g. some dinoflagellates) and accumulated through the food chain to levels dangerous for human consumers or for the species itself
MARPOL 73/78	The International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto
Meteorology	The study of weather and climate
Microbial food web	The food web that is sustained by picoplankton cells that are too small to be filtered from the water by suspension feeders
Moraine	A mass of debris carried by glaciers and forming ridges and mounds when deposited
North Atlantic Oscillation (NAO)	The North Atlantic Oscillation index is defined as the difference in atmospheric pressure at sea level between the Azores and Iceland and describes the strength and position of westerly air flows across the North Atlantic
Nutrients	Dissolved phosphorus, nitrogen and silica compounds
Organohalogens	Substances in which an organic molecule is combined with one or more of the halogen group of elements (i.e. fluorine, chlorine, bromine, iodine)
Phytoplankton	The collective term for the photosynthetic members of the nano- and microplankton
Plankton	Those organisms that are unable to maintain their position or distribution independent of the movement of the water. Plankton is categorised by its diameter into: - picoplankton: < 2 µm - nanoplankton: 2 – 20 µm - microplankton: 20 – 200 µm - macroplankton: 200 – 2000 µm - megaplankton: > 2000 µm
Pollutant	A substance (or energy) causing pollution
Pollution	The introduction by man, directly or indirectly, of substances or energy into the maritime area which results, or is likely to result, in hazards to human health, harm to living resources and marine ecosystems, damage to amenities or interference with other legitimate uses of the sea
Post-spawning	Pertaining to a population of organisms following breeding
Production, primary	The assimilation of organic matter by autotrophs (i.e. organisms capable of synthesising complex organic substances from simple inorganic substrates; including both chemoautotrophic and photoautotrphic organisms). Gross production refers to the total amount of organic matter fixed in photosynthesis and chemosynthesis by autotrophic organisms, including that lost in respiration. Net production is that part of assimilated energy converted into biomass and reflects the total amount of organic matter fixed by autotrophic organisms less that lost in respiration
Production, secondary	The assimilation of organic matter by heterotrophic organisms (organisms unable to synthesise organic compounds from inorganic substrates)
PSP biotoxins	Toxins of the saxitoxin group produced by some phytoplanktonic species of microalgae that, if transmitted through the food chain, cause a syndrome known as Paralytic Shellfish Poisoning (PSP) because it is mainly caused after the ingestion of shellfish and with respiratory paralysis as the most serious symptom
Pycnocline	A density discontinuity in a water column. This is commonly used to refer to the narrow depth zone at the base of the relatively uniform surface mixed layer within which the density of the water increases sharply either because of a decrease in temperature (thermocline) or an increase in salinity (halocline)
Radionuclide	Atoms that disintegrate by emission of electromagnetic radiation, i.e. emit alpha, beta or gamma radiation
Recruitment (fisheries)	The process by which young fish enter a fishery, either by becoming large enough to be retained by the gear in use or by migrating from protected areas into areas where fishing occurs
Remineralisation	The conversion of a substance from an organically bound form back to a water-soluble inorganic form, resulting in the release of inorganic nutrients (e.g. nitrate, phosphate), carbon dioxide or methane back into solution
Safe biological limits	Limits (reference points) for fishing mortality rates and spawning stock biomass, beyond which the fishery is unsustainable. Other criteria which indicate when a stock is outside safe biological limits include age structure and distribution of the stock and exploitation rates. A fishery which maintains stock size within a precautionary range (a range within which the probability of reaching any limits is very small) would be expected to be sustainable
Salinity	A measure of the total amount of dissolved salts in sea water
Seismic activity	Earthquake events that result from sudden releases of energy related to volcanic activity or rock movements caused by crustal movements
Shelf break	The outer margin of the continental shelf marked by a pronounced increase in the slope of the seabed; usually occurring at around 200 m in depth along European margins
Slope current	A current that follows the shelf break along a continental margin
Standing crop	The biomass of organisms per unit volume at a given time
Sverdrup	A unit of transport used in oceanography to quantify flow in ocean currents. It is equivalent to 10^6 m^3/s.
Terrigenous	Derived from land
Thermocline	A boundary region in the sea between two layers of water of different temperature, in which temperature changes sharply with depth.
Topography	The land forms or surface features of a geographical area
Total allowable catch (TAC)	The maximum tonnage, set each year, that may be taken of a fish species within an area. In the EU, the TAC is a central part of the Common Fisheries Policy. It establishes the total amount of each species that may be caught in EU waters annually. Each year the Council of Ministers establishes TACs for each species, and then each Member State is allocated a quota for each species
Toxaphene	A chlorinated insecticide with an average chemical composition of $C_{10}H_{10}C_{18}$. Primarily used in cotton farming
Toxin	A biogenic (produced by the action of living organisms) poison, usually proteinaceous
Trench	A narrow, elongated U-shaped depression of the deep ocean floor between an abyssal plain and the continental margin where subduction of oceanic crust occurs
Trophic	Pertaining to nutrition
Upwelling	An upward movement of cold, nutrient-rich water from ocean depths; this occurs near coasts where winds persistently drive water seawards and in the open ocean where surface currents are divergent
Vas deferens	The sperm duct
Water column	The vertical column of water extending from the sea surface to the seabed
Water mass	A body of water within an ocean characterised by its physicochemical properties of temperature, salinity, depth and movement
Zooplankton	The animal component of the plankton; animals suspended or drifting in the water column including larvae of many fish and benthic invertebrates

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