OSPAR Commission

for the Protection of the Marine Environment

of the North-East Atlantic

Quality Status Report 2000

Region IV Bay of Biscay and Iberian Coast

Quality Status Report 2000
Region IV – Bay of Biscay and Iberian coast

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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 Bay of Biscay and Iberian Coast

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France, Portugal and Spain shared the work for the preparation of the report; in the period 1995 – 1999 the RTT comprised the following persons:

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

QUALITY STATUS REPORT 2000: REGION IV – BAY OF BISCAY AND IBERIAN COAST

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.

The report presents an assessment of environmental conditions in that part of the maritime area which, for assessment purposes, is known as the Bay of Biscay and Iberian Coast or Region IV. The area extends from 48º N to 36º N and from 11º W to the coastlines of France, Portugal and Spain.

This is the first time a quality status report has been prepared for this region and the report is based upon the most recent information available, compiled initially by scientists based in government and university laboratories in France, Portugal and Spain. The information on human activities was provided by the respective administrations.

Biologically the region can be subdivided into a subtropical zone (from the Strait of Gibraltar to Finisterre) and a subtropical/boreal transition zone (from Finisterre to Brittany). Within the two major zones, the topographical diversity and the wide range of substrates result in many different types of coastal habitat. This diversity is reflected in the biological richness of the region, which includes a wide range of fish species many of these of commercial interest.

The coastal morphology varies considerably, ranging from long sandy beaches in Aquitaine and the Gulf of Cadiz to an almost continuous rocky stretch along the northern and north-western Iberian coast. In the Galician region the coast is dissected by a large number of rias. Rias are unique systems with a wind-modulated estuarine type of circulation; they are highly productive and contain the world's largest mussel raft cultures.

The morphology of the seabed is also highly variable. The continental shelf is relatively wide along the eastern coast of the Bay of Biscay and virtually absent along its southern coast, as well as off the Iberian west coast to the south of Lisbon. Several submarine canyons dissect the continental margin, two of these being among the most pronounced in the world.

Eight river systems represent the principal sources of freshwater input to the region, together comprising an average annual input of 180 km^3; 50% flowing into the Bay of Biscay and 10% into the Gulf of Cadiz. This distribution is a consequence of the position of Region IV relative to the main weather systems. As a result of river regulation, fine particulate material is virtually the only type which reaches the estuaries and adjacent coastal areas. These silt and mud deposits tend to act as sinks for contaminants.

On the continental shelf, the transport is driven by tides and wind, with buoyancy important off major rivers during periods of high run-off, particularly in the Bay of Biscay. Typical tidal ranges of 2.5 m and associated tidal currents of 0.1 m/s may reach 6 m and 1 m/s in confined sections of the Bay of Biscay shelf. Sea and swell dominate from the north-west (the south-west in the Gulf of Cadiz), with higher seas occurring in autumn and winter. Storm waves are the main agents promoting sediment mobilisation over the shelf. Seabed disturbances are relatively short-lived, mainly occurring during repetitions of energetic events.

The most conspicuous upper layer mesoscale features are a poleward-flowing slope current in autumn and winter, and wind-induced coastal upwelling in spring and summer. At intermediate levels the dominant mesoscale phenomenon is the northward propagation of cores of Mediterranean Water. Eddies, and in summer upwelling filaments, are the structures that most effectively transport mass and heat between coastal and offshore waters.

Assessment

A lack of information concerning many aspects of the human activities in Region IV has meant that unambiguous conclusions about the effects of these activities could not be drawn and that it was difficult to establish the appropriate levels of concern. However, it was concluded that the quality status of the Bay of Biscay and Iberian Coast is generally good.

Eutrophication does not appear to be a problem in Region IV although an apparent increase in the occurrence of harmful algal blooms has been reported in recent decades. Contamination by metals and organic compounds associated with urban activities, old mining areas and industrial sources is observed but is rarely of concern, except in some urbanised estuaries.

Several issues are highlighted as being of particular concern because of their present impacts or their possible future impacts:

- several fish stocks – sardine, hake, anglerfish, megrims and swordfish – are outside safe biological limits for sustainable fisheries. This results from the combined effects of overfishing and the influence of natural processes on the recruitment and abundance of these resources;
- mariculture is mainly confined to the cultivation of bivalve molluscs (mussels, oysters and clams) and its impact is usually minimal. However, in some areas the deposition of organic detritus beneath suspended mussels has resulted in benthic enrichment, with an increase in the organic content of the sediments, a decrease in faunal diversity and a predominance of opportunistic organisms;
- that only a small proportion of shellfish farming areas are of good microbiological quality;
- recurrent shellfish toxicity outbreaks caused by marine biotoxins;
- effects in harbours and estuaries associated with the release of TBT from TBT-based antifouling paints;

- conflict of uses in the coastal zone that can lead to a loss of important components of the ecosystem and habitats. For example, damming rivers reduces freshwater flow which may induce coastal erosion;
- a loss of biodiversity due to human impact;
- an increase in mean sea level as a consequence of climate change;
- the risk of introducing non-indigenous species in ballast waters; and
- the sources and effects of marine litter.

A major obstacle to the assessment of environmental quality in Region IV was the lack of comparable, compatible and verifiable data. This lack of fundamental information hinders a prediction of the effects of human activities in the region. Nevertheless, it is recommended that the appropriate authorities consider:

- establishing a Code of Good Practice for Coastal Zone Management;
- implementing the FAO Code of Conduct for Responsible Fisheries;
- increasing the use of Marine Protected Areas as tools for the integrated management of coastal zones, their living resources and the protection and conservation of biological diversity;
- promoting more studies on ecosystem functioning and the sources of variability (natural and anthropogenic), as well as on investigations into the impact of human activities on coastal and marine habitats;
- increasing research on non-indigenous species, ballast water transfers and the control of particular nuisance species;
- increasing research on toxification and detoxification processes, phytoplankton bloom dynamics and their relation to oceanographic events, and inputs of nutrients and organic matter of anthropogenic origin;
- implementing the 1994 ICES Code of Practice on the Introductions and Transfers of Marine Organisms;
- improving the monitoring and forecasting of human impact on the marine ecosystem, identifying trends in marine ecosystems based on key species and by monitoring the state of conservation in selected areas (mainly estuaries and coastal lagoons);
- developing research and management policy programmes for all activities affecting the marine environment, including the obligatory establishment of environmental assessments for specific areas of concern related to significant effects of human activities;
- applying the precautionary approach to fisheries management;
- promoting experimental work on resident biota in different coastal ecosystems to establish reference levels for marine contaminants; and
- establishing national programmes aimed at the recovery of degraded coastal habitats.

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 species and communities and, when practicable, 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.

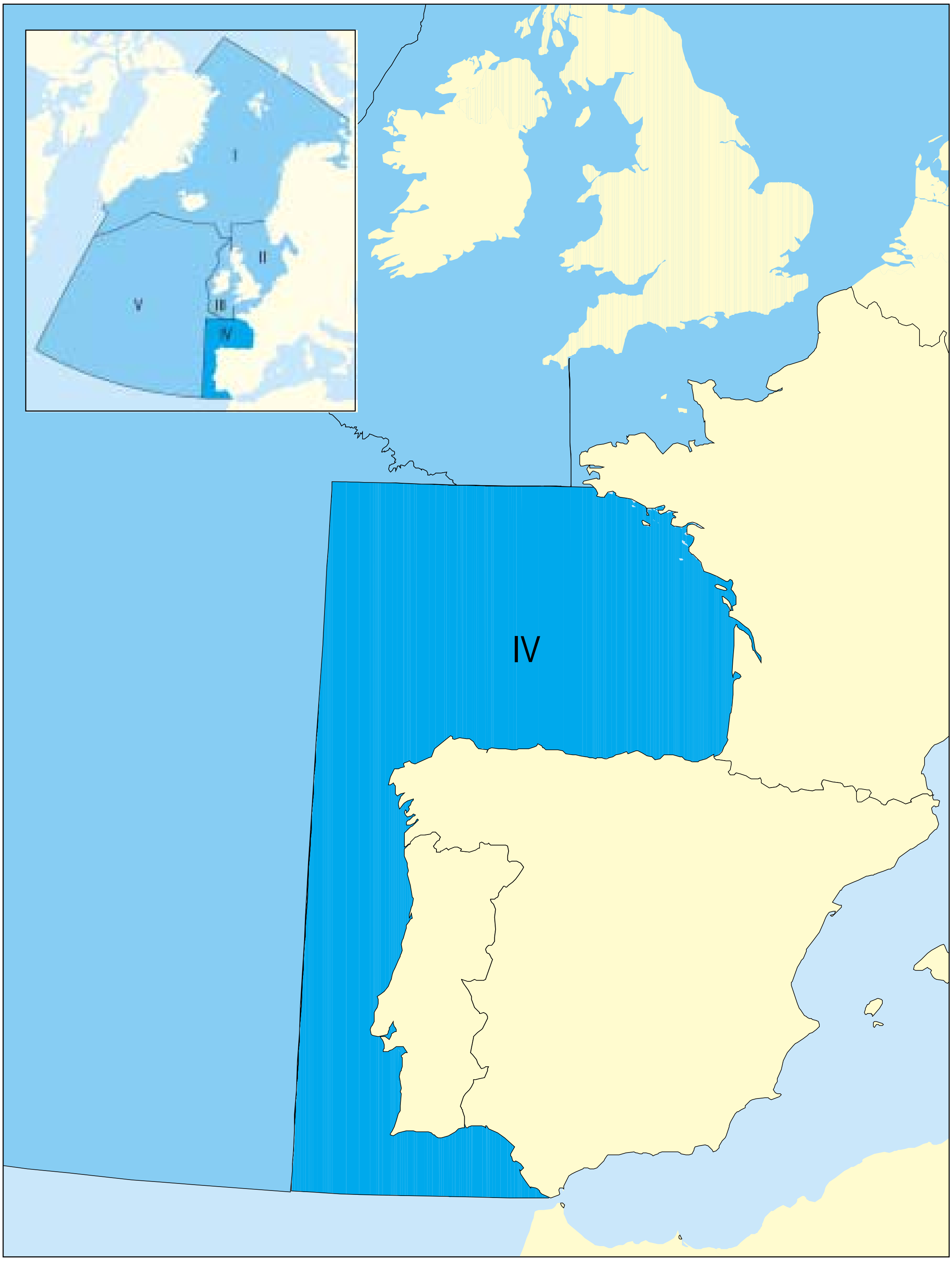
This report presents an assessment of environmental conditions in that part of the Maritime area which, for assessment purposes, is known as the Bay of Biscay and Iberian Coast or Region IV ***(Figure 1.1)***. This area extends from 48º N to 36º N, and from 11º W to the coastlines of France, Portugal and Spain. Together with similar quality status reports for the other four OSPAR regions, this report forms the basis of a holistic and integrated summary of the quality status of the entire OSPAR Maritime area.

The report describes the physical, chemical and biological characteristics of the coastal and marine ecosystems and examines the impact of human activities, evaluating the information available. The information used in the report was compiled initially by scientists based in government and university laboratories in France, Portugal and Spain; information on human activities was provided by the respective administrations. Inevitably, the amount of information available for each topic differed considerably.

1.2 The assessment process

The assessment is based upon 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. 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 consideration of historical conditions. While every effort has been made to ensure the comparability of data from different times and locations,

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



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, identifying localities most affected and 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, makes recommendations for managerial and scientific actions needed to redress them.

Each chapter is accompanied by a list of references to the major sources of information. The terminology used has been kept as non-technical as possible, but where scientific and other terms have had to be used their meanings have been defined in a glossary of terms. The Latin names of the organisms referred to in the text are listed in an appendix, together with their common names in English, French, Portuguese and Spanish.

chapter 2

Geography, hydrography and climate

2.1 Introduction

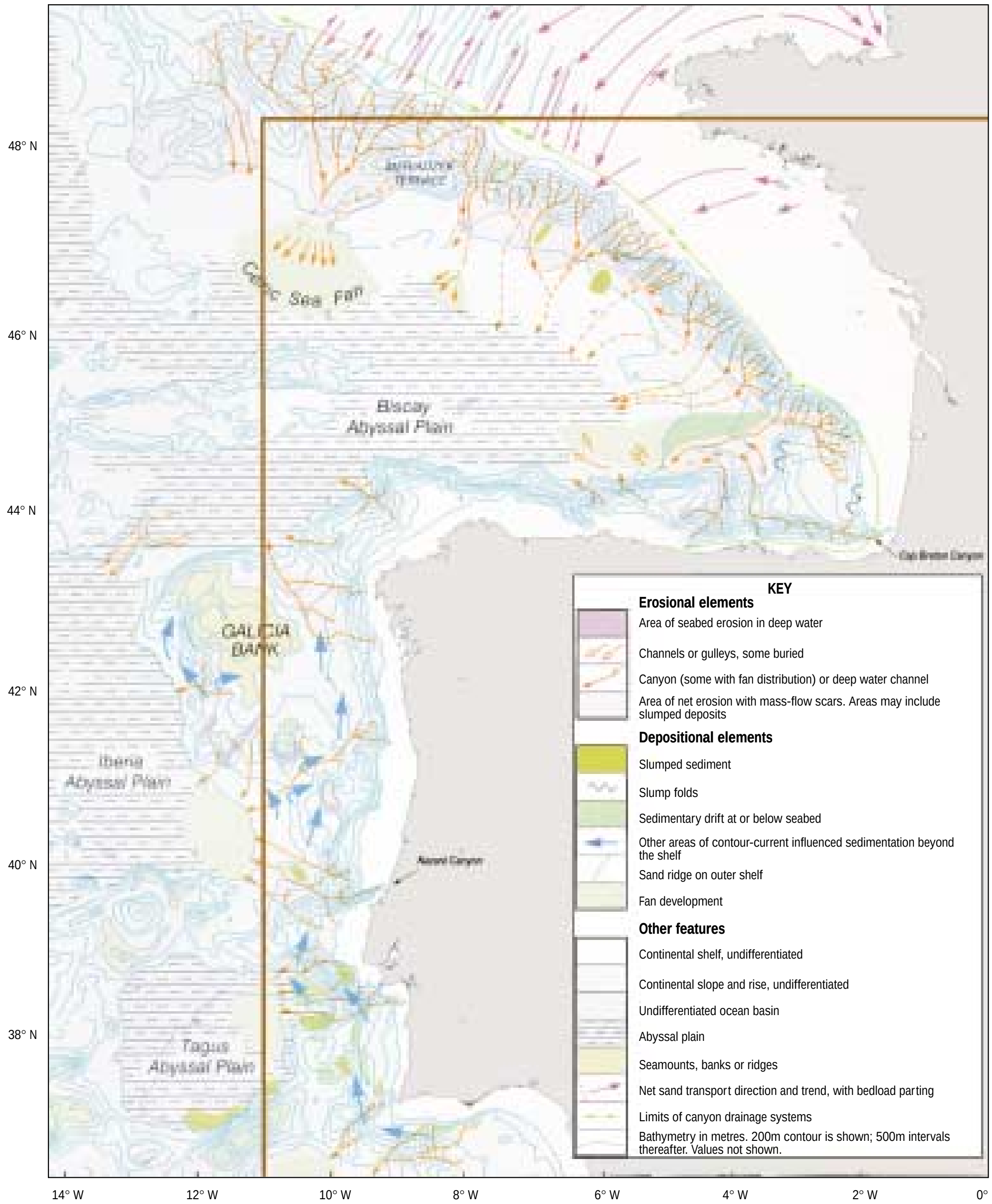
This chapter addresses general aspects of the southern sector of the OSPAR Maritime area and places these within an Atlantic context. A brief description of the geomorphology and geology of the region is followed by reference to the freshwater inputs to the coastal environment, paying particular attention to areas at the interface between the continental margin and the ocean.

2.2 Definition of the region

Region IV comprises the area to the south of 48° N and to the north of 36° N. The western limit is defined by 11° W and the eastern limit by the river catchments that drain into the Atlantic. The region comprises almost the whole of the Bay of Biscay, the European sector of the Gulf of Cadiz and the western Iberian margin *(Figure 2.1)*. These areas fall under the national jurisdiction of France, Portugal and Spain.

The eastern limit of Region IV is a natural feature, easy to identify as it is based on the continental topography. The northern limit is also based on a natural feature and roughly corresponds to the boundary between the Armorican shelf (in Region IV) and the Celtic Sea (in Region III). The western boundary however is an arbitrary geographical limit which transects the coastal margin, and results in some geomorphological features related to the continental mass (for example the submarine mountains of Galicia Bank, see *Figure 2.1*) being addressed within the quality status report for the principally oceanic Region V. Thus some physical processes that are essentially characteristic of a coastal transition zone (see Section 2.10), and

Figure 2.1 **Bathymetry, topography and geology of Region IV. Source: ENAM.**



most appropriately considered within the present report, are addressed within the report on Region V.

The French Central Massif, the northern and western Pyrenees, and the Iberian and Betic mountain systems represent the continental limits to a catchment area of nearly 700 000 km^2. The catchment area is limited to the north by the hills of Normandy and Brittany and includes several important cities. Eight river systems represent the principal sources of freshwater to a sea area of around 550 000 km^2; the majority of the runoff occurring in the northern half of the region.

2.3 Bottom topography

The variable nature of the seabed in Region IV reflects the interaction between the processes that shape the Earth internally and those that work upon its surface. This interaction has occurred since the opening of the Atlantic Ocean. The resulting bottom topography is an important means of identifying current sediment dynamics (i.e. areas of sedimentation and erosion, and the routes by which sediments are transported).

The continental margin is divided into subregions by the occurrence of seamounts, banks and submarine canyons *(Figure 2.1)*. Some of these canyons are particularly prominent, such as the Cap Breton Canyon, where the 1000 m isobath is to be found only 3 km from the coast.

The continental shelf is an area of gentle slopes and small-scale rock outcrops (Vanney and Mougenot, 1981). These slopes reflect current sediment accumulation processes as well as long-term changes that have occurred since the last glaciation. The continental shelf is particularly important in the northern Bay of Biscay, where it is more than 140 km wide and has a very gentle slope of 0.12%. In contrast, the shelf may be as narrow as 12 km along the Cantabrian coast. Off western Iberia the only relatively wide section is between the river Miño and the Nazaré Canyon, whereas the continental shelf in the Gulf of Cadiz is of the order of 50 km wide, particularly to the east.

The shelf-break occurs at depths of around 180 – 200 m in the area to the north of the Nazaré Canyon and at 130 – 150 m in the Gulf of Cadiz.

The continental slope, which marks the transition between the continental shelf and the deep-sea environment, is relatively steep throughout most of Region IV with a slope of the order of 10 – 12% and is dissected by numerous valleys. The continental slope is not as steep in the Gulf of Cadiz.

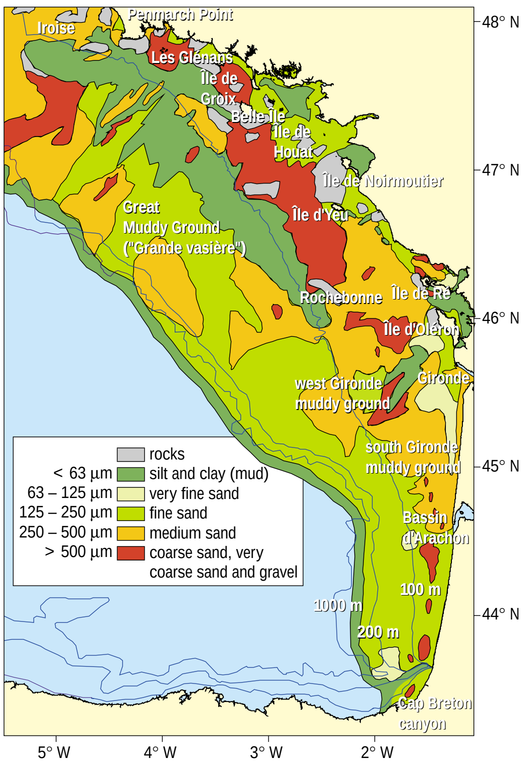
2.4 Geology and sediments

The area has undergone several mountain-forming cycles that are reflected in the geological record. Oceanic sediments deposited more than 250 million years ago show a history of folding, fracturing and metamorphism due to the intrusion of granite. These rocks were the main source of later detrital sediments. Younger sedimentary rock strata are based on these detrital sediments together with carbonate. These were deposited when the ocean was opening and afterwards deformed by compression (Pinheiro *et al*., 1996). As sea level fluctuated during these events, various rock types occur, such as evaporites, märls, sandstones, limestones and mudstones.

At the bottom of the continental margin the sediment cover mainly consists of thick turbiditic sheet-fan deposits, laid down during episodes of tectonic instability. These alternate with deposits reflecting periods with less energetic sedimentation, and which tend to have a higher silt and clay content *(Figure 2.2)*. Contouritic deposits occur in the Cantabrian Sea and, particularly in the Gulf of Cadiz, in areas where the current slackens or the flow reaches deeper parts of the margin with more gentle slopes.

The continental shelf and upper slope sediments originate mostly from the continent. These terrigenous particles are either transported to the oceanic environment by rivers or are the products of the erosion of rocky coastlines, further mixed with organic and autigenic particles. Their grain size depends on their proximity to the source *(Box 2.1)* and on mean sea level fluctuations since the last glaciation (20 000 years ago); during the last

Figure 2.2 **Surface sediments on the continental shelf, eastern Bay of Biscay. Source: Allen and Castaing (1977).**



glaciation mean sea level was approximately 130 m lower than at present (Dias, 1987; Turcq *et al.*, 1986).

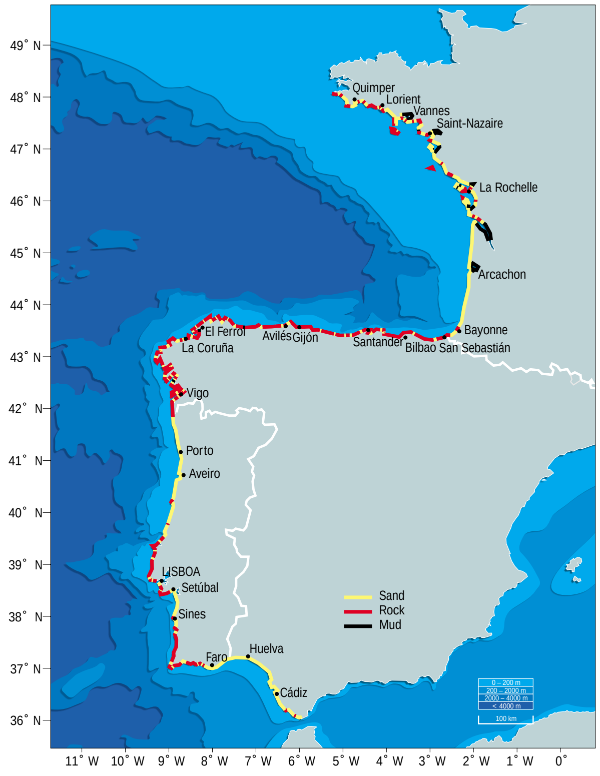
2.5 Description of the coastal margin

The coastal margin represents a transition zone between land and ocean. Its morphology reflects historical and present-day changes in sea level, human activities within the coastal zone, river loads, longshore transport and the sediment budget. *Figure 2.3* provides a simplified overview of coastal morphology.

From Penmarch Point, at the extreme north-western end of Region IV, to the Vendée coast the coastline is jagged and composed of volcanic and metamorphic rock formations with abrupt slopes of variable height. The NW-SE orientated littoral is particularly battered. The region between Belle-Ile to Noirmoutier Island is relatively protected by islands and shoals and large mud banks occur at depths of 30 m or less. Between the islands of Noirmoutier and Ré, the Vendée coast is a discontinuous strand of coastal dunes.

From the Charante narrows to the right bank of the Gironde estuary, the coastline is calcareous and represents a transition to detrital and clay formations. *Figure 2.4* illustrates the widespread areas of marshland which occur on this section of the French Atlantic Coast.

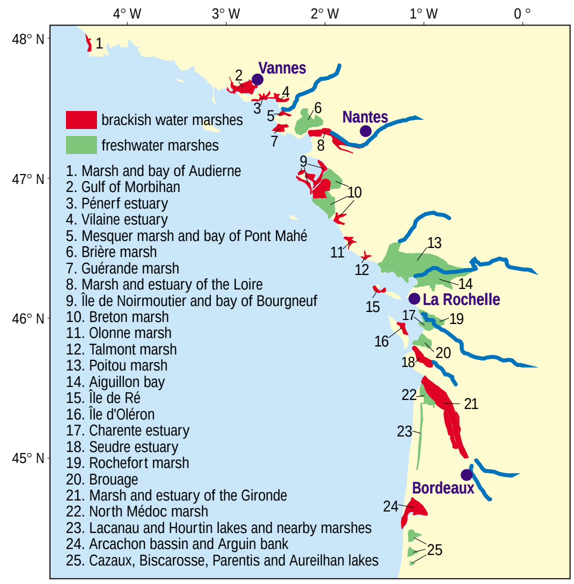
Figure 2.3 **Coastal morphology. Source: EC – Corine coastal erosion database.**



Box 2.1 Continental shelf sediments

Sediments generally become progressively finer as water depth and distance to the coast increase. However, as this is also the case during periods of low sea level, relic coarser deposits may also be found on the mid and outer shelf – the western Iberian shelf is one example of where these occur. Finer deposits (i.e. silt and clay) may also be found on the shelf ***(Figure 2.2)***; these occur in the vicinity of major estuaries in restricted patches protected from wave action (Castaing and Jouanneau, 1987) or result from the retention of suspended particles in winter thermohaline fronts.

Figure 2.4 **Marshlands of the French Atlantic coast. Source: IFREMER; IFEN.**



South of the Gironde, the Aquitaine coast is rectilinear, devoid of islands and directly exposed to the swell. The sandy coastline is in a constant state of change and being eroded at rates of 1 – 5 m/yr. The eroded material is then moved southwards.

A major change is observed with the transition to the Basque coast. This coastline is mountainous, precipitous and very jagged, with numerous rivers and gullies along its length. The rocky coastline extends for 1075 km along the Cantabrian coast, and then for 1354 km, first westwards and then southwards, along the Galician coast. It is the most irregular section of the Iberian Peninsula and contains many rias (see Section 2.6.2). Beaches cover 6.3% of the Cantabrian coast and 13.8% of the Galician coast.

South of Galicia, but to the north of 41° N, the coastline is mostly rocky and shallow. To the south of 41° N, a rectilinear sandy coast extends to just north of the Nazaré

Canyon, interrupted only by Cape Mondego, just north of 40° N. Further south, beaches are replaced by cliffs which extend to Cape Raso, at the latitude of Lisbon. Carbonate rocks are eroded by wave action and the sediments rapidly transported out of the area. Sediment only accumulates at the mouths of small rivers and creeks. From Cape Raso to Cape Sines (38° N) two irregular rocky sections of coastline alternate with two smooth sandy sections. Steep cliffs occur to the south of Cape Sines, with a few beaches at the mouths of small creeks and coastal inlets.

Cliffs also characterise the western section of the southern Iberian Peninsula. To the extreme west the cliffs are cut in carbonate rocks and the beaches are small and mainly associated with creek mouths. Proceeding eastwards the cliffs become cut in detrital rocks, and the lower levels of consolidation allow more extensive strands. As a rule, both types of cliff are actively and strongly subject to erosion. As the littoral drift is mainly eastward, sediment accumulations occur to the east of the water lines (Dias, 1987).

To the east of 8° 20' W, a continuous sandy strip occurs at the base of a line of cliffs. As a result of the increasing protection provided by the sand deposits, cliffs are no longer subject to erosion and further inland fossil cliffs occur. Roughly between 8° W and 7° 30' W there is a series of barrier islands which correspond to the outer limit of a lagoonal area known as Ria Formosa. This contains bars which migrate eastwards at rates of up to 100 m/yr. Further east, a wide coastal plain extends to the mouth of the Guadalquivir Estuary. Marshes and spits (Huelva and Seville) give way to a rocky relief combined with sandy beaches, dunes and marshes, as well as a wide bay (Cadiz). At the south-eastern end, between Sancti Petri and Punta Tarifa, steep slopes and cliffs predominate, with sandy beaches at their base.

2.6 Estuaries, rias and wetlands

2.6.1 Estuaries

Estuaries occur at the transition between river basins and the ocean, often in association with wetlands, sometimes with rias. Throughout history, estuarine areas have been the focus of dense human settlements.

Most estuaries are affected by human activities to some extent, for example, agriculture, cattle breeding, industry, urbanisation, sanitation and transport. The Miño estuary however, is an example of one which has remained relatively undisturbed. The Miño is the second most important river on the north-western Iberian coast; good water quality, a low population density and almost no industry at the margins have resulted in a relatively pristine environment suitable for conservation and protection.

Box 2.2 The Loire and Gironde estuaries

The Loire estuary has a surface area of 60 km^2. During periods of low run-off, the upstream tidal and saline limits are currently 100 km and 73 km from the river mouth respectively. Dredging and sand extraction since the early 1900s have displaced these limits upstream by almost 30 km. During periods of average run-off, the suspended particulate load in the estuary varies from 0.05 x 10^6 t on neap tides to 1 x 10^6 t on spring tides; the difference forming temporary deposits of fluid mud 1 – 3 m deep. At low run-off, this turbid layer extends up the estuary for about 40 km, its upper limit being 80 km from the river mouth. Under flood conditions, these sediments are partly (30%) expelled from the estuary and the upper limit of the turbid layer is only about 20 km from the river mouth. Sedimentation in the estuary together with various engineering works have reduced the area of sand and mudflats between Saint-Nazaire and Nantes by almost 30% since 1957 (55% since 1881) (Migniot and Le Hir, 1997). The accumulation of particulate matter in the estuary, derived from phytoplankton production upstream in the river, causes a high oxygen consumption on summer spring tides. The resulting anoxia affects the estuary over several tens of kilometres, is harmful to estuarine wildlife and causes frequent fish kills (Sauriau et al., 1996).

The Gironde is the largest and one of the most well known estuaries in Europe (Mauvais and Guillaud, 1994). It is 80 km long, has a surface area of 625 km^2 and the tidal effect is felt well into the lower courses of the two contributory rivers – the Garonne and the Dordogne – some 160 km from the river mouth. On spring tides, the tidal range is a constant 5.5 m within a distance of 120 km from the sea. The turbid layer (4 – 5 x 10^6 t) extends over 40 km, depending on river flow. On average river flow varies from 175 m^3/s in August–September to 1620 m^3/s in February; a flow > 2000 m^3/s is required to remove the turbid layer from the estuary and at flows < 700 m^3/s it migrates upstream. The average retention time of particles in the turbid layer is about two years and on average the turbid layer is pushed out of the estuary on around 30 days a year. Almost 50% of the suspended particulate matter is thus trapped in the estuary and contributes to its silting. Between 1900 and 1973 the volume of the estuary in low run-off summer conditions fell from 2.35 km^3 to 2.16 km^3. During conditions of low summer run-off, oxygen saturation has been observed to drop to 30%; a level regarded as a threshold for the survival of fish.

Dams generally cause major changes in estuarine systems. One example of where major changes have occurred is the Vilaine estuary, in Brittany. Since the Arzal dam was completed in 1970, the length of the estuary has reduced by 80%, the fluctuating volume by 40% (Gouleau *et al*., 1981), the saline layer has increased and the sediment load has greatly reduced (Le Hir *et al*., 1986).

The Guadiana estuary on the southern Iberian Peninsula is another example. More than 40 dams, built since the 1960s, regulate about 75% of a catchment area where the precipitation has consistently fallen. The result is an extremely low run-off in summer (sometimes none) and a major decrease in the volume of sediment supplied from the river to the estuary. Jetties built since 1974 have also modified sediment dynamics within the delta, resulting in considerable changes in its morphology (Morales *et al*., 1997). A major dam is currently being built far downstream on the Guadiana river; potentially this will create the largest artificial lake in Europe. Harbours also affect estuaries. Since the mid 1800s dredging in the estuaries near Bilbao has greatly reduced the tidal flats.

The Vouga Estuary, on the west coast of Portugal, is a coastal lagoon that has little interaction with the coastal ocean. A large complex of chemical industries located near the estuary has had a considerable impact on bottom sediments. Further south the waters of the Tinto and Odiel rivers, which discharge into the Gulf of Cadiz, are both acidic (occasionally falling to a pH of 2 or 3) and contain considerable quantities of metals derived from mining activities. Their fine estuarine sediments are significantly contaminated by heavy metals in apparent association with high levels of organic carbon, resulting from the precipitation of dissolved matter in the river (Nelson and Lamothe, 1993).

As a result of rising sea level many estuaries are currently becoming silted. Most of the sand particles transported by rivers, as well as by longshore drift, are retained in estuaries. Although fine particulate material (< 63 mm), generally enters the oceanic environment in the form of surface plumes and bottom fans, studies suggest it is the dispersion of estuarine waters that is the principal mechanism by which particulate material is transferred to the ocean. The Loire and Gironde estuaries are used to illustrate this point *(Box 2.2)*.

2.6.2 Rias

Rias are coastal inlets found around the north-western and northern Iberian Peninsula. They resemble fjords, although their width and depth tend to decrease monotonically inward, and their freshwater run-off is much less than through a fjord. Some rias support extremely productive ecosystems that form the basis of important economic activities. For example the Ria of Arosa, on the west coast of Galicia, has the world's largest mussel production site, producing > 100 000 t/yr. Most rias provide very good shelter from the open ocean and this has led to the establishment of important harbour facilities in some. Vigo is Spain's main fishing harbour and around 400 000 people live in the vicinity of the ria.

The mussel industry generates substantial quantities of suspended solids, in addition to those carried into the rias by the rivers. The near bottom water layers are therefore very murky, while the bottom is muddy and anoxic conditions occur in the sediments. Active circulation inside the rias however, prevents the development of anoxic conditions in the water column. The active circulation also prevents silting in the ria proper, but not necessarily in the estuarine sectors (see also *Box 2.3*).

Box 2.3 The rias of Galicia

The Galician rias have a common origin in the Miocene, Pliocene and Pleistocene Epochs, when erosive processes reshaped the bedrock through deep weathering in pre-existing fault areas (Cotton, 1956). A ria consists of three sections: the estuary (near the head), the ria proper (a central channel along the longitudinal axis) and the bay (at the mouth). Some of the bays are partly closed by islands, as in the case for the rias Vigo, Pontevedra and Arosa, thus creating channels of different sizes and providing shelter from direct oceanic influence. Fine sediments with high organic contents cover the bottom of the estuary sections, particularly at the northern margins (Acosta, 1982; Vilas *et al*., 1996), while sand and gravel dominate the bay sections. The rias bajas (i.e. Vigo, Pontevedra, Arosa and Muros) are sunken river valleys caused by the increase in sea level since the last glaciation. The rias altas (to the north of Finisterre) as well as the Ria of Muros are much more exposed, due to their orientation or to the absence of sheltering islands.

The basic pattern of circulation within a ria is caused by the density difference between the river water flowing out of the ria at the surface and the denser saline water flowing into the ria underneath, with some mixing between the two (Otto, 1975). The direct importance of the tide in the water exchange between the ria and the continental shelf is small (the tidal range is 2 m). However it does promote mixing, which thus reduces the salinity difference between the layers and increases the water volume that is exchanged (Fernández de Castillejo and Lavin, 1982).

The winds that blow over the continental shelf also act upon the rias (Blanton *et al*., 1984, 1987). Northerly winds during summer promote the offshore displacement of surface water which is replaced at the coast by water upwelled from deeper levels (see also Section 2.9.3). This water is cooler and richer in nutrients and so contributes to an increase in primary production near the coast (Fraga, 1981). The northerly winds also increase the flushing rates and the estuarine circulation within the rias, as well as increasing their nutrient contents by renewal with upwelled water. In contrast, the westerly or southerly winds during winter pile surface water up against the coast, a proportion of which sinks near the coast and promotes the intrusion of nutrient-poor water into the rias (Blanton *et al*., 1984), reducing the estuarine circulation.

Industrial effluents from chlorine-soda and paper pulp factories reduce water transparency in the Ria of Pontevedra. Industrial pollution in the remaining rias is negligible, except in areas close to harbours.

2.6.3 Wetlands

Coastal marshlands are situated on low-lying alluvial deposits at the edge of the tidal plains. Tides affect the flow of water through the marshes and they are important for the fish stocks of the neighbouring sea areas. The marshes protected by dikes that were traditionally used for salt production and aquaculture for example, are now used less and less for economic reasons, and 80% of those used for such purposes in France are now under-exploited.

On the French Atlantic coast the seventeen main groups of marshes form a link in the water cycle between land and sea (*Figure 2.4*; see also *Box 2.4*). On the northern Iberian coast there are two main marshes: the Urdaibai (30 km north-east of Bilbao) and the Oyambre (west of Santander) and these are both Nature Parks. On the western Iberian coast important salt marshes occur around the estuaries of the Vouga, the Tagus and the Sado rivers. They are important feeding areas for resident and migratory waterfowl, as well as for young fish. In the Gulf of

Box 2.4 Major marshlands of the French Atlantic coast

The Gulf of Morbihan is similar to a 115 km^2 inland sea and contains 40 islands. It has a negligible drainage basin and communicates with the ocean via a narrow inlet. The area is under pressure from tourism and urbanisation.

The Vilaine Estuary occurs at the mouth of the main waterway in Brittany. This flows through important cattle breeding and associated farming areas and is subject to pollution by pesticides and fertilisers. It is also affected by effluents from the city of Rennes.

The Loire Estuary is affected by pollution from land-based sources and its marshes have reduced from 40 000 ha to 18 000 ha over the last 100 years.

The Bay of Bourgneuf with the Breton marsh and the Ile de Noirmoutier.

The Vendée coast (marshes of Olonnes and Talmont).

The Charente Estuary, the Ile de Ré marsh and the very shallow Poitou marsh (a complex hydrological system 5 m deep which is very sensitive to pollution but also has some purifying capability) and the marshes near La Rochelle (close to land supporting cattle breeding activities and subject to urban pressure around the city).

The Bay of Marennes-Oléron (Rochefort marsh, Seudre Estuary and Ile d'Oléron) contains important shellfish farms.

The Gironde Estuary which contains the city and harbour of Bordeaux.

Box 2.5 Salt marshes in the Bay of Cadiz

The Sapal de Castro Marim is a Nature Park on the right bank of the Guadiana.

The Piedras Estuary is a semi-enclosed estuarine area delimited by a longshore spit bar (the Rompido), with a low freshwater run-off and a restricted sediment supply due to the presence of a dam built in 1968.

The Tinto and Odiel Estuary is another semi-enclosed estuarine area delimited by a spit bar (Punta Umbria). The region is almost 72 km^2 and includes five different biotopes. It is a declared Nature Place and a Unesco Biosphere Reserve.

The Doñana Nature Park covers an area of > 27 000 ha of marshes (including an animal reserve) and has a 32 km long unspoilt beach with active and stabilised sand dunes covering 507 km^2 on the right bank of the Guadalquivir Estuary. The region is a Unesco Biosphere Reserve and holds a Category A Diploma of the Council of Europe.

The Sancti Petri marshes in the southern Bay of Cadiz cover a total of 170 ha, comprising a tidal plain, a lake corresponding to an old swamp, and a chain of sand dunes and beaches.

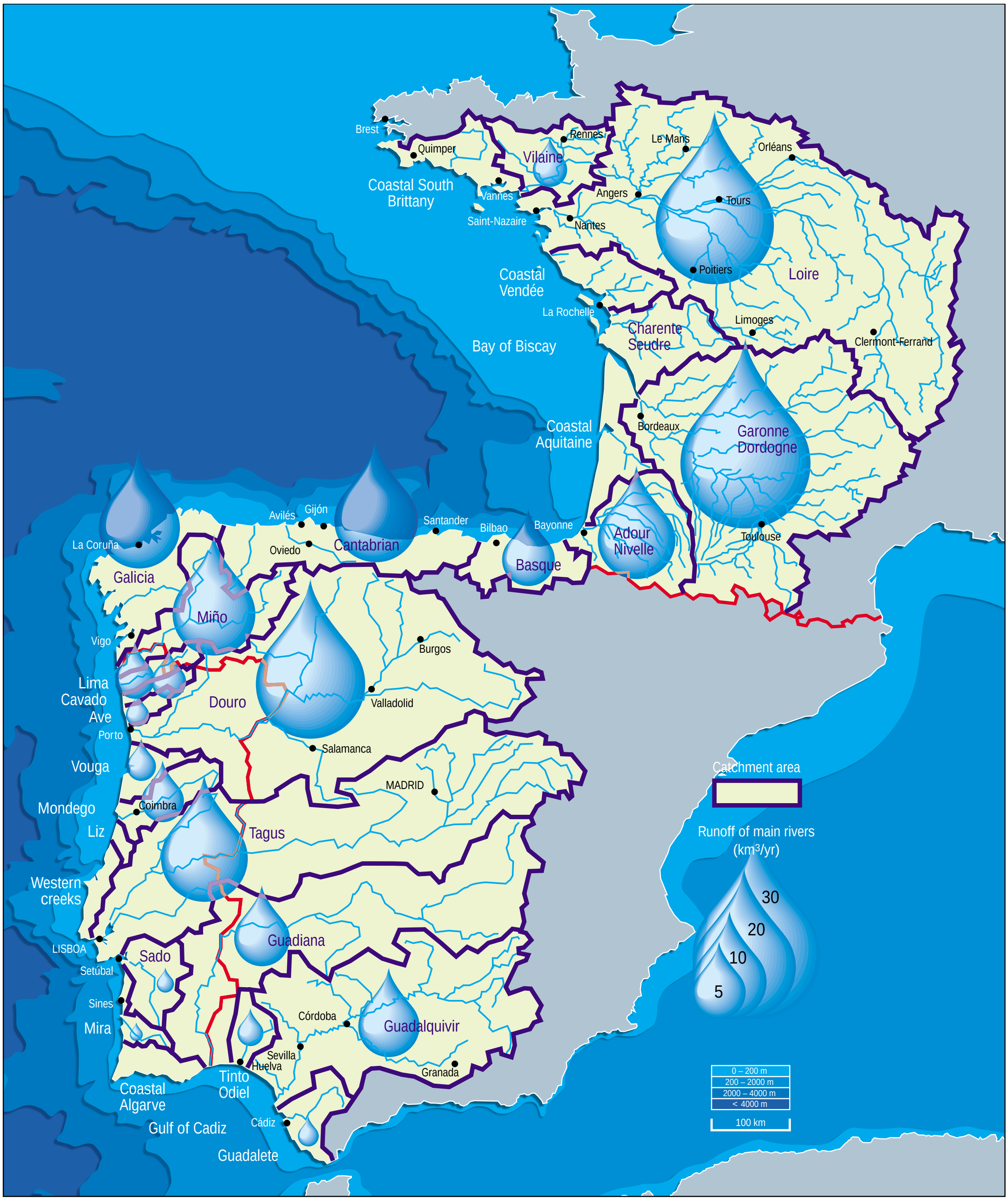
Box 2.6 Coastal lagoons

The Arcachon basin is a large Atlantic lagoon connected to the ocean. The region supports shellfish production and an important tourism industry. It is located in the middle of an area mainly characterised by forestry and associated industries.

The Ria Formosa is a Nature Park on the southern Iberian coast. It is located between the mainland and a system of barrier islands formed after the Middle Ages, when sea level was considerably lower (Dias, 1987). Inappropriately referred to as a ria, the Ria Formosa has a very low freshwater input, virtually none in summer, and its dynamics are dominated by tidal flushing, with a significant residual circulation. The region supports fishing activities, aquaculture (fish and shellfish), tourism, a busy harbour, and the city of Faro and its airport. Rising sea levels, together with severe winter storms, are causing the coastline to retreat. Also, recent building activities on the barrier islands (particularly the westernmost island), and the construction of jetties to the west of the ria are affecting the dynamic balance of the system.

The Bay of Cadiz is a semi-enclosed shallow water lagoon; the external bay is influenced by the wind, tide and local currents, while the hydrodynamics of the inner bay are strongly related to tides. The innermost marshes and wetlands are dissected by meandering channels.

Figure 2.5 **Catchment areas and run-off from the main rivers.**



Cadiz the major salt marshes occur in association with estuaries *(Box 2.5)*.

The main coastal lagoons of Region IV occur on the French Atlantic coast and in the Gulf of Cadiz *(Box 2.6)*. Small lagoons with intermittent communication with the sea also occur along the central Iberian west coast, for example at Óbidos, Albufeira, Melides and Santo André. They are minor fishing and shellfish collection sites and are also used for leisure activities.

2.7 Catchment areas and river systems

The catchment areas that drain into Region IV *(Figure 2.5)*

Table 2.1 Characteristics of the catchment areas for Region IV.

Basin	Catchment area (km^2)	Run-off (km^3/yr)	Variability (%)	Dams	Storage capacity (km^3)	Available resources (km^3/yr)	Agricultural demand (km^3/yr)	Urban demand (km^3/yr)
Coastal southern Brittany	7 080	-	-	-	-	-	-	-
Vilaine	10 420	2.1	-	-	-	-	-	-
Loire	118 420	26.0	-	-	-	-	-	-
Coastal Vendée	7 500	-	-	-	-	-	-	-
Charentes/Seudre	11 970	-	-	-	-	-	-	-
Garonne/Dordogne	79 180	31.2	-	-	-	-	-	-
Coastal Aquitaine	7 660	-	-	-	-	-	-	-
Adour/Nivelle	17 100	10.7	-	-	-	-	-	-
Basque	5 720	5.3	-	-	-	0.31	0.20	0.27
Cantabrian	17 330	13.0	-	-	-	1.47	0.08	0.21
Galicia	13 130	12.6	-	-	-	0.86	0.53	0.21
Miño	17 081	12.8	39	39	2.8	3.44	0.53	0.21
Lima	2 480	2.9	43	3	0.5	-	-	-
Cávado	1 589	2.3	40	8	1.2	-	-	-
Ave	1 390	1.0	50	5	< 0.1	-	-	-
Douro	97 682	22.4	53	64	8.2	8.13	3.60	0.21
Vouga*	3 268	2.0	51	3	0.5	-	-	-
Mondego	6 644	3.4	58	22	0.5	-	-	-
Liz	-	0.3	39	0	0	-	-	-
Tagus	80 629	14.0	55	141	13.3	7.07	1.87	0.74
Sado	7 640	1.1	82	8	0.6	-	-	-
Mira	1 576	0.3	-	1	0.2	-	-	-
Algarve†	3 848	0.5	-	2	-	-	-	-
Guadiana	66 960	5.6	85	> 40	> 8.7	2.71	2.12	0.12
Tinto/Odiel	7 030	1.3	-	-	-	0.26	0.17	0.04
Guadalquivir	54 970	7.1	-	-	8.1	3.32	2.88	0.42
Guadalete	6 440	0.8	-	-	-	0.31	0.26	0.11
TOTAL	654 737	178.7	-	> 336	> 44.7	-	-	-

*catchment area excludes the area of the Ria de Aveiro; †corresponds to the basins of all rivers and creeks flowing off the Portuguese south coast (the main one being the river Arade) and therefore excludes those that are part of the Guadiana catchment area; - zero or not known.

cover approximately 700 000 km^2 and have an average annual run-off of approximately 180 km^3 *(Table 2.1)*. Over half the total catchment area and the total annual run-off correspond to rivers that drain into the Bay of Biscay. From another perspective, more than half the run-off is due to four river systems which discharge into the sea in relatively small areas: the mouths of the Loire and Gironde are only 220 km apart, and those of the Miño and Douro only 100 km apart. These values contrast strongly with the 15 km^3 that discharge into the Gulf of Cadiz in an average year, and the 1.4 km^3 that discharge into the coastal waters off the southern Iberian west coast.

The ratio of river run-off to catchment area is greatest for the basins of the Basque area, as well as for northern and north-western Iberia. This is due to the proximity of the mountains to the sea in these areas and helps to explain why the interannual variability in river run-off is highest in the south where run-off is at a minimum. The alternation between high and low run-off appears to correspond to periodicities of 8 to 13 yr in the Gironde and 20 yr in the Loire. This periodicity may be associated with atmospheric variability affecting the occurrence and intensity of precipitation (see Section 2.13).

The basins of many of the international Iberian rivers are significantly regulated, with installed storage capacities ranging from 25% to 200% of the average annual run-off. It is possible to store 95% of the run-off in the Tagus, while the storage capacity of the Guadiana is currently 1.5 times larger than the annual run-off, and this will increase dramatically once the Alqueva dam is finished. However, although there is no evidence that river regulation has contributed to any drop in the interannual variability of run-off *(Table 2.1)*, dams do affect hydrological systems; damping seasonal variability and interrupting the supply of sand to the ocean. These reductions in the supply of sand have contributed to the serious problems of coastal erosion.

2.8 **Water masses**

The majority of Region IV corresponds to the continental margin of the southernmost part of the OSPAR Maritime area. Most of the water masses occurring in Region IV *(Table 2.2)* have a North Atlantic source or result from interaction between waters formed in the Atlantic with water of Mediterranean origin. Deep winter mixing beyond the continental slope north of 40° N is also likely to give rise to the formation of water masses in the upper ocean (0 – 500 m), particularly in the western Bay of Biscay. This process is subject to significant interannual variability (Pollard *et al*., 1996).

2.8.1 Deep layers

Perturbations propagate cyclonically within the vicinity of an ocean boundary (Gill, 1982), i.e. with the coast to their right in the northern hemisphere. Water masses with the strongest signal are thus expected to reach Region IV from the south, except in the wind-driven surface layer where atmospheric forcing is the major factor driving transport. At deeper levels, water masses with a northern origin tend to reach the ocean boundary from offshore; turbulent diffusion playing an important role in this process. Deep water masses from the north, such as Labrador Sea Water (LSW), are thus most likely to be detected in the north-western Bay of Biscay (Fruchaud-Laparra *et al*., 1976).

2.8.2 Intermediate layers

Mediterranean Water (MW) occupies the intermediate levels of the water column in Region IV. Due to excess evaporation within the Mediterranean Sea, a sea surface slope is established between the Atlantic and the Mediterranean. This causes a surface inflow of Atlantic water through the Strait of Gibraltar and an outflow of MW at the deepest levels of the Strait. The process is intermittent and highly dependent on wind forcing (Candela *et al*., 1989; Gründlingh, 1981). In the eastern Gulf of Cadiz the warm (12.7 °C), saline (38.4) outflow from the Mediterranean is very dense and sinks under water of Atlantic origin until it reaches an equilibrium level. Initially it flows as a single core while its salinity is drastically reduced by mixing with the surrounding Atlantic water. At about 8° W, in the western Gulf of Cadiz, it reaches density values corresponding to those of mid-depth Atlantic layers and splits into two cores, characterised by intermediate maxima of temperature (‘upper’ core) and salinity (‘lower’ core), and separates from the bottom. A third, ‘shallow’, core acquires individuality at the western Gulf of Cadiz, but remains identifiable only along the south-west coast of the Iberian Peninsula (Âmbar, 1983; Hinrichsen and Rhein, 1993). The temperature and salinity characteristics of these three cores are given in *Table 2.2.*

Table 2.2 Water masses in Region IV. Source: Âmbar (1983); van Acken and Becker (1996); Âmbar and Howe (1979a); Emery and Meinke (1986); Maillard (1986); Pollard *et al*. (1996); Rios *et al*. (1992).

Water mass	Depth (m)	Potential temperature (°C)	Salinity	Potential density anomaly (kg/m^3)
Eastern North Atlantic Central Water				
subtropical branch	< 300	> 12.5	> 35.75	< 27.05
subpolar branch	< 400	10.5 – 12.5	35.55 – 35.70	27.05 – 27.15
Bay of Biscay	< 600	10.5 – 11.5	35.55 – 35.60	27.15 – 27.25
Mediterranean Water				
shallow	400 – 700	11.8 – 12.2	35.80 – 35.90	27.20 – 27.30
upper	700 – 900	10.5 – 13.5	35.8 – 36.8	27.40 – 27.65
lower	1000 – 1500	9.5 – 12.5	35.8 – 37.5	27.70 – 27.85
Eastern Atlantic Subarctic Intermediate Water*	500 – 1500	6.0 – 9.0	35.1 – 35.3	27.40 – 27.60
Labrador Sea Water†	1500 – 3000	3.4 – 4.0	34.90 – 34.95	27.70 – 27.80
Lower Deep Water‡	> 3000	< 3.3	34.90 – 34.95	> 27.80

* this water mass is only identifiable in the north-west of Region IV; † the salinity minimum characteristic of LSW is clearly visible to the north-west of Region IV, elsewhere its characteristics are ‘blurred’ by the influence of MW from above and North Atlantic Deep Water from below; ‡ Lower Deep Water comprises contributions from the Iceland–Scotland overflow water, the deeper levels of the LSW (that give rise to North Atlantic Deep Water) and some Antarctic Bottom Water that penetrates into the North Atlantic through Discovery Gap on the western flank of the Madeira–Tore Rise

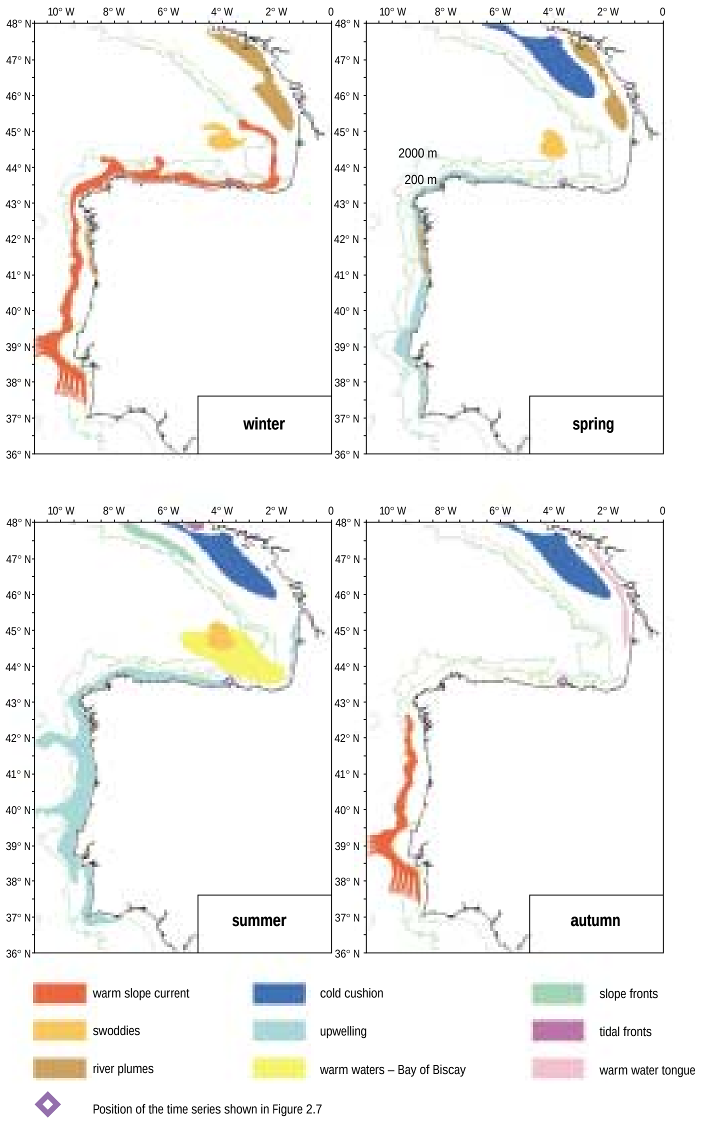
2.8.3 Upper layers

Eastern North Atlantic Central Water (ENACW) occupies the upper water layers, i.e. those affected by winter mixing and overlain by the seasonally varying surface water. ENACW is formed in two main areas; a subpolar branch is formed just to the south of the North Atlantic Current and spreads southwards or south-eastwards into Region IV (Pollard *et al*., 1996), while a subtropical branch is formed at the northern margin of the Azores Current (roughly at the southern limit of the Convention area) and moves north-eastwards towards the Iberian coast (Pingree, 1997). Within the Bay of Biscay, winter convection is also likely to give rise to a particular mode water (Fraga *et al*., 1982) that does not appear to undergo significant exchange with the surrounding Atlantic waters. The two main branches of the ENACW converge off the north-west corner of the Iberian Peninsula, where the subpolar branch sinks and spreads southwards under the subtropical branch. The subtropical branch tends to lose its identity to the north of the convergence area (Fraga *et al*., 1982; Rios *et al*., 1992). The temperature and salinity characteristics of the three modes of ENACW are given in *Table 2.2*.

2.8.4 Seasonal variability

Figure 2.6 illustrates the main features of the hydrography and circulation in Region IV, with emphasis on the shelf and the upper ocean layers. The annual sequence of events generally follows the seasonal cycle of temperate

Figure 2.6 **Seasonal variation in the main hydrographic features of Region IV. Source: based on the approach of Koutsikopoulos and Le Cann (1996).**



seas. For example on the Cantabrian shelf (Lavín *et al.*, 1998) the principal processes concern coastal upwelling in spring and summer and in winter, a warm poleward-flowing slope current and freshwater run-off at the surface. Wind forcing, heating, rainfall and river run-off modify the characteristics of these waters, and impose considerable spatial, seasonal and interannual variability. For example, *Figure 2.7* shows a warming trend which occurred between 1991 and 1995 in the surface waters off Santander (Lavín *et al.*, 1998).

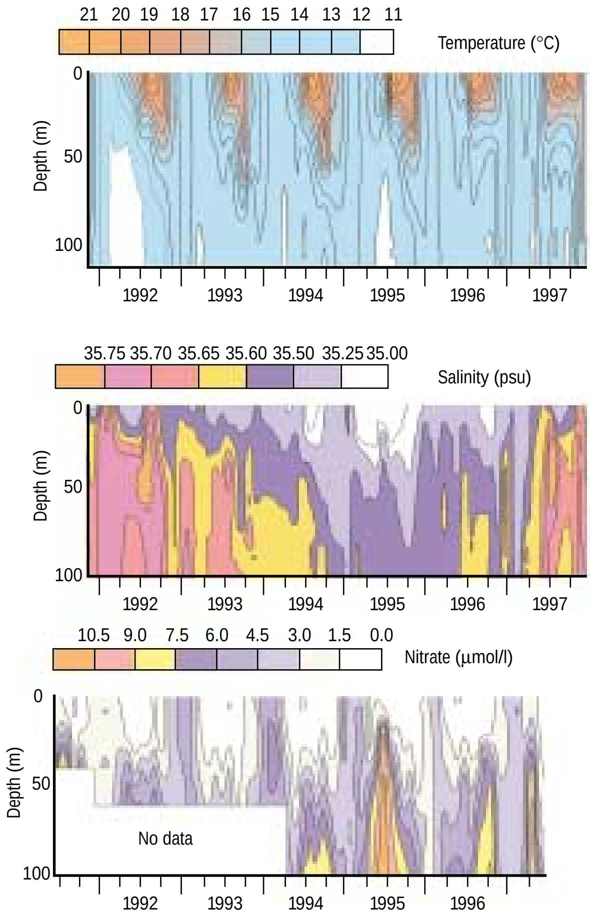
During winter, cold, low salinity waters occur over the continental shelf off the main rivers. As river water is colder than sea water during winter, thermal inversions sustained by haline stratification are commonly observed over the shelf. This is also the season when the warm, highly saline, poleward-flowing slope current (see Section 2.9.2) presents its clearest surface signal and its northernmost extent. Westerly or south-westerly winds keep the river plumes close to the coast. A change in the wind field (see Section 2.12) promotes vertical mixing over the inner shelf, a process that is further assisted by the presence of thermal inversions. River plumes will tend to dilute the water column, lowering salinity and temperature over the inner shelf and helping to sustain a cross-shore gradient between shelf water and the slope current. This process may be seen in satellite images of sea surface temperature.

In spring the low salinity waters cover a significant part of the continental shelf, depending on river run-off and the wind regime. The seasonal thermocline at the base of the thin wind-mixed surface layer appears on the outer shelf in April and the coastal area in May. Although the importance of river run-off is reduced during spring and summer, it does contribute to the thermal stratification. Below the seasonal thermocline, a cold cushion (11 °C) of water centred over the 100 m isobath appears off the French coast, extending from southern Brittany to the latitude of the Gironde Estuary. This is observed throughout the year, showing weak temperature variations (< 1 °C).

Coastal upwelling (see Section 2.9.3) begins to become evident off the Iberian Peninsula in late spring *(Figure 2.6)* and reaches a maximum in summer, at which time it also occurs in the south-eastern Bay of Biscay. In summer and early autumn, the interaction of tidal currents and bottom topography results in the formation of seasonal thermal fronts in the Bay of Biscay, as is the case for example with the Ushant Front off western Brittany. Several other mixed areas occur along the French coast, generally in the vicinity of islands. Along the Armorican and Celtic slopes, frontal zones are induced by internal waves. At that time, upwelling filaments off the Iberian coast usually reach their maximum extent.

As the atmospheric forcing changes, upwelling ceases and autumn is marked by the surface expression

Figure 2.7 **Seasonal and interannual variation in temperature, salinity and nitrate over the outer shelf off Santander (43° 34.5' N, 3° 47' W).**



of the poleward-flowing slope current off western Iberia. In the Bay of Biscay, the main feature characteristic of autumn is a warm water mass (14 – 16 °C) extending up the coast as far as the Loire Estuary.

2.9 Circulation and volume transport

The hydrodynamics of Region IV are dominated by the following features:

- a weak anticyclonic circulation in the oceanic part of the Bay of Biscay;
- a poleward-flowing slope current. This is due to the geostrophic adjustment of the cross-shore density gradient that occurs when the large-scale eastward flow meets the continental boundary;
- coastal upwelling. This is particularly evident along the western Iberian coast, although it also occurs off northern Iberia and to a limited extent off south-west France. It results from the persistence of longshore

equatorward winds during spring and summer, with a southward jet over the shelf, offshore transport in the upper water layers (especially in association with filaments) and compensatory onshore transport at subsurface levels;

- the northward flow of MW. This is particularly relevant to the (bottom-trapped) shallow and upper cores, and to the generation and displacement of eddies carrying MW out of Region IV;
- the shelf circulation. This is governed by the combined effects of tides (which are particularly important over the Armorican shelf and the southern Celtic Sea), buoyancy (coastal currents induced by run-off from the main rivers) and wind; and
- cross-shelf transport along the axes of submarine canyons. This is due to amplified tides and non-linear wave-current interactions, and is particularly important in relation to the canyons dissecting the shelf between Cap Breton and Nazaré.

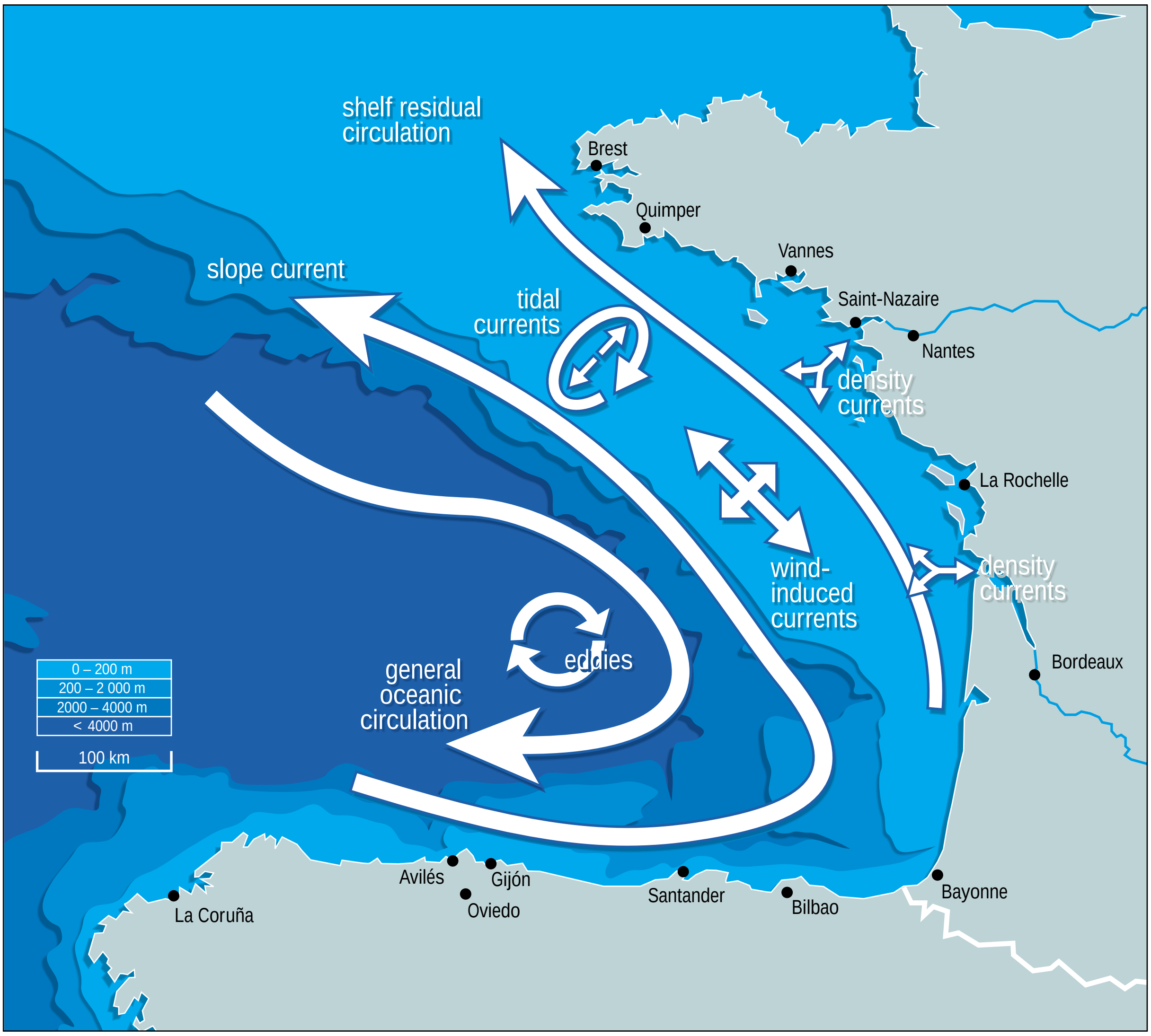
2.9.1 Bay of Biscay

The oceanic part of the Bay of Biscay is characterised by a weak (1 – 2 cm/s) and variable anticyclonic circulation (Saunders, 1982; Koutsikopoulos and Le Cann, 1996), as well as by cyclonic and anticyclonic eddies shed by the slope current (Pingree and Le Cann, 1992a). These features are illustrated in *Figure 2.8*.

2.9.2 Slope current

A warm, saline intrusion is often observed off the Iberian

Figure 2.8 **Schematic illustration of circulation in the Bay of Biscay. Source: Koutsikopoulos and Le Cann (1996).**



coast during winter; trapped within 50 km of the shelf edge, flowing poleward at speeds of 20 – 30 cm/s and with transport increasing in the direction of flow (Frouin *et al*., 1990; Haynes and Barton, 1990). It tends to reach the Cantabrian slope around Christmas, hence the name ‘Navidad’ given by Pingree and Le Cann (1992b), and is sometimes seen as a continuous feature extending from the western Iberian slope to, at least, 46° N on the Armorican slope *(Figure 2.9)*.

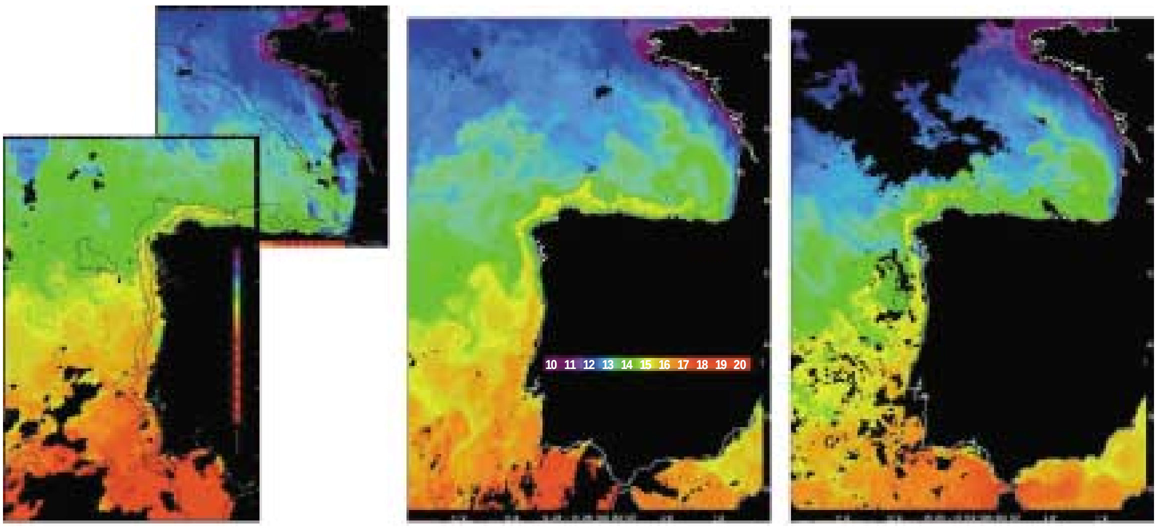
Observations off the west and northern coasts of the Iberian Peninsula during 1994–6, revealed consistent poleward flow in winter down to 400 m. Monthly means in the upper 150 m in excess of 20 cm/s, and maximum values of > 40 cm/s (Jorge da Silva, 1996; Díaz del Río *et al*., 1996), agreed with previous findings by Pingree and Le Cann (1990). Assuming the current field to be spatially uniform along the entire continental slope of Region IV, implies that a ‘particle’ released at 40° N in October would enter the Cantabrian area one month later and would reach the northern limit of Region IV in March of the following year. Strong temporal and spatial variability have been observed on the outer Celtic shelf, together with weak (5 – 10 cm/s) residual currents, apparent ‘counter-currents’ and some seasonal changes (Pingree and Le Cann, 1989, 1990). Mean monthly transport in the upper 500 m is around 1.5 Sverdrup. Maximum values (of up to 2.5 Sverdrup) occur in late summer on the northern part of the Celtic slope (to the north of Region IV), in late autumn off western Iberia and in winter along the Cantabrian slope.

According to Huthnance (1984) the slope current is predominantly non wind-driven (although wind forcing is probably responsible for seasonal changes). The meridional density gradient, observed in the upper 200 – 300 m of the North-east Atlantic (Pollard and Pu, 1985) as a result of the poleward cooling of the ocean surface, is balanced by an eastward flow of less dense water, which in turn causes a height difference between shelf waters and deep-sea. This causes a cross-slope density gradient, which results in the formation of a geostrophically balanced poleward flow.

Whenever the wind is equatorward a surface water flow develops in the same direction. The density-driven slope current then becomes an undercurrent, its core weakens and is displaced slightly offshore. This is the situation most commonly observed in summer (although it may also occur at other times of the year when a blocking high pressure centre persists to the west of the Iberian area). The most typical winter situation corresponds to forcing by shifting westerly winds, associated with travelling low pressure systems (see Section 2.12). These cause the water to pile up at the continental margin which, in combination with the meridional density gradient, reinforces the slope current. At such times, the slope current develops surface expression (*Figures 2.6* and *2.9*), achieves its greatest velocities, is present over the upper slope, and eventually invades the outer shelf.

When the slope current has surface expression it tends to act as a boundary, preventing upper layer exchanges between the shelf and the deep-sea. On these occasions, any exchanges must take place near the bottom and the nepheloid layer (see Section 2.11) is likely to play an important role (although measurements to support this idea are not available). However, surface water exchange is not totally blocked by the slope current system; current instabilities caused by interactions with

Figure 2.9 **Weekly composite sea surface temperature images, winter 1995/6. Land and cloud covered areas appear black. Source: CCMS.**



31 Dec 1995 – 6 Jan 1996 | 14 – 20 Jan 1996 | 28 Jan – 3 Feb 1996

the topography may result in the generation of eddies. Cyclonic eddies are relatively short-lived and anticyclonic eddies relatively long-lived. Pingree and Le Cann (1992a) referred to them as SWODDIES (Slope Water Oceanic eDDIES). With typical diameters of 100 km (*Figures 2.6*, *2.8* and *2.9*) and a depth of approximately 500 m, they are fed by slope current water and their influence is felt to 1500 m. They tend to move westwards in the Bay of Biscay carrying water offshore and may therefore provide a mechanism to promote mixing in areas of very weak circulation.

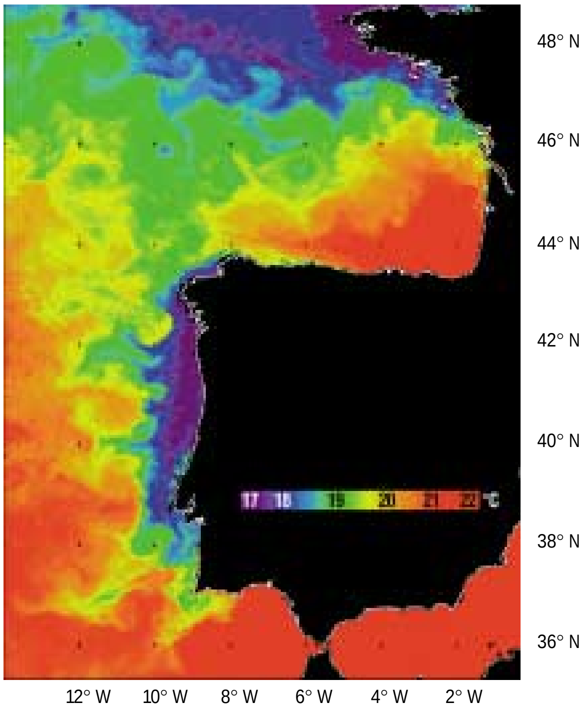
Cross-shore height differences in association with oceanic eastward flow cannot develop off zonal (east-west) boundaries. Thus, in the absence of any additional forcing mechanism, the poleward flow can only decay away from such boundaries. This is the case off the northern coast of the Iberian Peninsula. This does not necessarily imply a reduction of velocities, and they may actually increase as long as the flow becomes narrower (e.g. due to a steeper slope). On the other hand, recruitment of water may occur anywhere along a meridional (north-south) boundary, giving rise to an increase in transport that may be reflected in measurements along a zonal boundary before any significant decay has occurred. Although few systematic observations of the large-scale zonal baroclinic flow have been conducted, it appears that the underlying meridional density gradient varies, being stronger at certain latitudes (Ahran *et al*., 1990). This is important as in addition to promoting the intensification of the slope current, it may even underlie its generation.

2.9.3 Coastal upwelling

Coastal upwelling is the most significant hydrodynamic process occurring during summer in Region IV. It typically develops between April and October in response to persistent stable northerly winds (Wooster *et al*., 1976; Fiúza *et al*., 1982; Blanton *et al*., 1984). Off the western Iberian coast coastal upwelling intensifies at typical periods of four to ten days, the same periodicity that characterises variability in the meteorological forcing (Fiúza, 1983; Vitorino, 1989), decaying during calm periods and receding with inversions in the wind field.

During an upwelling event the surface water layer moves offshore through the combined effect of the equatorward wind acting upon the surface and the Coriolis force (due to the rotation of the Earth). Continuity requires that water transported offshore is replaced at the coast by water from deeper levels. This occurs within a narrow band whose width, of the order of 10 km, depends on the stratification. As the upwelled water is cooler than the surrounding surface water, it is easily detected in sea surface temperature images obtained by remote sensing *(Figure 2.10)*.

Figure 2.10 **Composite sea surface temperature image showing upwelling near the western Iberian coast (2–8 Aug 1998). Source: CCMS.**

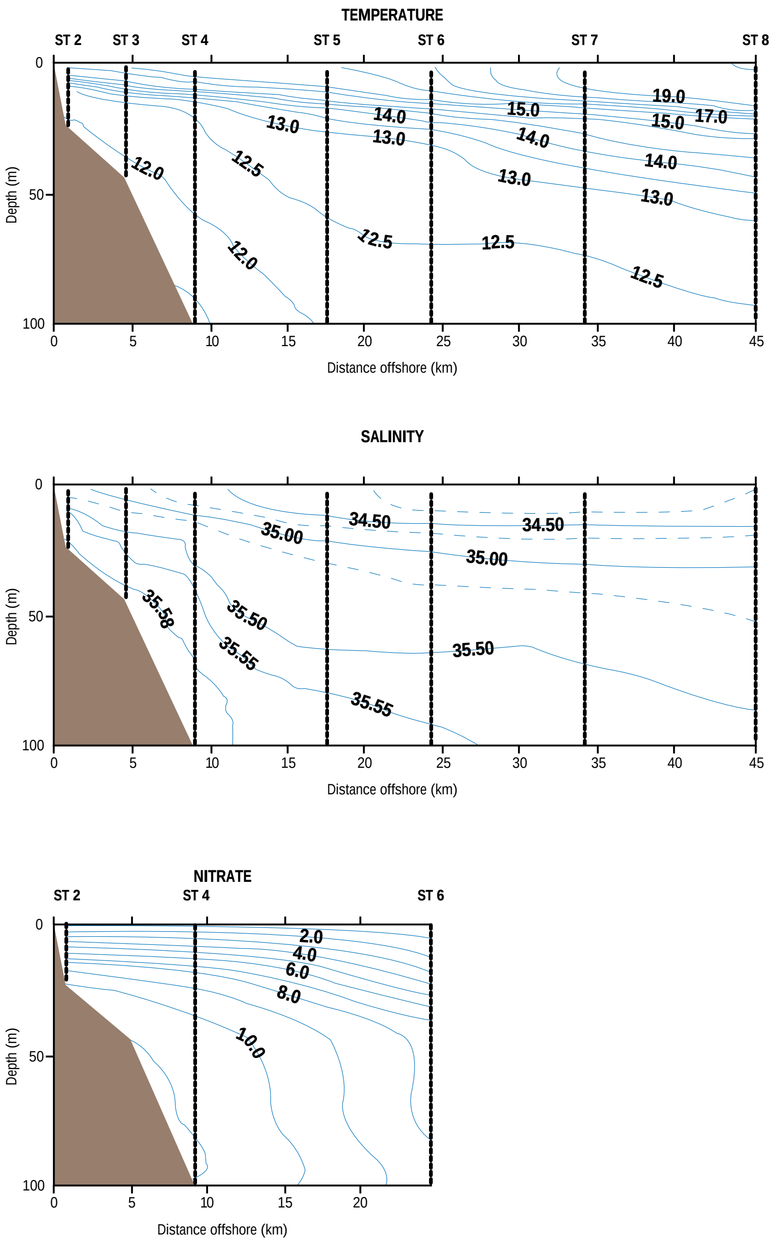


In most upwelling systems, the circulation pattern induced by favourable wind events is characterised by longshore shelf currents which are stronger than the cross-shelf components (Smith, 1981). Within one day of the onset of the wind a surface equatorward jet develops at the coast and begins extending downwards, while moving offshore as the wind event persists (Jorge da Silva, 1992). The cross-shelf flow is seaward in the surface layer, with a shoreward flow at intermediate depth. On the northern Iberian west coast, the strength and persistence of favourable wind events appear to determine the depth to which the coastal jet penetrates, as well as its outermost position and the cross-shelf circulation pattern. A poleward undercurrent is present as a feature of the slope regime rather than the shelf regime.

Surface offshore transport is not uniform and is concentrated within upwelling filaments. These are recurrent structures, characterised by cross-scales of up to 30 km and offshore extents sometimes greater than 200 km, that seem to protrude from the upwelling front when it reaches the shelf-break *(Figure 2.10)*. Some of the filaments appear to be associated with particular areas (Haynes *et al*., 1993) and are presently being studied. An upwelling filament typically covers the upper 100 m, but its effect is felt to at least 200 m (Barton, 1995). Offshore velocities of 10 – 20 cm/s have been observed in the upper 60 m of the filaments, within a typical width of 10 – 20 km (Budgell and Johannessen, 1995). The transport associated with each filament is thus equivalent to that induced in the surface waters by a steady and moderate (8 m/s) longshore wind acting upon a 100 km long section of coastal water. Thus, upwelling filaments provide effective means of exporting heat and mass from coastal areas to the deep-sea. Roed (1995) reports on an EU-funded study which aimed to reproduce realistic filaments off the western Iberian Peninsula using a range of high resolution (~ 2 km) models.

Upwelling events have also been reported for the western part of the southern Bay of Biscay (Botas *et al*., 1990; Lavín *et al*., 1998), associated with easterly winds during summer. Upwelling events off Santander (in the south-eastern Bay of Biscay) are apparent for June in the time series shown in *Figure 2.7*. The event of June 1995 is particularly apparent and corresponding cross-sections are given in *Figure 2.11*. Local upwelling induced by northerly winds often occurs in summer over the shelf south of the Gironde Estuary *(Figure 2.6)* (Castaing and Lagardre, 1983; Jegou and Lazure, 1995) and along the south coast of Portugal whenever the wind shows a significant westerly component (Fiúza, 1983).

Figure 2.11 **Temperature, salinity and nitrate cross-sections over the outer shelf off Santander (3° 47' W) July 1995. Source: Lavin *et al*. (1998).**



2.9.4 Mediterranean Water

The inflow of water from the Mediterranean into the Atlantic (described in Section 2.8.2) has been estimated at 0.7 – 1.2 Sverdrup, in a process that is highly dependent on tidal and atmospheric forcing (Crépon, 1965; Gründlingh, 1981; Lacombe and Richez, 1982; Candela *et al*., 1989; Ochoa and Bray, 1991; Bryden *et al*., 1994). Once the equilibrium depth is attained the Mediterranean outflow divides into two main cores (Zenk, 1970; Âmbar and Howe, 1979a,b). Downstream entrainment of Atlantic water leads to an almost ten-fold increase in transport by the time the undercurrent reaches Cape St Vincent on the south-western Iberian Peninsula (Smith, 1975; Ochoa and Bray, 1991). At that point, some of the outflow spreads radially into the North-east Atlantic, while the majority flows around the cape and then northwards along the western Iberian continental slope, at depths ranging from 600 to 1300 m (Howe, 1984; Zenk and Armi, 1990). The intermediate salinity maximum is identifiable along the entire slope of Region IV.

Mediterranean water spreads well beyond the western boundary of Region IV, through diffusion, mixing and geostrophic turbulence. The latter is the most important mechanism for exporting heat, salt and contaminants. The mesoscale Mediterranean water EDDIES (MEDDIES), first observed in the late 1970s, are coherent structures embedded within the water column which transport MW detached from the main body of the undercurrent *(Box 2.7; Figure 2.12)*. With typical diameters of 50 km, vertical extents of 600 – 800 m and centred at about 1000 m, they have positive temperature and salinity anomalies of up to 2.5 °C and 1 psu respectively, relative to the surrounding water. They contain the equivalent of ten days of salt contribution from the Mediterranean (Armi and Zenk, 1984) and are capable of transferring heat, salt and other passive tracers thousands of kilometres across the Atlantic (McDowell and Rossby, 1978).

Most Meddies occur between 36° N and 39° N, west of 8° W. They rotate anticyclonically (clockwise) over periods of six to eight days, corresponding to azimuthal velocities of 20 – 30 cm/s, and are displaced south of their apparent area of formation (Bower, 1996). The mechanism by which Meddies are formed is presently subject to active investigation (Käse *et al*., 1989; Griffiths and

Figure 2.12a **Sea surface temperature off the southern part of the western Iberian Peninsula 14 April 1994. A and B represent the extreme positions of the section shown in Figure 2.12b. The two small circles represent the positions of the drogued surface buoy at the beginning and end (23 Feb 1994) of the observations. The larger circles with crosses show the locations at which the two subsurface floats surfaced (11 and 20 Mar 1994). The dotted line represents the movement of Meddy Pinball from the beginning to the end of observations (12 May 1994), based on data from the drogued buoy, the subsurface buoys and remote sensing. Source: R.D. Pingree, PML.**

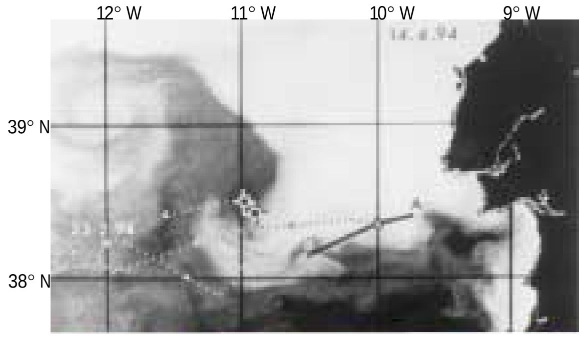
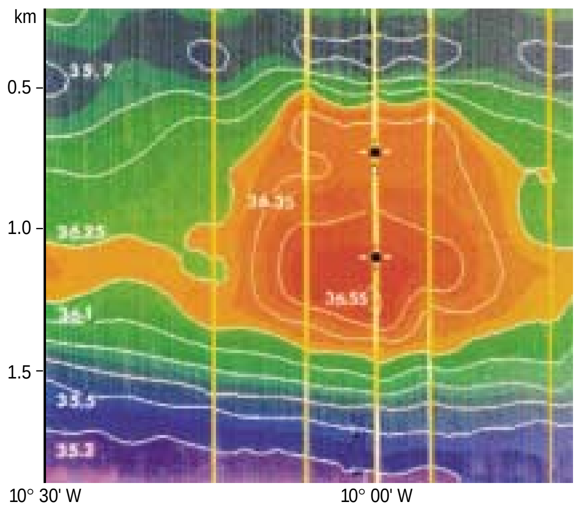


Figure 2.12b **Vertical salinity section through Meddy Pinball. The yellow lines represent CTD profiles. The black circles represent subsurface floats deployed at depths corresponding to the upper (temperature maximum, not shown) and lower (salinity maximum) cores of the eddy. The white circle represents a drogue tethered to a satellite-tracked surface buoy. All observations occurred on 8 Jan 1994.**



Box 2.7 Meddy Pinball

Subsurface floats were used to follow the movement of Meddy Pinball for seven months, while its kinematics were studied with surface drogued buoys and CTD (conductivity, temperature, depth) profiles (Pingree, 1995). Meddy Pinball was found against the continental slope near the Lisbon canyon. The maximum salinity occurred at 1260 m ***(Figure 2.12)***, but the maximum rotation rate with a period of about 2.5 days occurred in the upper core near 700 m, where temperatures reached 13.2 °C. The azimuthal transport to a radius of 50 km was nearly 13 Sverdrup. Meddy Pinball moved 550 km over 204 days, between the continental slope and the Tagus Abyssal Plain ***(Figure 2.12)***.

Linden, 1981; Nof, 1990). Their formation appears linked to sudden changes in bottom topography, although it is unclear whether the key factor is the change in contour direction or the presence of submarine canyons (Pichevin and Nof, 1996; Bower, 1996).

2.9.5 Buoyancy driven coastal currents

Freshwater inputs from the Loire, Gironde and Adour estuaries induce buoyant plumes which drive significant northward currents over the inner Armorican shelf *(Figure 2.6)*. As river water is considerably colder than sea water in winter and spring, the river plumes are easy to identify in satellite images of sea surface temperature *(Figure 2.9)*. As shown by a recent three-dimensional hydrodynamic model (Lazure and Jegou, 1998), freshwater run-off imposes seasonal variability and its interaction with the wind-induced circulation promotes mesoscale variability.

Smaller river run-off and a much narrower shelf off the Iberian Peninsula make buoyant plumes much less persistent than over the Armorican shelf. Only the Douro and Miño rivers contribute significant inputs to the coastal waters, sometimes identifiable as cold plumes in winter, but no significant density-induced currents occur, except under exceptional circumstances and for short periods.

2.10 **Waves, tides and storm surges**

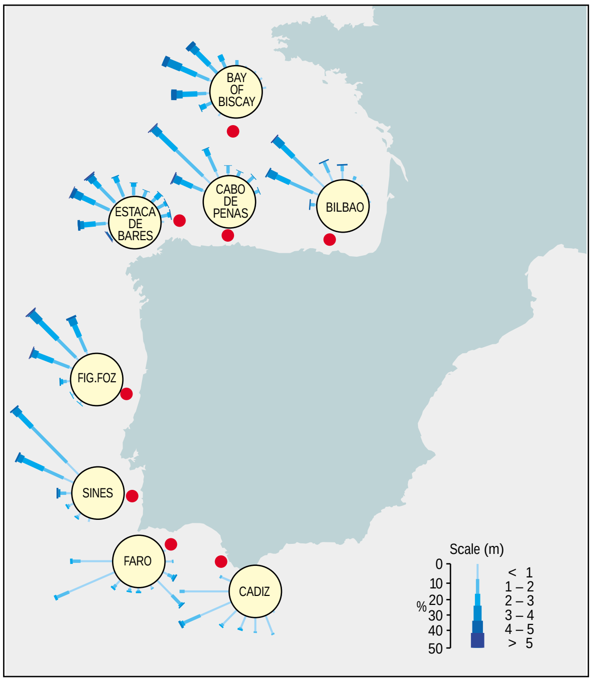
2.10.1 Waves

Portugal and Spain operate networks of directional wave buoys around the whole Atlantic coast of the Iberian Peninsula. France has only recently started directional measurements of waves in the Bay of Biscay and no data are yet available. However information derived from satellite scatterometer data for the Bay of Biscay was combined with statistics from the wave buoys to generate wave and swell roses for this area *(Figure 2.13)*.

Waves of large amplitude originate from storms in the eastern Atlantic, around 50 – 55° N, and thus arrive from the north-west. The most frequent conditions are significant wave heights of about 2 m, a zero-crossing period of nearly 8 seconds, movement in a west to north-west direction in the Bay of Biscay and a north-west direction along the Portuguese coast. Higher mean sea state conditions occur at higher latitudes, as is also the case for the severity of extreme conditions. The 100-year extreme significant wave height decreases from nearly 20 m in the north of Region IV to about 14 m to the south-west of Portugal. Winter and autumn experience the most severe conditions, with conditions during autumn almost as severe as during winter.

Waves only partly reflect the wind regime. In the Bay of Biscay, for example, easterly winds are almost as

Figure 2.13 **Wave and swell roses for Region IV.**



frequent as westerlies. However, due to the difference in fetch, which favours the eastward propagation of swell generated far out in the Atlantic, only 5% of the observations have easterly components. More than 80% of the time the sea is crossed (i.e. several wave systems from different directions can be observed at the same time), such as when there is swell with a 10 – 12 s period and wind waves with a period of 6 s.

In the Gulf of Cadiz, the mean wave conditions are much less severe since the area is not exposed to the swell generated in the North Atlantic. The dominant wave directions are SW–W and SE, with monthly mean significant heights of 0.6 to 1.5 m. The most frequent storms are from the south-west. Owing to the very shallow location of the Cadiz wave buoy, virtually no easterly wave components are detected at that site, although they are actually quite frequent and relatively important in that area.

2.10.2 Tides and tidal currents

Tides along the Iberian Peninsula and in the Bay of Biscay are mainly due to the gravitational forces exerted by the Moon and the Sun acting upon the water mass of the Atlantic Ocean. This gravitational forcing, together with the Coriolis force and the boundary conditions imposed by the continental margins of Europe, Africa and North America, result in the tides propagating in a rotary pattern known as an amphidromic system. Thus, along the coasts of Region IV, the tides propagate from south to north, according to an anticlockwise rotation about the North

Atlantic amphidromic point, located at approximately 52° N, 40° W. Amplitude increases with increasing distance from the amphidromic point.

The tides in Region IV are semi-diurnal, with the range increasing eastwards towards the coast, particularly as the shelf areas are crossed. Maximum ranges occur in narrow passages (e.g. La Rochelle and the Loire Estuary) where they may reach 6 m. Tidal phases are almost constant in the cross-shelf direction, but increase northwards such that a time lag of 1.2 hr exists between Cadiz and Brest.

Tidal currents usually have an oscillatory component (predominantly semi-diurnal in Region IV) and a long-term component (the residual current). The semi-diurnal component is greatest near the Strait of Gibraltar and over the north-west Armorican shelf, where values may reach 1 m/s, decreasing to 10 cm/s over the western Iberian shelf. The residual component tends to be < 1 cm/s over most the shelf, although locally it may be up to one order of magnitude higher. This is the case near the islands of Noirmoutier, Oléron and Ré, where it may reach 10 cm/s and play a major role in long-term transport.

Over steep slopes and around sharp shelf-breaks tidal oscillations may dominate the current dynamics. That appears to be the case over the Cantabrian slope where 56% of the kinetic energy is derived from the semi-diurnal tidal oscillations (Alonso, 1996). This is often due to the contribution of the internal tide (i.e. shelf-break generated internal oscillations with tidal frequency due to the presence of stratification in the water column). Tides interact with the topography and tidal currents are significantly amplified during their propagation towards the shore by the continental slope (Jezequel *et al*., 1998).

At the Armorican shelf-break, when the water column is vertically stratified, tides generate internal waves that propagate both on- and off-shelf from about 5° W to 9° W (see *Figure 2.6*). Such waves appear to be responsible for significant mixing and the upwelling of nutrients. Oscillations at a sharp interface (for example a seasonal pycnocline) may produce surface signatures (Ermakov *et al*., 1996), as well as reinforce the barotropic current or generate long period phenomena.

2.10.3 Storm surges

During a storm, when atmospheric pressure drops abruptly and significantly and the wind blows onshore, the water tends to pile up along the coast and, in combination with the tidal elevation, results in the generation of a storm surge. This effect is greatest during spring tides and over wide shallow shelf areas and along low coastal stretches, as occurs in the North Sea. Such areas do not occur in Region IV. Thus, estuaries and coastal lagoons are the locations potentially subject to storm surges, although their amplitudes are not usually dramatic. Nevertheless a 50 cm storm surge ***(Figure 2.14a)*** may be enough to submerge coastal roads or cause flooding in the lower parts of coastal towns. Especially as storm surges are often accompanied by heavy rains associated with the storm.

The dynamics of the tides and storm surges were examined by Alvarez Fanjul *et al*. (1998) who found good agreement between model results and measurements from a net of tide gauges in Spanish waters. Off the Iberian Peninsula, the largest storm surges (> 80 cm) were observed in the Gulf of Cadiz ***(Figure 2.14b)***, with surges of 65 cm and 56 cm respectively, for Galicia and the Cantabrian Sea. Conversely, tidal records along the French coast suggested 100-year storm surges of between 0.6 and 0.7 m. These surges exhibit a low correlation with local wave height, probably because the waves are generated in a much wider and deeper area.

2.11 Transport of solids

Rivers are the main routes by which sediments are transferred from the continent to the ocean; 1.5 x 10^9 t are transferred each year to the ocean basins by the world's rivers, 90% in the form of suspended material (Milliman and Meade, 1983). Coarse particles settle as soon as there is a substantial reduction in the kinetic energy associated with the river flow. After this, suspended matter is removed by flocculation promoted by the increase in salinity. Thus, particle size tends to decrease with increasing distance from the source. It is generally accepted that particulate matter is almost entirely transported in suspension by the turbid plumes that flow out of the estuaries ***(Box 2.8)***. An understanding of the role played by suspended matter in sedimentary processes should help to clarify aspects of pollutant transport and to identify the silting and resuspension mechanisms in estuarine and shelf areas.

2.11.1 Coarse material

Oliveira *et al*. (1982) estimated that prior to the building of dams in 1930, the total littoral transport of coarse sediments off the Portuguese coast north of 40° N was of the order of 2 x 10^6 m^3/yr, with the river Douro (see *Figure 2.5*) contributing 90% of this amount. By the end of the 1960s, the contribution from the river Douro had been reduced to 1.3 x 10^6 m^3/yr and Oliveira *et al*. (1982) expected a further reduction to 0.25 x 10^6 m^3/yr by 1985, once the Crestuma-Lever dam (30 km from the river mouth) was finalised. As the littoral drift is unlikely to have changed significantly, the reduction in coarse sediment input has certainly been a major factor contributing to the erosion of the northern Portuguese coast. Somewhat similarly, in the eastern Bay of Biscay, sand deposits tend to result from the erosion of the coasts, as evidenced by an average retreat of 1 m/yr along the Aquitaine coast.

Figure 2.14a **Tidal record during a storm surge at Aveiro, Oct 1987.**

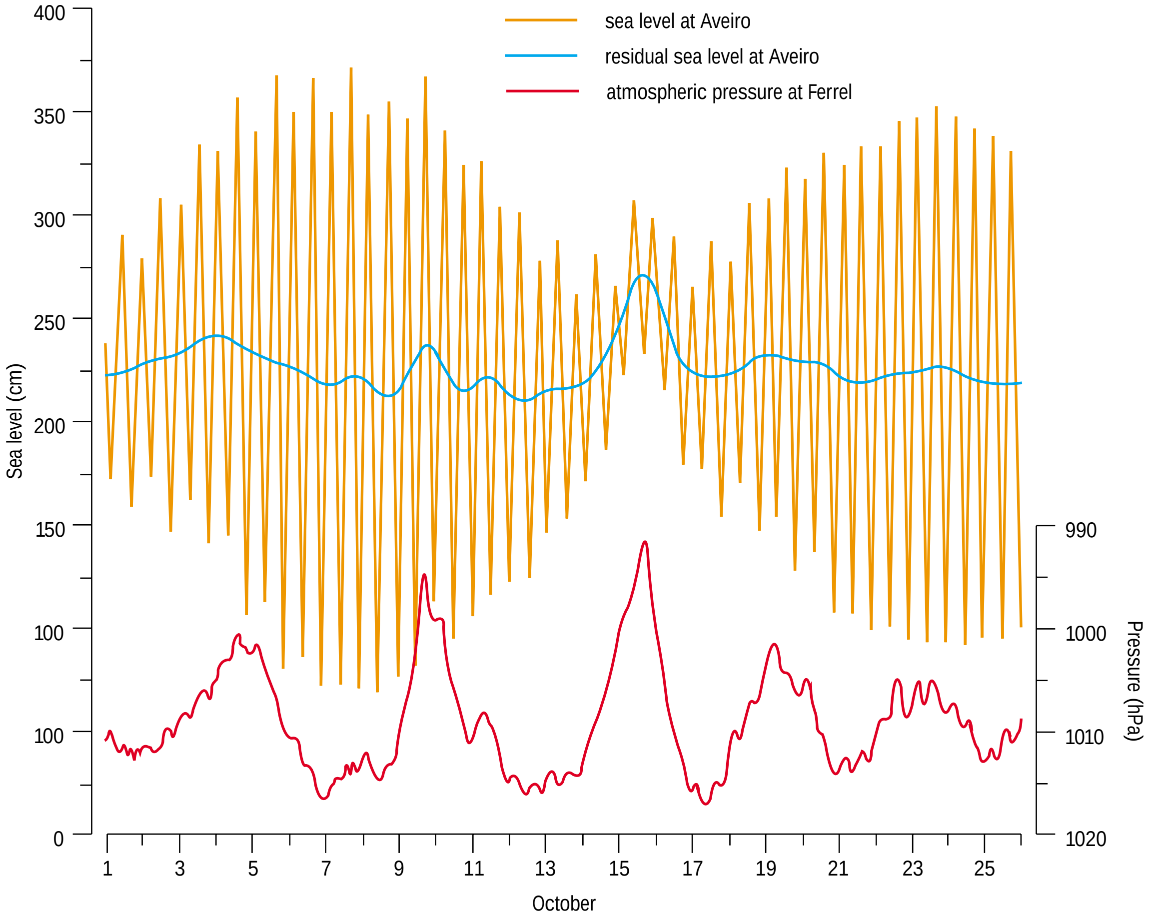
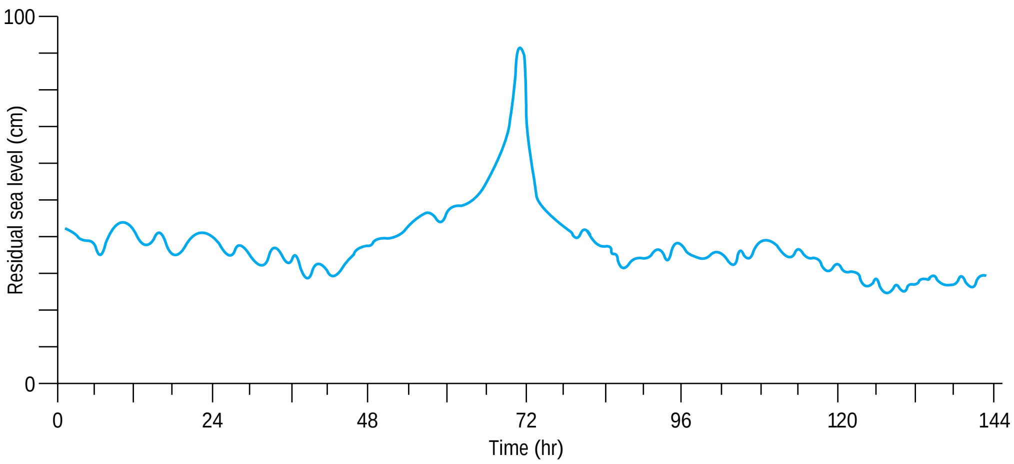


Figure 2.14b **A large storm surge observed at the Huelva tide gauge 3 – 8 Nov 1997.**



Box 2.8 Wind forcing of turbid plumes at the continental shelf

Wind is the main driving force of the turbid plumes when river run-off is low and tidal forcing is weak. This may be illustrated using the Gironde plume as an example.

The Gironde plume generally covers 200 – 600 km2, rarely extends beyond 1° 40' W and there are no clear relationships between variations in flow and the extent of the plume (Froidefond et al., 1998). The river spate of January 1994 was exceptional in this respect and the plume extended off-shore to the 100 m isobath, at 2° 30' W. Maximum plume dimensions usually occur during and just after a spring tide. When there is no wind, or when the wind is weak compared to the buoyancy induced by the river run-off, a density current is generated and the plume extends north-westward ***(Figure 2.15a)***. Winter winds blow most frequently from the west and south-west. This causes water to pile up at the coast and the geostrophically balanced density current associated with the high winter run-off is reinforced by the wind effect. In summer the reverse is the case; the wind is often northerly or north-westerly and pushes the (weaker) plume southwards ***(Figure 2.15b)***.

2.11.2 Fine material

Due to river regulation, around 90% of the suspended solids in rivers are silts and clays with grain sizes of the order of 10 µm (Weber *et al*., 1991). These fine sediments play a major role in the transport of pollutants as they provide relatively large surface areas for adsorption.

On average, a third of the sediments carried in suspension by the main rivers discharging to the French coast of the Bay of Biscay remains permanently in the estuaries *(Figure 2.16).* Approximately 3.7 x 10^6 t/yr are carried by the five main rivers; 2.4 x 10^6 t/yr being transferred to the shelf area, the Gironde accounting for about 60%. Most of the fine alluvium is retained on the coastal mudflats and on the continental shelf. Only 2 – 3% of the river-borne sediments cross the continental shelf and end up in the abyssal deep (Ruch *et al*., 1993). The concentration of suspended particulate matter varies from 10 – 20 mg/l near the coast, to 1 – 5 mg/l at mid shelf, to $<$ 1 mg/l beyond the shelf-break, with in addition, a decreasing trend from north to south (Castaing, 1981). Concentrations are greatest near the mouths of the Gironde and Loire, where they may reach 100 mg/l during flood events, they then decrease below the surface to increase again near the bottom where the swell and currents tend to resuspend fine sediments.

In the Cantabrian estuaries, suspended sediment concentrations are 3 – 30 mg/l under normal circumstances, reaching 100 mg/l at Bilbao (Ruiz *et al*., 1994) or during flood events (FTLQ, 1993). Off the west coast of Galicia, in the rias bajas area *(Box 2.3)*, the mussel industry generates considerable quantities of mud, which adds to that carried in suspension by the rivers. The bottom sediments of the rias are muddy and, to a great extent, anoxic while the bottom water layers are very murky. A large proportion of these sediments are transferred from the rias to the continental shelf, and stretches of muddy sediment may be seen in front of the rias over the sandy bottom of the continental shelf. Due to their particular type of circulation systems, there are neither serious overflow problems nor anoxia in the waters of the rias. The only evidence of silting is in the inner part of the Ria of Vigo.

The only Portuguese estimates concerning the quantities of suspended solids introduced into estuarine systems are for the Tagus *(Table 2.3)*. The sewage component is important, around half the riverine input in recent years (possibly more since the Trancão was, until

Figure 2.15 **NOAA-11 AVHRR images of near infrared reflectance showing the propagation of the Gironde surface turbid plume under (A) a weak wind and strong buoyant current and (B) a northerly wind and a relatively weak current. Source: CNRS (Satmos/UMR-EPOC).**

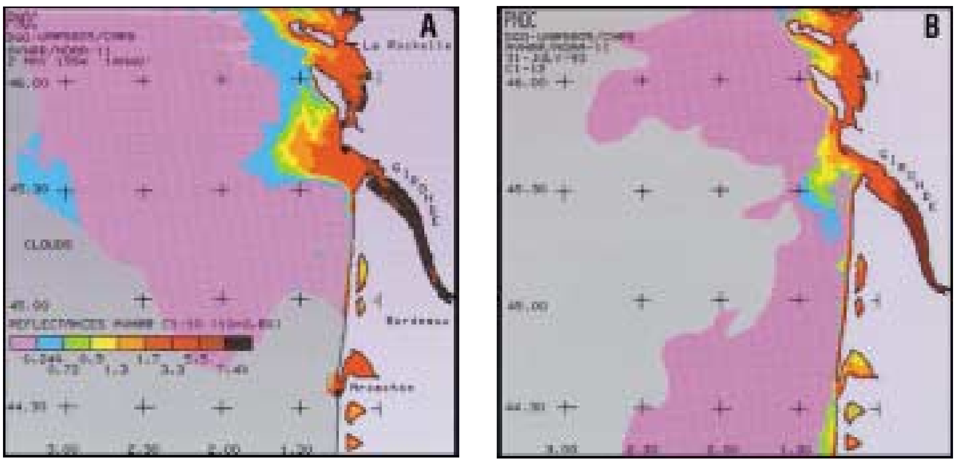
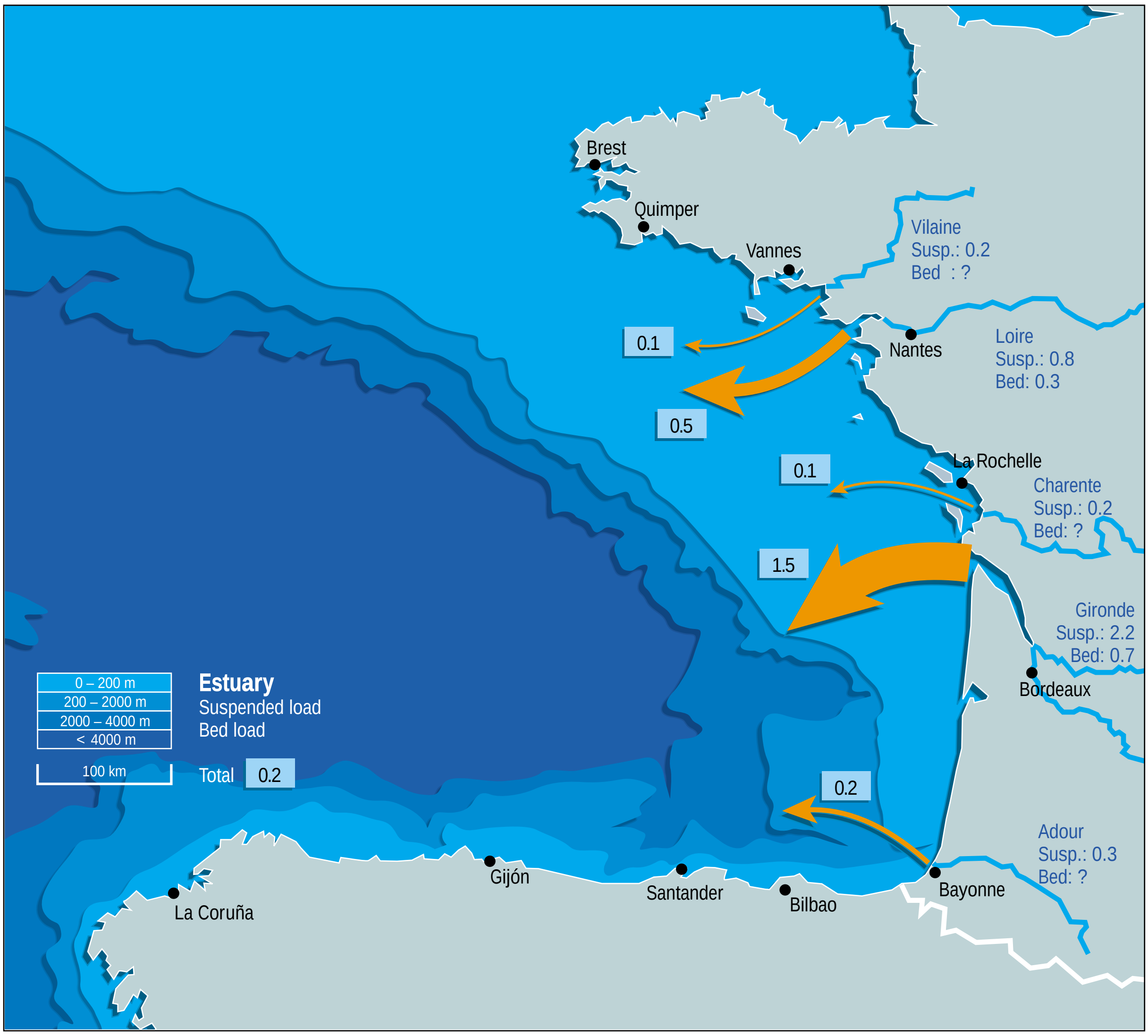


Figure 2.16 **Mass balance of fine sediment input (t x 10⁶ yr) to the estuaries of the French Atlantic coast and suspended sediment transfer to the ocean. Source: Castaing (1981).**



recently, used almost as a sewer). Jouanneau *et al*. (1998) estimated the amount of suspended matter discharged through the Tagus Estuary into the adjacent shelf area to be 0.4 – 1.0 x 10^6 t/yr. This estimate agrees with the 1980 input in *Table 2.3*, but is almost an order of magnitude higher than the corresponding estimates for 1992–5. Castanheiro (1984) estimated sedimentation rates to be around 0.8 cm/yr for the upper estuary, but reported that the maximum values had increased in the lower estuary from 0.7 cm/yr for 1893–1939, to 1.9 cm/yr for 1939–54, to 3.4 cm/yr for 1954–60. Jouanneau *et al*. (1998) derived estimates of 0.07 – 0.18 cm/yr for the adjacent shelf, with maxima of 0.16 – 2.13 cm/yr, and suggested that a significant component of the continental fluxes fails to reach the deep ocean, despite the narrowness of the shelf off the Tagus Estuary.

High sediment loads are carried into the Atlantic within cores of MW, partly due to the strong interaction between the Mediterranean outflow and the seabed in the Gulf of Cadiz (Heezen and Johnson, 1969; Thorpe, 1972). Recent findings indicate seasonal variability in the total quantity of suspended particles carried by the MW, with the organic fraction the most significant component (Abrantes *et al*., 1994).

2.11.3 Remobilisation and sediment transport on the continental shelf

As a result of the combined action of waves, swell and currents upon the seabed, sediments undergo displacements on the continental shelf. Barthe and Castaing (1989) conducted a theoretical study of the conditions

Table 2.3 Annual input of suspended particulate matter (t x 10^3) to the Tagus Estuary. Source: 1980 (Castanheiro, 1984); 1992–5 (Instituto da Agua).

	1980	1992	1993	1994	1995
Riverine inputs	142.3	74.2	118.3	125.0	44.4
upstream of estuary	140.2	25.1	66.3	83.6	33.3
Sorraia river	2.1	?	24.8	21.0	?
Trancão river	?	49.1	27.2	20.4	11.1
Sewage inputs	193.3	45.1	45.1	45.1	43.4
treated	-	3.6*	3.6*	3.6*	11.6
untreated	193.3	41.5*	41.5*	41.5*	31.8
TOTAL	335.6	119.3	163.4	170.1	87.8

* estimate; ? unknown.

required to mobilise sediments (mainly sand) over the shelf in the Bay of Biscay, and derived some values for the temporal and spatial scales involved in the motions. Two of their main conclusions were that, across the entire continental shelf, tidal current velocities near the bottom are always lower than the theoretical speeds required to mobilise the sediment and that storm waves are capable of stirring up sediment anywhere on the continental shelf. Fine sediments are actually brought to the sea surface at mid shelf after a week of strong winds and high seas *(Figure 2.17a)* and released back into the water column and onto the seabed when calm conditions return *(Figure 2.17b)*.

On the seabed disturbances are relatively short-lived, lasting for periods that depend on depth; 47 – 88 d/yr at depths of 10 – 30 m and < 1 d/yr at the outer shelf *(Figure 2.18)*. These are maximum theoretical figures which are probably not achieved *in situ*. Radioactive tracers show that sand displacements are actually very small (Castaing, 1981). At the decadal scale, sediment drift is only significant at depths of < 10 m, falling off rapidly with increasing depth. Thus, only the repetition of energetic events can explain any major mobilisation of sediments. Dynamic studies at a recent silt and clay deposit on the outer shelf to the west and north of the River Douro did in fact show that fine sediments were resuspended during severe winter storms, but not in-between storms (Vitorino *et al*., 1997).

2.12 Meteorology

Atmospheric circulation in the mid latitudes of the North Atlantic and over Western Europe is governed by the existence of two main centres of activity: an anticyclonic zone south of 40° N centred near the Azores (the 'Azores High') and a low pressure area centred around 60° N near Iceland (the 'Iceland Low'). Between these two areas, the prevailing winds are from the west to south-west, strongest in winter and lighter and less regular in summer.

The position of the two centres of activity is not fixed. In winter, when the anticyclone moves towards the south-east, temperatures are lowest over the continental land masses (i.e. North America, Greenland and Europe), while the temperature of the Atlantic Ocean remains relatively high, at around 10 °C. In addition, the difference between the warm waters of the Gulf Stream and the cold waters of Labrador gives rise to a surface weather front (the 'Polar Front'). This difference in temperature encourages the formation of very pronounced depressions over the ocean. Superimposed on the basic wind system, moving

Figure 2.17 **SeaWIFS images of reflectance at 555 nm showing (A) surface turbidity over the shelf due to sediment stirring during a storm, superimposed on the Gironde surface turbid plume, and (B) the return to calm conditions with redeposition of shelf sediments and a northward flowing Gironde plume. Source: CCMS.**

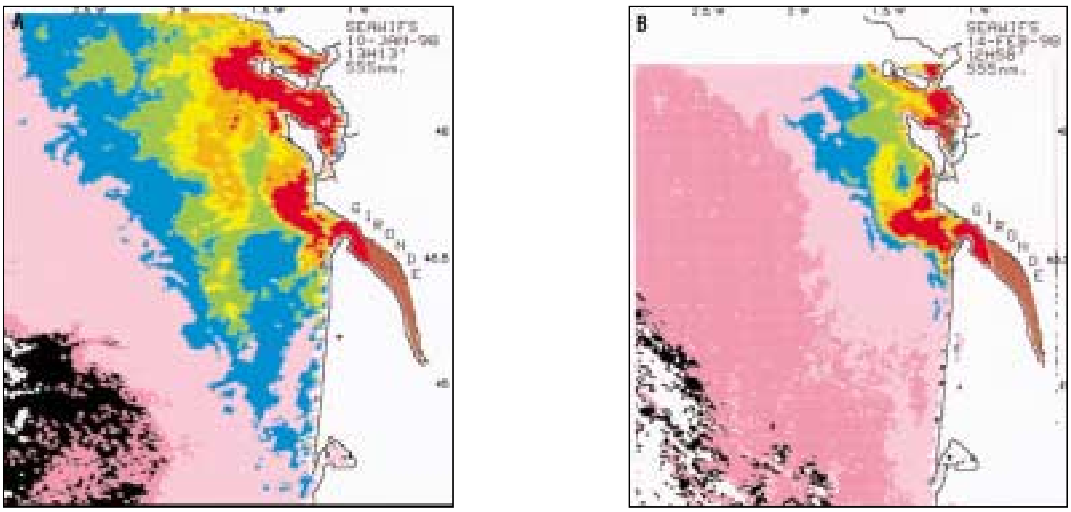
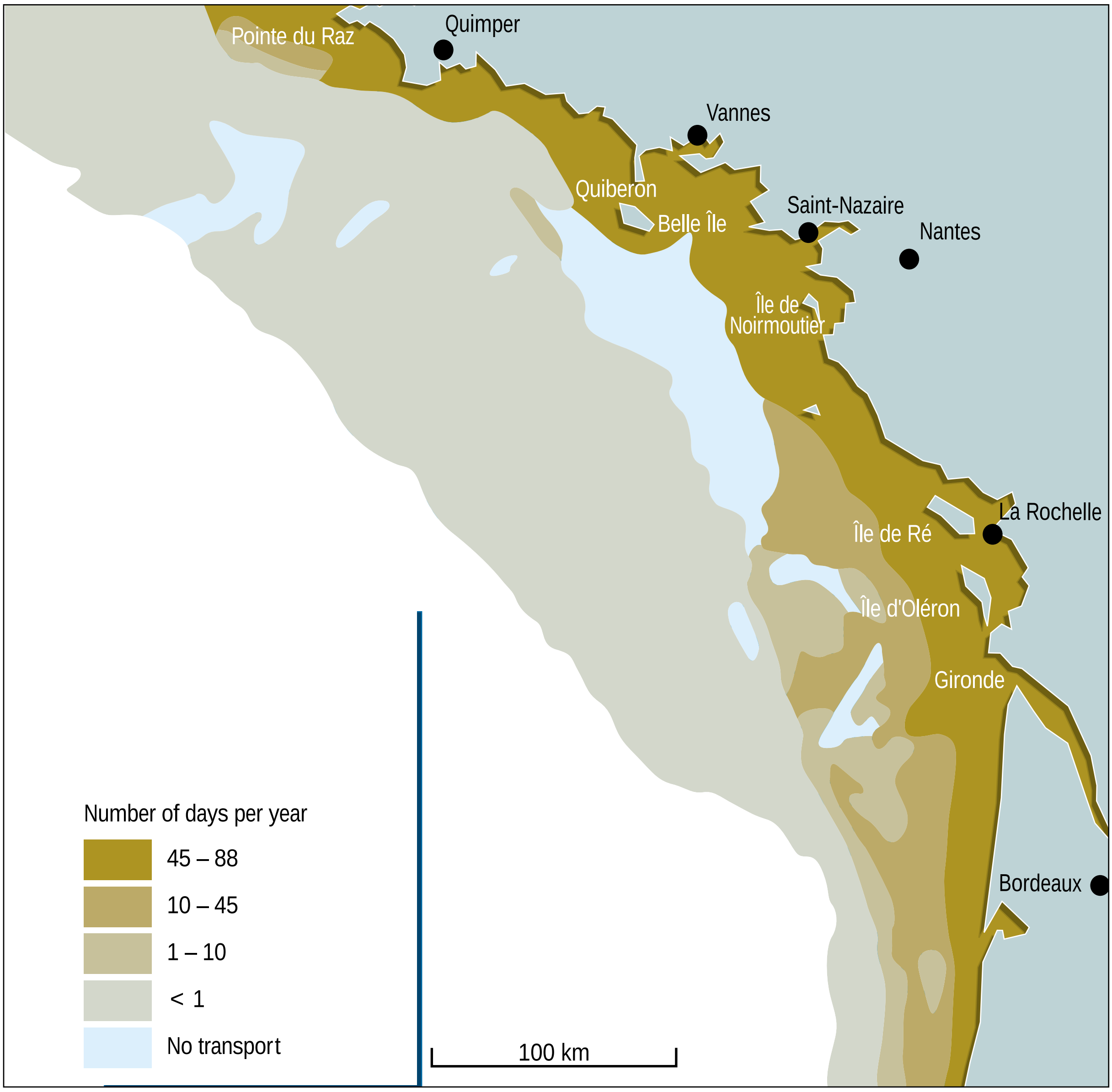


Figure 2.18 **Theoretical effective duration of sediment transport by the combined action of swell and tidal currents over the Aquitaine and Armorican shelf. Source: Castaing (1981).**

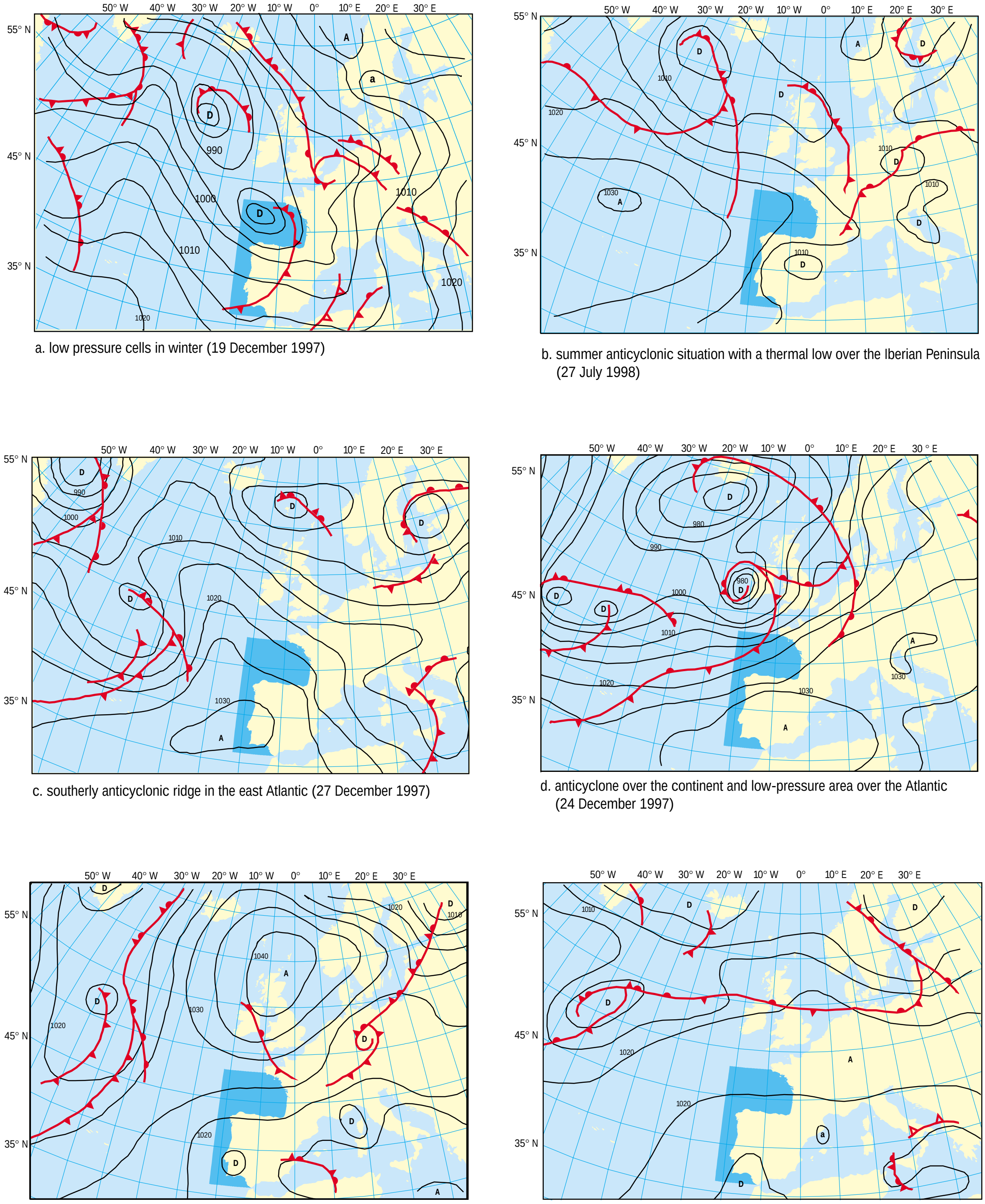


in succession from Newfoundland to Europe and causing the wind direction to rotate from south-west to north-west with sudden violent squalls, these depressions and associated perturbations of the Polar Front travel to quite low latitudes *(Figure 2.19a)*.

In summer, the Azores High moves towards the north-west, influencing the ocean as far north as 45° N, often extending a ridge towards Western Europe. A thermal low develops over the Iberian Peninsula between April and September *(Figure 2.19b)* which, together with the anti-cyclone, give rise to generally equatorward coastal winds. Sometimes they reach near gale force off the west coast, particularly during the afternoon as a result of the heating over the continent. This is the situation that is most favourable to upwelling (see Section 2.9.3) off the Iberian coasts.

The position and intensity of the anticyclone also vary at time scales shorter than seasonal. Typically, in spring and summer, the anticyclone extends in a ridge towards Iceland, and a low pressure area is present to the east of the British Isles *(Figure 2.19c)*. Moderate to strong north-westerly winds occur over the Bay of Biscay, with a weak circulation over most of the Iberian Peninsula. A relatively common winter situation corresponds, on the other hand, to an anti-cyclone over the continent and a fairly broad, deep low-pressure area in the North Atlantic *(Figure 2.19d)*,

Figure 2.19 **Surface weather maps for typical meteorological situations. Source: Météo France.**



a. low pressure cells in winter (19 December 1997)

b. summer anticyclonic situation with a thermal low over the Iberian Peninsula (27 July 1998)

c. southerly anticyclonic ridge in the east Atlantic (27 December 1997)

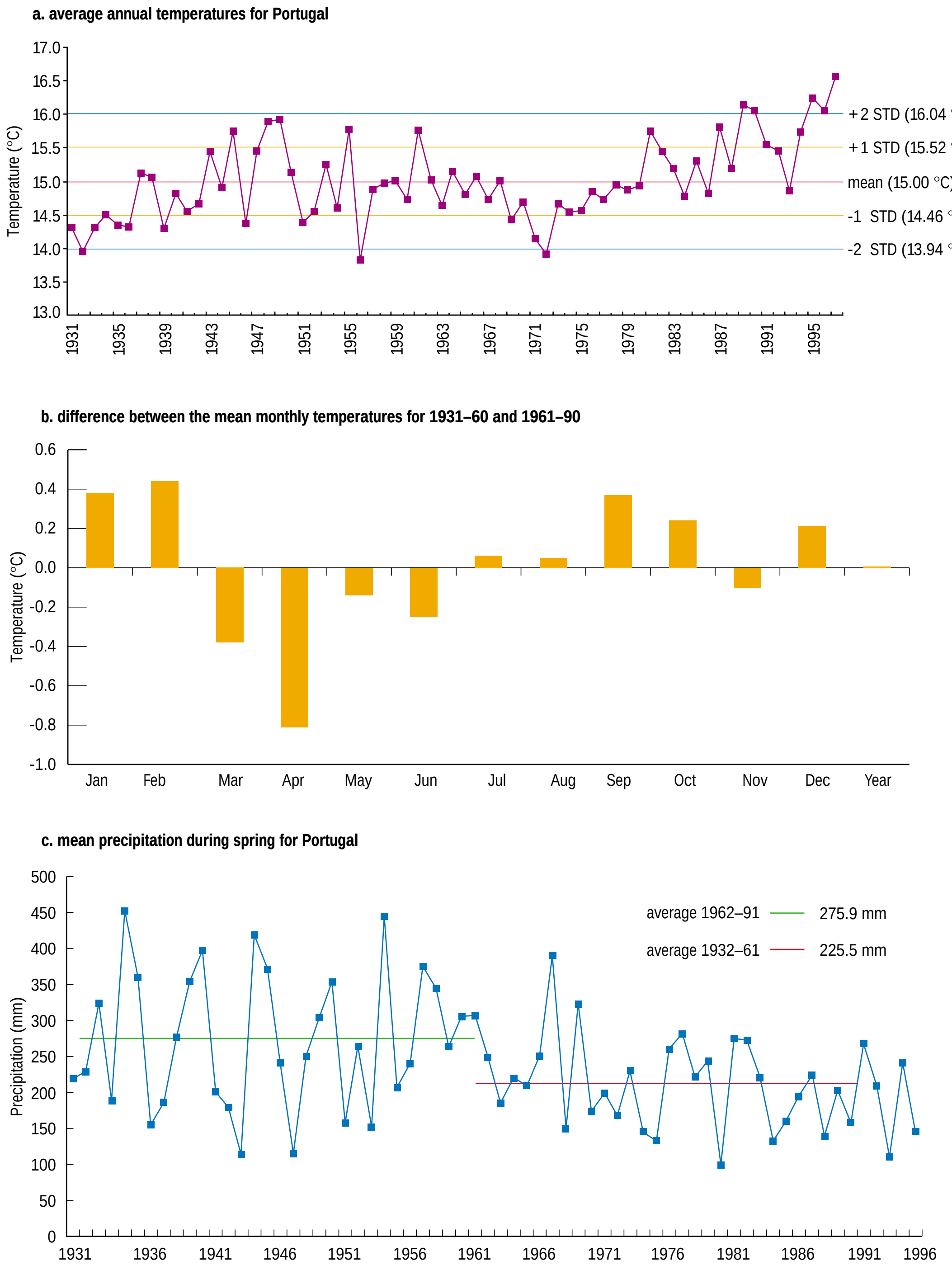
d. anticyclone over the continent and low-pressure area over the Atlantic (24 December 1997)

e. anticyclone over the British Isles, with ridge towards the south-west and low-pressure over the continent (24 January 1998)

f. anticyclone over central Europe, low pressure over North Africa (7 August 1998) causing a south-westerly flow to prevail over most of Region IV. The relief of the Iberian Peninsula plays an important role in these situations deflecting the winds off the west coast, where they become southerly and weak, strengthening them off Cape Finisterre, and protecting the inner area of the Bay of Biscay whose southern part experiences light westerlies.

Another common summer situation corresponds to an anticyclone over the British Isles extending a ridge towards the south-west, across the near Atlantic, and a low-pressure area over the Mediterranean *(Figure 2.19e)*. North-easterlies occur over the whole of Region IV, particularly off Cape Finisterre, while the southern Bay of Biscay is usually unaffected. Finally, an important situation to the

Figure 2.20 **Variation in average annual temperature and precipitation in Portugal, 1931–97. Source: Instituto de Meteorologia.**



south of Region IV corresponds to an anticyclone over central Europe and a depression over the coastal area of north Africa *(Figure 2.19f)*. The western Mediterranean is swept by fresh to near gale easterlies – the Levante – that turn to the south-east as they travel westward along the Gulf of Cadiz. Most frequent between July and October, the Levante may, however, blow in any season.

2.13 Climate variability

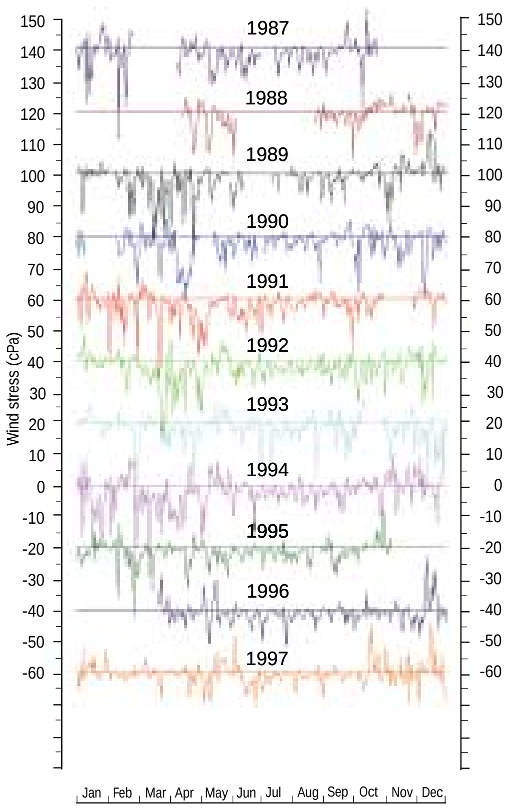
Climatic conditions in Europe and North America have changed noticeably over the last fifty years. Since the mid 1960s, precipitation has increased over the northern European countries that border the Atlantic, and has decreased in the southern area, from the Iberian Peninsula to Turkey. The average winter air temperature over the area from Scandinavia to Siberia has also increased during this period.

Annual average temperatures in Portugal indicate an increasing trend since 1972, with 1997 being the warmest year since 1931 *(Figure 2.20a)*. Although 30-year averages did not change much from 1931–60 to 1961–90, an increase did occur in autumn and winter, with a decrease in spring *(Figure 2.20b)*. The decrease matches a clear reduction in precipitation during the spring months *(Figure 2.20c)*, particularly since 1972 (and in winter since 1979), as well as an increase in the importance of northerly winds during winter and spring at the west coast of Portugal since 1989 *(Figure 2.21)*.

Variability coefficients (the standard deviation divided by the mean) computed for 30-year periods since 1900 for various measurements taken at the Spanish Atlantic stations reveal, on the other hand, that a period of relative stability until the 1950s was followed by increasing instability. This is particularly noticeable in terms of precipitation, with wet and dry years alternating with a higher frequency after the 1950s than before. Present variability, however, is no higher than was observed during the last 30-year period of the Nineteenth Century.

At the beginning of the Twentieth Century meteorologists noticed that variations in winter air temperature between Iceland and Scandinavia were out of phase. They called this climatic variation the North Atlantic Oscillation (NAO). Since then the phenomenon has been redefined and the present NAO index refers to the difference in atmospheric pressure at sea level between the Iceland Low and the Azores High. A positive value is associated with a deep low over Iceland and a large anticyclone over the Azores. In these circumstances, strong westerly winds occur over the North Atlantic, below normal temperatures are observed in the area from Labrador to Greenland and above normal temperatures in North-western Europe. A negative value is associated with opposite anomalies. These oscillations affect the

Figure 2.21 **Daily average N–S wind stress (positive northwards) on the west coast of Portugal. Source: Instituto Hidrográfico.**



whole Atlantic basin, from both atmospheric and oceanic points of view. Consequently, they have a direct effect on Region IV.

Typical periodicities for the NAO are twenty-four, eight and two years. From 1900 to the 1930s, with the exception of the winters between 1916 and 1919, westerlies were anomalously strong and the climate of Western Europe was tempered by the influence of the ocean (Parker and Folland, 1988). From the 1940s to the early 1970s there was a decrease in the NAO index, the tendency was reversed, and the period was marked by unusually cold winters. The past twenty-five years, except for 1996, have again seen an increase in the NAO index, which has been strongly positive for the last fifteen years, contributing to an increase in surface temperatures in t he northern hemisphere (Wallace *et al.*, 1995). These variations in the NAO index are accompanied by changes in storm tracks and precipitation (Hurrell, 1995). During winters with a high NAO index storms occur further north. Central and southern Europe, as well as the Mediterranean, experience a shortfall in precipitation, while excesses are recorded from Iceland to Scandinavia.

chapter 3

Human activities

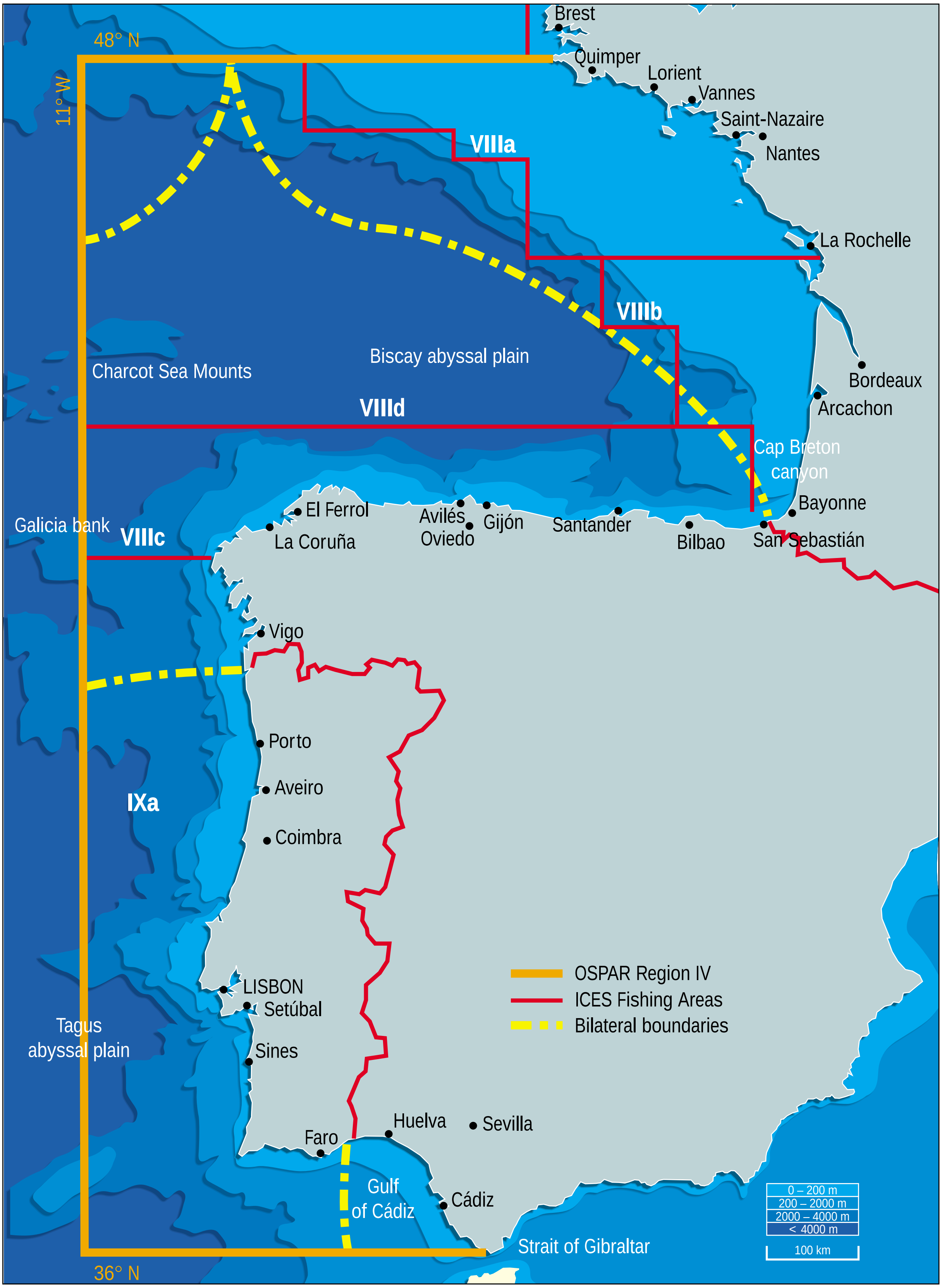
3.1 Introduction

The various activities undertaken by France, Spain and Portugal in the coastal and offshore waters of Region IV require consideration when assessing the environmental quality of the Bay of Biscay and Iberian coast. These include substantial fishing activities, recreation, agriculture and aquaculture. Each nation benefits from Exclusive Economic Zones (EEZs) extending 200 nautical miles (370.4 km) from national shorelines. Neighbouring zones are delineated by boundaries equidistant from each country or by international agreement.

Five of the fishing areas delineated by ICES fall within Region IV (*Figure 3.1)*. These are subject to regular assessment concerning fishing activities. The distribution of target species for the commercially exploited stocks are assessed in the northern Bay of Biscay (Divisions VIIIa, VIIIb, VIIId) and in the Iberian region (Divisions VIIIc, IXa). Regulations and measures concerning the management of fisheries fall within the auspices of the European Community (EC). The International Maritime Organisation (IMO) deals with shipping safety and the protection of the marine environment from the harmful effects of shipping. No IMO Special Areas have been designated in Region IV.

As the western European maritime areas are far from the centre of Europe, the 'Atlantic Arc' was created in October 1989 to develop interregional cooperation, under the auspices of the Conference of Peripheral Maritime Regions of the EEC. Sixteen counties and regions from the three countries of Region IV represent the 'Southern Arc'; six French regions, five autonomous Spanish regions and five Portuguese administrative regions *(Figure 3.2)*.

Figure 3.1 **Bathymetry, ICES Fishing Areas and major cities. Source: IFREMER.**



3.2 Demography

Approximately 47.2 million people live in the catchment areas draining into Region IV *(Figure 3.3)*. These represent 60% of the total continental surface area of the three countries, corresponding to a mean population density of 71 inh/km², a relatively small figure compared to the average for the European Community, i.e. 113 inh/km². Of the total population living in the Region IV catchment area 6.5 million live in twenty-four principal coastal cities.

There are fourteen administrative regions of France, Spain and Portugal bordering Region IV, at least in part. This corresponds to 36.6 million inhabitants in an area of 343 000 km², and thus an average density of 106 inh/km². In France, only Brittany has a population density of this magnitude. In Spain, the three northern coastal regions are densely populated: Pais Vasco (290 inh/km²), Cantabria (100 inh/km²) and Asturias (104 inh/km²). In Portugal, the northern regions have similar population densities: Norte (162 inh/km²) and Lisboa-vale do Tajo (288 inh/km²).

A study of a 10 km-wide coastal strip, between the northern limit of Region IV in Brittany, and the French/Spanish border (IFEN, 1997), identified 1.6 million inhabitants living in an area of 11 100 km², corresponding to an average population density of 141 inh/km². However this coastal strip does not include some of the larger cities (e.g. Nantes and Bordeaux) which restricts an evaluation of pressures on the coastal zone. The population density of this coastal strip has increased during the most recent censuses: 111 inh/km² in 1962, 126 inh/km² in 1977, 134 inh/km² in 1982 and 141 inh/km² in 1990.

3.3 Conservation

3.3.1 Ecological conservation

France, Spain and Portugal are signatories to several International Conventions concerning the conservation of natural environments. Two EC Directives complete this international system; the Wild Birds Directive (79/409/EEC) and the Habitats Directive (92/43/EEC) *(Table 3.1)*. All the international designations of protected areas have been mapped on the basis of the European classification of administrative areas *(Figure 3.4)*.

The variety of national initiatives concerning the designation of parks and natural reserves within the coastal areas of Region IV create difficulties in attempting to summarise the network of protected areas. *Table 3.2* summarises this information according to the categories for protected areas as defined by the International Union for Conservation of nature and Natural Resources (IUCN) (the differing levels of national protection should eliminate any apparent overlap).

Figure 3.2 **Atlantic Arc regions, 1996. Source: Conference of Peripheral Maritime Regions of the EEC.**

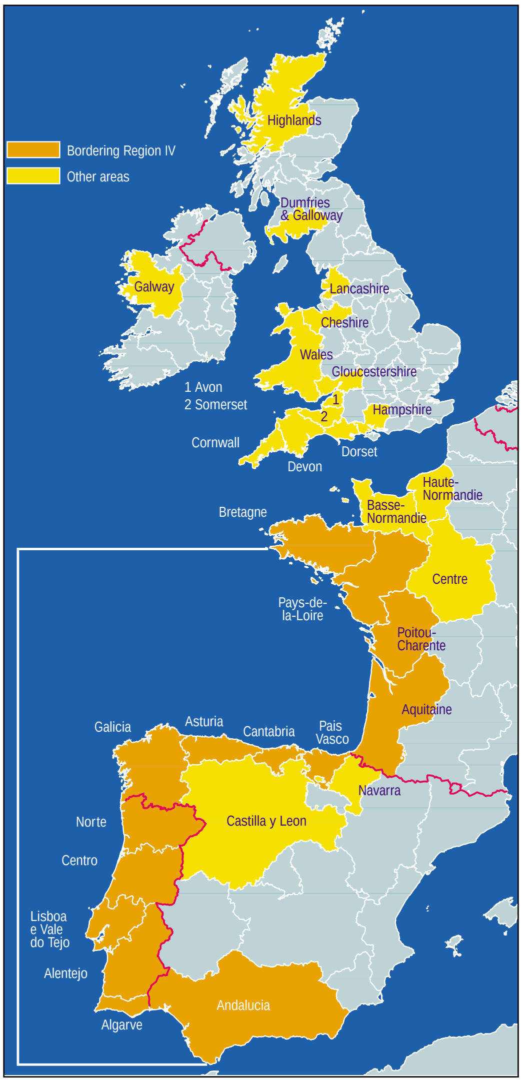


Table 3.1 Number and size (km²) of protected areas – international designations.

	Bird Directive (79/409/EEC)		Habitats Directive (92/43/EEC)	
	number	size	number	size
France	30	7 280	543	10 580
Spain	23	7 506	588	70 250
Portugal	15	2 293	65	12 150
TOTAL	68	17 079	1 196	92 980

Other international designations: Ramsar sites – wetland areas of international importance, particularly those containing waterfowl habitat; Biosphere Reserves – ecosystems recognised within the framework of UNESCO's Man and the Biosphere (MAB) Programme. Biosphere Reserves – examples of natural European heritage, UNESCO's World Heritage Sites (Convention, 1972).

Figure 3.3 **Catchment areas and population distribution, 1990. Source: INSEE.**

Figure 3.4 **Protected areas – international designations, 1998. Source: Council of Europe; EC; EEA; ETC/NC; WCMC.**

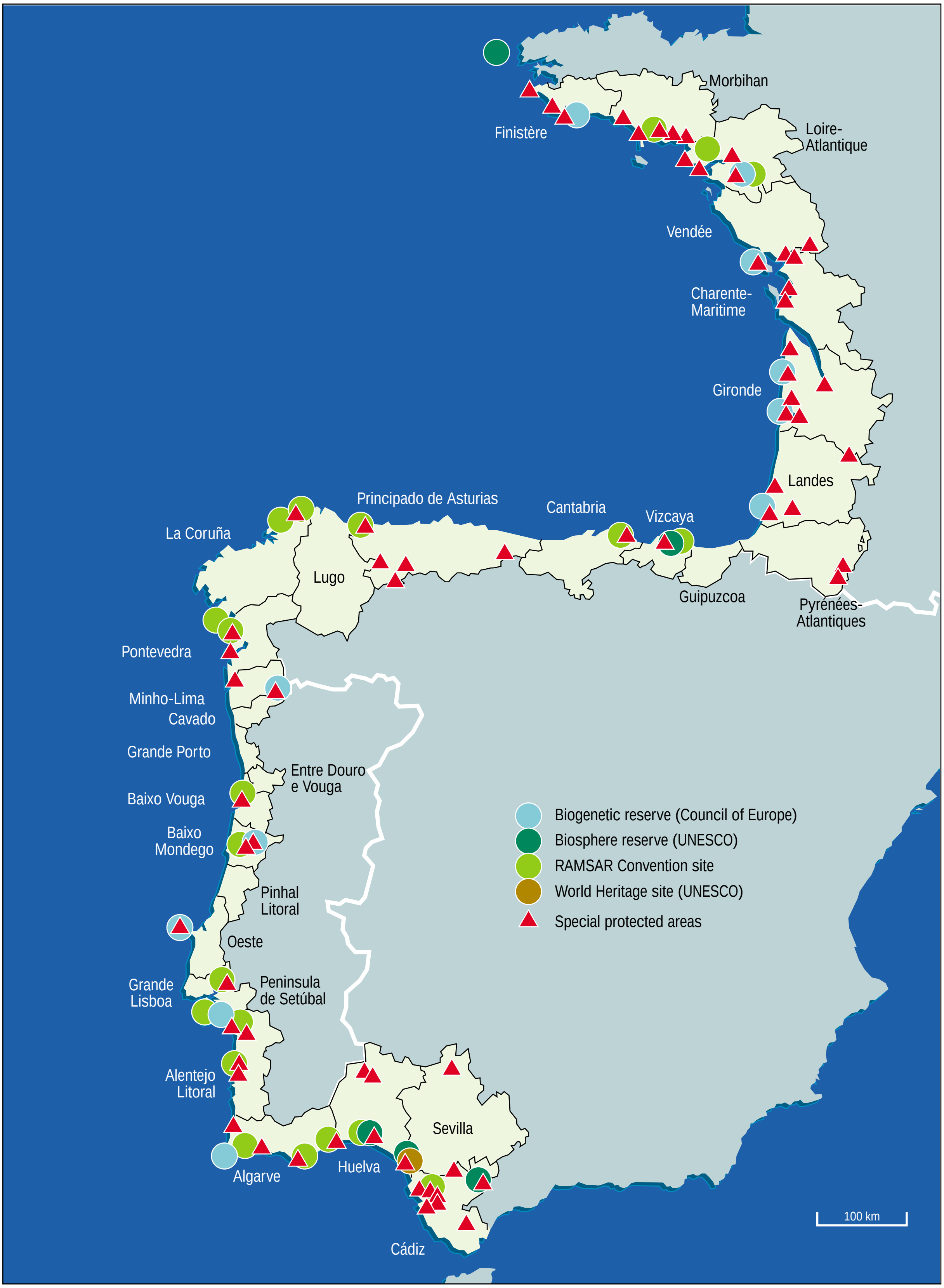


Table 3.2 Number and size (km^2) of protected areas – national designations.

	I		II		III		IV		V	
	number	size	number	size	number	size	number	size	number	size
France	-	-	0	0	2	1.2	130	286	2	3 020
Spain	7	7.4	2	1 154	0	0	16	4 264	23	7 411
Portugal	1	10.8	1	211	6	7.6	6	411	7	1 595
Region IV	8	18.2	3	1 365	8	8.8	152	4 961	32	12 026

IUCN categories for protected areas (plus management strategy): I Strict Nature Reserve / Wilderness Area (scientific study or wilderness protection); II National Park (ecosystem protection and recreation); III Natural Monument (conservation of specific natural features); IV Habitat / Species Management Area (conservation through management intervention); V Protected Landscape / Seascape (landscape / seascape conservation and recreation).

Over 50% of the wetlands present in France a hundred years ago have disappeared (i.e. at least 25 000 km^2) and the degradation and destruction of those remaining has accelerated during the last fifteen years (de Monza, 1994). A governmental plan of action for national wetlands was adopted in March 1995, principally to create a National Wetlands Observatory (ONZH). This observatory oversees information for seventeen wetlands on the Region IV coast.

3.3.2 Archaeological conservation

Owing to its history and situation, Spain has a considerable coastal and marine archaeological heritage. The north coast is rich in archaeological remains and includes cave paintings of great interest. Throughout history there have been a great number of shipwrecks on the coasts of Galicia and the Gulf of Cadiz; approximately 700 of these date from the sixteenth to the nineteenth centuries.

Portugal also has an extremely rich underwater cultural heritage, owing to its position along the corridor serving the Mediterranean–Atlantic navigation routes. The archaeological inventory includes over 6000 pieces found in Portuguese coastal waters.

3.4 Tourism

In France, the Atlantic region contains 24% of the available accommodation for visitors and 25% of the potential for overnight stays in hotels and campgrounds. Brittany and Aquitaine are the two biggest tourist areas *(Table 3.3)* each possessing 7% of the national accommodation available for visitors; although this capacity has more to do with the extended coastline in these regions than with a higher density of tourists. Of these regions Vendée and Charente Maritime head the list. In France, the tourist season is focused on the two summer months, particularly from mid-July to mid-August (IFEN, 1997). This seasonal tendency is becoming increasingly marked as the holiday period is shortening, and thus translating to an increased environmental pressure. During summer, the resident population is multiplied by a mean factor of 1.4 in Brittany, 3.2 in Aquitaine and 3.5 in the Loire and Charente. The maximum is a factor of 6.0 for Vendée.

The Spanish Atlantic coast is not a frequent destination for tourists; the total number of overnight stays in local hotels on the Atlantic coast represents 6% of overnight stays in Spain and 87% of the visitors are Spanish.

A total of 1.2 million people visited the five Portuguese administrative regions along the Region IV coast in 1996; 50% visiting the Algarve, the most southern and smallest region.

Table 3.3 Tourism within the coastal areas bordering Region IV.

Region	10^3 overnight stays*	10^3 number of beds†
France		
Brittany	-	330
Pays de Loire	-	300
Poitou Charente	-	200
Aquitaine	-	980
SUB-TOTAL	-	1 810
Spain		
Pais Vasco	1 230	20
Cantabria	1 030	60
Asturia	1 010	40
Galicia	3 130	90
Andalucia	2 370	70
SUB-TOTAL	8 770	280
Portugal		
Norte	380	-
Centro	160	-
Lisboa-vale do Tajo	470	-
Alentejo	240	-
Algarve	2 300	-
SUB-TOTAL	3 550	-
Region IV	12 320	2 090

* Spain: overnight stays in hotels for residents and non-residents in 1993, Portugal: overnight stays in coastal tourist resorts in 1996; † Spain: hotels, tourist apartments and campgrounds, Portugal: hotels and campgrounds; - not known.

3.5 Fishing

Fishing activities in the Bay of Biscay and on the Iberian coast are characterised by a wide variety of fishing vessels, equipment and fishing techniques, as well as by the large number of fish species targeted. Over a hundred species are targeted, including valuable estuarine species.

3.5.1 Catches

Total French catches from the Bay of Biscay exceeded 90 000 t in 1997 ***(Table 3.4)***. Anchovy (*Engraulis encrasicolus*) and pilchard (*Sardina pilchardus*) represented over half the pelagic catch, while hake (*Merluccius merluccius*), sole (*Solea solea*) and anglerfish (*Lophius piscatorius* + *L. budegassa*) dominated the demersal catch. The major French shellfish fishery is Norway lobster (*Nephrops norvegicus*) and this is located on the Grande Vasière in southern Brittany, as well as on the Vasière of the Gironde. Prawns and large crustaceans accounted for < 2500 t of total landings from the Bay of Biscay. Catches of cuttlefish (*Sepia officinalis*) and squid (*Loligo vulgaris*) vary from year to year depending on their relative abundance; landings exceeded 6000 t in 1997.

In Spain, hake is the principal target species found off the French coast. The annual hake catch is nearly 16 000 t from the 'northern stock', which includes ICES Fishing Areas VI and VII ***(Table 3.4)***. A long-term series of international landings from the Bay of Biscay is given in *Figure 3.5*. Anchovy is fished in the Bay of Biscay in spring and summer while pilchard is targeted throughout the year, especially off Galicia. The anchovy catch varies widely from year to year depending on recruitment and has ranged from 6000 to 20 000 t/yr in recent years. The pilchard catch off the Spanish coast dropped sharply during the last few years, and is currently < 30 000 t/yr. In the Gulf of Cadiz, anchovy catches totalled 1000 to 4000 t/yr and pilchard catches 3000 to 7000 t/yr.

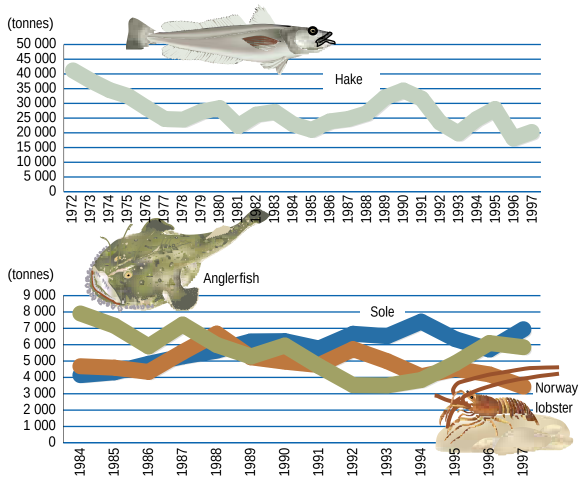
In Portugal, total catches for the ten most important species fell from 263 400 t/yr to 214 600 t/yr between 1986 and 1996. Of these species, the four most important in terms of quantity are pilchard, albacore (*Thunnus alalunga*), horse mackerel (*Trachurus trachurus*) and octopus (*Octopus vulgaris*), together representing 128 100 t, which is 63% of the total catch.

Table 3.4 Landings (t) in 1996 (Portugal) and 1997 (France and Spain).

	France	Spain	Portugal	Region IV
Demersal species				
anglerfish	5 300	10 500	-	15 800
conger	2 400	-	-	2 400
hake	9 500	15 800	5 000	30 300
Norway lobster	3 400	-	-	3 400
seabass	1 700	-	-	1 700
sole	5 500	-	-	5 500
whiting	2 300	-	-	2 300
SUB-TOTAL	30 100	26 300	5 000	61 400
Pelagic species				
albacore	3 400	13 300	15 600	32 300
anchovy	12 000	19 000	-	31 000
Atlantic mackerel	7 200	31 100	-	38 300
black scabbardfish	-	-	7 000	7 000
cod	-	-	5 100	5 100
horse mackerel	8 700	35 800	14 000	58 500
pilchard	10 900	25 700	86 900	123 500
silver scabbardfish	-	-	8 400	8 400
SUB-TOTAL	42 200	124 900	137 000	304 100
cephalopods*	6 000	-	11 600	17 600
others	12 120	-	61 000	73 120
TOTAL	90 420	151 200	214 600	456 220

* includes cuttlefish, squid and octopus.

Figure 3.5 **Fish landings – ICES areas VIIIa and VIIIb to French harbours, 1972–97. Source: IFREMER.**



3.5.2 Fishing fleets

In France, trawlers are the main fishing vessels used to land pelagic and demersal species, representing 61% and 50% of the catch, respectively. Purse-seines, traditional nets, lines, dragnets and traps are also used, but to a lesser extent. Nearly 2500 French fishing boats are currently active in the Bay of Biscay. This fleet can be divided as follows: 66% are 'territorial' and remain within 12 nm of the shore (length 6 – 10 m), 13% are 'coastal to offshore' and venture beyond the 12 nm zone (length > 15 m), and 20% are 'mixed' fishing the inshore zone as well as offshore fishing grounds (length 9 – 18 m).

The Spanish fishing fleet is a mix of several types of vessel employing various techniques. Trawlers and line fishing boats traditionally target the demersal species and are relatively common within the fleet. Other types of vessel include purse-seiners, gillnetters, trap-net boats and a large fleet of smaller, artisanal boats. The number of vessels in the Spanish fishing fleet decreased during the 1990s and is currently around 9000. Spanish artisanal vessels work different seasonal fisheries over the course of the year; hake and mackerel (*Scomber scombrus*) in the winter, anchovy during spring, and albacore in summer and autumn.

There was an overall decrease in both the number of vessels (16 244 to 11 597) and the power of the fishing fleet between 1986 and 1996 in Portugal. The fleet is currently dominated by smaller, inshore boats (86%) mainly comprising open-decked wooden vessels. These typically fish for short periods of time, sometimes seasonally. In terms of tonnes caught, the multi-use segment of the fleet (i.e. vessels fishing both inshore and offshore waters) accounted for 77% of the catch; the ten main species accounting for 76%. Between 1986 and 1996 there were substantial increases in tuna, octopus and scabbardfish (*Aphanopus carbo*) catches and significant decreases in cod, hake and mackerel catches.

3.5.3 Fisheries management

Catch restrictions for the Bay of Biscay are recommended on the basis of scientific advice (ICES, STECF). Total Allowable Catches (TACs) are shared between France and Spain for several species (e.g. anchovy, hake, whiting (*Merlangius merlangus*)) while the TAC for sole is shared with Belgium and the Netherlands. Certain species range beyond the Bay of Biscay and so stock estimations for determining TACs take this extended range into account. The same system is practised in Iberian waters where Spain and Portugal share TACs for stocks occurring in ICES Sub-Areas VIIIc and IXa.

The EC has attempted to limit the total engine power of the national fishing fleets in order to reduce the impact of fishing on certain species. Measures have been adopted which attempt to adjust the rates of reduction in engine power according to the fishing techniques used and the species targeted. In addition to these restrictions imposed by the EC, France and Portugal use a licensing system to limit the number of active fishing boats, while Spain has a register which limits the total number of boats according to the type of fishing gear used and the area fished.

A new rule of ‘Technical Measures’, adopted by the EC in March 1998 and applied January 2000, standardises the mesh size of trawl nets at 70 mm for both fish and Norway lobster. Nevertheless, smaller mesh sizes will continue to be used for some other species (e.g. prawn, anchovy).

3.6 Aquaculture

Marine aquaculture is spread widely along the Atlantic coast and concentrated in several well defined areas. In France, southern Brittany and the areas around Bourgneuf Bay, Ré Island, Marennes-Oléron and Arcachon Bay, are all major sites of aquaculture. In Spain, aquaculture takes place along the greater part of the coastline, being particularly important in Galicia and on the north-west coast. In Portugal, marine aquaculture occurs along the western and southern coasts, particularly in some of the more important estuaries. The Ria Formosa lagoon is important for mollusc culture. *Table 3.5* shows production in Region IV for 1996 (Spain and Portugal) and 1997 (France).

3.6.1 Molluscs

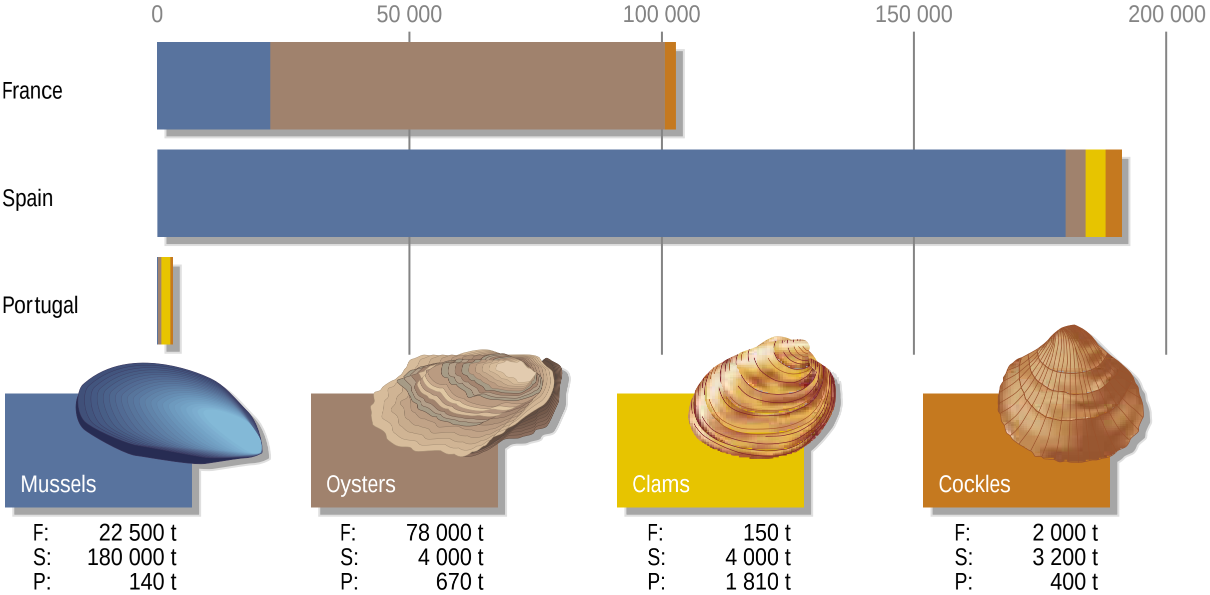
Oyster and mussel cultivation dominates aquaculture in France. Approximately 3500 farms are involved in the production of around 100 000 tonnes of oysters and mussels per year *(Figure 3.6)*. All the spat used is collected from Region IV waters before being exported to cultivation centres in Brittany and Normandy.

In Spain, mussels comprise around 90% of the total aquaculture production. Total production oscillates around 200 000 t/yr; during 1987 to 1996 ranging from a low of 105 000 t in 1993 to a high of 250 000 t in 1988. These variations are mainly due to changing levels in mussel production which are, in turn, greatly influenced by annual variations in the presence of harmful algae. Spanish mussel culture takes place almost exclusively in Galicia through the capture of seed from the natural environment and the subsequent raising of mussels on ropes suspended from floating rafts. The remaining mollusc

Table 3.5 Aquaculture production (t) in 1996 (Spain and Portugal) and 1997 (France).

	France	Spain	Portugal	Region IV
Shellfish				
clams	150	4 000	1 810	5 960
cockles	2 000	3 200	400	5 600
mussels	22 500	180 000	140	202 640
oysters	78 000	4 000	670	82 670
SUB-TOTAL	102 650	191 200	3 020	296 870
Crustaceans				
shrimp	22	80	-	102
Fish				
seabass	300	-	330	630
seabream	-	-	520	520
turbot	700	2 200	100	3 000
SUB-TOTAL	1 000	2 200	950	4 150
Algae				
Undaria	3	-	-	3
TOTAL	103 675	193 480	3 970	301 125

Figure 3.6 **Shellfish production (tonnes), 1996. Source: IEO; IFREMER; IPIMAR.**



production is distributed equally between clams (grooved carpet-shell (*Tapes decussatus*)) and oysters (flat (*Ostrea edulis*) and cupped (*Crassostrea angulata*)), both groups producing around 4000 t/yr between 1987 and 1996. Oyster production is concentrated on the Cantabrian and Galician coasts and clam production on the Galician and southern coasts.

The Portuguese aquaculture industry is heavily dependent on the culture of molluscs and has an annual production of around 3000 t. The most important species (clams, oysters and cockles (*Cerastoderma edule*)) all showed a marked decrease in production during 1990 to 1996. This can be attributed to excessive animal concentrations, the use of inadequate seed-oysters and the progressive deterioration of water quality.

3.6.2 Fish and crustaceans

Atlantic production in France (1000 t/yr) is concentrated around Ré, Oléron and Noirmoutier islands and all the farms use saltwater tapped from below ground in order to avoid low water temperatures during winter. Spanish production grew significantly from 1987 to 1996, mainly due to the development of turbot (*Psetta maxima*). Turbot production has stabilised at around 2200 t/yr with production concentrated in Galicia where cultivation takes place in onshore tanks. Portuguese production has been relatively stable, or has even increased, for seabass (*Dicentrarchus labrax*; from 2 t in 1990 to 327 t in 1996), seabream (*Sparus aurata*; from 105 t in 1990 to 519 t in 1996) and turbot (from 35 t in 1994 to 102 t in 1996).

Production of eel (*Anguilla anguilla*), once of great importance (979 t in 1994), has declined dramatically in recent years (21 t in 1996) due mainly to the high cost of the juveniles which arrive each year on the Portuguese coast, before passing through the estuaries to the rivers, where they are captured.

Crustacean production in Region IV is relatively low at around 100 t/yr and occurs primarily along the southern French coastal marshes and on the Spanish Atlantic coast of Andalucia.

3.7 Coastal protection and land reclamation

Regional variation in coastal erosion is shown in *Figure 3.7*. The many contributory factors include tidal action, littoral currents and rising sea level. The slow rise in sea level (currently 1.5 to 1.9 mm/yr), having increased by 50 m over the last 10 000 yr, may continue to increase due to the effects of global warming. The coastal zones between Biarritz and Adour are currently the most problematic in terms of erosion, due to a powerful swell (reaching a wave height of 15 m) and a continuing deficit in sediment replenishment. In central Aquitaine, the average retreat of sandy beaches is estimated at 0.5 – 1.0 m/yr; German bunkers originally constructed above the high tide level during the Second World War serve as beach erosion gauges and are currently located in the sea 50 – 100 m from the shore.

Coastal winds also affect coastal erosion. The inshore movement of sand from coastal beaches can be signifi-

Figure 3.7 **Regional variation in coastal erosion, stability and growth. Source: EC – Corine coastal erosion database.**

cant, reaching 20 000 – 40 000 m^3 per year and per kilometre of shoreline, as exemplified on the Landes coast. In extreme cases, as for the Pyla dunes, this can reach 200 000 m^3 per year and per kilometre.

In Spain, the purpose of the 1988 Law of Coasts is 'the determination, use and policing of the terrestrial maritime public domain and especially of the seashore'. This law establishes that the shore and estuary banks are in the public domain and prohibits building and inter-community road construction within 100 m of the mean high tide level while allowing for free public access to the ocean.

Coastal erosion is a problem affecting important areas along the Portuguese coast. The severe reduction in sediments to replenish the coastal zones is one of the primary causes of this coastal retreat. There has been considerable construction of protective measures (e.g. spurs and rock walls) in such areas, although until now the solutions adopted have always involved the construction of emergency measures, without any associated impact assessments.

3.8 Wave, tide and wind power generation

There are no installations for harnessing wave or tidal energy in Region IV. However, in 1991 Spain approved the Energy Saving and Efficiency Plan which gave strong support to the use of renewable energy sources, particularly wind power. In 1997, 332 MW were derived from wind turbines with 164 MW from the peninsula (Andalusia: 86 MW near Tarifa Point, and Galicia: 78 MW near Finistère).

3.9 Sand and gravel extraction

In France, there are considerable sand and gravel resources along the Atlantic seaboard: 24 x 10^9 m^3 of siliceous sediments and 0.17 x 10^9 m^3 of calcareous sediments. The Loire Estuary is currently the largest producer of siliceous marine sediments in France with a production of 1.6 x 10^6 m^3/yr. The extraction of calcareous sediments is focused on Brittany and concerns conchiferous sands and Maërl (*Lithothamnion*). Marine sediment extraction off the French Atlantic seaboard represents 60% of national production. Marine aggregates are considered as ore products and so are subject to French mining regulations.

In Spain, the 1988 Law of Coasts prohibits the extraction of aggregates from the coast, except for beach replenishment in which case it requires that the effects be assessed, both in terms of the site from which the aggregate will be extracted and the site where it will be deposited. The volume of sand extracted from the Peninsula coasts between 1983 and 1992, was 12 x 10^6 m^3. Of this total, 4.8 x 10^6 m^3 were extracted from the northern coast and 7.3 x 10^6 m^3 from the southern. Between 1993 and 1994 more than 3 x 10^6 m^3 were extracted and used to replenish eroded beaches.

In Portugal, a similar system is practised in which aggregates extracted from coastal areas must be used for beach replenishment. Despite recent legislation restricting the total amounts extracted, extraction from river beds, river margins, estuaries, navigation channels and coastal areas continues to occur at a relatively high rate. Total extraction is around 2000 t/yr. The various governmental bodies with jurisdiction over the coastal areas have differing attitudes regarding management. Areas under the jurisdiction of the Institute for Nature Conservation are protected from sand extraction, whereas coastal areas under port jurisdiction (Figueira da Foz and Aveiro Ria, in particular) are subject to sand extraction.

3.10 Dredging, dumping and discharges

3.10.1 Dredged material

Sediments may be dredged from harbour areas, estuaries and navigation channels. The material excavated is usually sand, silt or gravel. Pipeline and hopper dredging, which use hydraulic principles, are the most common techniques used. The quantities of dredged material vary from year to year. In total around 21 x 10^6 m^3 of dredged material are dumped within Region IV; 83% from France ***(Table 3.6)***.

In France, the main ports are managed by autonomous port authorities. For the French coastal and estuarine areas of the Bay of Biscay, the quantity of dredged and dumped material was approximately 18 x 10^6 m^3 in 1996. This material is usually dumped at licensed sites off the main harbours. In Spain, the main ports are managed by the national organisation, State Ports, while autonomous communities manage the less important ports. Depending on the coastal sector, the amounts dredged and dumped into the sea by the State Ports authority from 1993 to 1996, varied between 2 and 3 x 10^6 m^3. In Portugal, the main ports are managed by port administrations. In 1995, legislation was enacted concerning the assessment and management of dredged material and dumping operations. Dredging carried out by the Institute of Nature Conservation at APPLE (Protected Landscape of Esposende Littoral Area) and PNRF (Ria Formosa Natural Park) is aimed at opening navigation channels and at the reinforcement of dunes and sandy beaches. The volume of sand dredged from these areas between 1994 and 1997 was 105 x 10^3 m^3 at APPLE and 958.5 x 10^3 m^3 at PNRF.

The recommendations for dumping dredged material as outlined by OSPAR (1998) form the basis for identifying suitable material for dumping and the selection of the dump sites. An example of their application is the solution found for the port of Huelva in 1995. Given the high content of heavy metals (mainly arsenic) in some of the estuarine sediments, the following actions were agreed: disposal of the most contaminated mud (1 x 10^6 m^3) in a specially constructed enclosure, dumping of 1 x 10^6 m^3 in the sea at a depth of 20 m, and the use of 4 x 10^6 m^3 of clean sand for beach regeneration. Another example is their use by the French working group GEODE of the Ministries of Equipment and Environment, which defines reference levels and the maximum allowable concentrations of metallic contaminants and polychlorinated biphenyls in dredged material for dumping.

3.10.2 Other wastes

There is no sewage sludge dumped at sea along the Atlantic coast by France, Spain or Portugal, either from land or ships. In 1993 Spain stopped the dumping of mud containing heavy metals originating from titanium dioxide production. There are no French or Portuguese titanium dioxide plants in the catchment area of Region IV.

There are four Spanish nuclear power reactors (Almaraz 1 and 2, José Cabrera and Trillo) and one fuel fabrication plant (Juzbado) within the OSPAR Convention area. None of these are located near the coastal environment. Discharges and emissions have always been within or below the common ranges, except for effluents from the José Cabrera reactor whose normalised activity was out of range during 1994 due to the shutdown of the plant between 10 January 1994 and 13 June 1995. The activity released from Juzbado is well below the authorised limit for fuel fabrication plants.

The only French nuclear power station located in Region IV is situated on the Gironde Estuary, at Le Blayais (4 x 910 MW). Ecological surveys commissioned in 1975 have not revealed any adverse environmental effects arising from the small increases observed in local water temperatures.

Table 3.6 Dredged material (m^3 x 10^3) from ports dumped in 1996 (France and Spain) and 1997 (Portugal).

Administrative area	Port	Quantity
France		
Brittany (south)	Lorient	ns
Pays de Loire	Nantes-Saint-Nazaire	10 210
Poitou Charente	La Palice, La Rochelle and others	620
Aquitaine	Bordeaux	6 030
	Bayonne	660
SUB-TOTAL		17 520
Spain		
Pais Vasco		0
Cantabria	Santander	1 970
Asturias		0
Galicia	Ferrol, Corona, Pontavedra, Vigo	20
Andalucia	Huelva, Seville, Cadiz	70
SUB-TOTAL		2 060
Portugal		
Norte		340
Centro		250
Lisboa-vale do Tajo		1 020
Alentejo		ns
Algarve		ns
SUB-TOTAL		1 610
TOTAL		21 190

ns: not significant.

3.10.3 Litter

Large quantities of litter are being added to the general debris (e.g. seaweed and driftwood) washing up along coastlines. The majority is slow to decompose. This debris tends to be most abundant at river mouths, near urban communities, in tourist areas and along shipping lanes. Plastics are the main constituent of litter found in the open ocean, representing 60 – 95% of the total depending on the area. The main types of plastic litter are bags, bottles and various wrappers. Glass bottles and metal objects may also be found in areas where litter collects, while debris associated with fishing actives (e.g. fishing lines, ropes and nets) can be substantial in certain zones.

Fieldwork carried out since 1992, provides an overview of litter concentrations in the Bay of Biscay *(Figure 3.8)*. For the area as a whole, there are at least 50 million individual items of litter for the regions up to 200 m deep. For areas of greater depth (1800 m, e.g. canyons off Cap Breton and Cap Ferret), concentrations are around 15 items/ha. No data currently exist concerning fluxes in relation to estuaries and river deltas.

A monitoring programme coordinated by a Portuguese environmental association has surveyed much of the Portuguese coastline. This work is mainly carried out during the winter months and has formed part of the project Coastwatch Europe. In 1997, 109 km of the ~ 1800 km of Portuguese coastline were studied.

Beach cleaning operations take place along the French and Portuguese coasts. These are carried out by local authorities before the beginning of summer.

3.11 Oil and gas industry

In France, the large sedimentary basins of Aquitaine (i.e. Parentis and Adour) contain hydrocarbon deposits which extend offshore. However these deposits are exploited on land at Lacq. Although intensive geophysical field campaigns have been undertaken and research permits have been authorised for northern Aquitaine almost as far as Bayonne, none of the test-drilling has led to offshore drilling. The total hydrocarbon production for the terrestrial region is of the order of 300 000 t/yr.

Oil rigs and production wells are located on the northern and southern shores of Spain. The 'Gaviota' production rig, situated a few kilometres off the Basque coast, is no longer productive but the reservoirs are used to store gas. The subsea gas production wells situated in the Gulf of Cadiz between the mouth of the Guadiana and the Tinto/Oriel are located in the seabed and connected to land by a pipe to ensure that contaminated water is not discharged to the OSPAR Maritime area.

In Portugal, a terminal for natural gas and underground storage is sited on the southern coast.

3.12 Shipping

3.12.1 Port traffic

Port traffic along the Atlantic seaboard is about 180×10^6 t/yr. Ports handling $> 10 \times 10^6$ t/yr control nearly 82% of the port traffic in Region IV. Port activities are centred on twenty principal ports; the three most important being Nantes-Saint-Nazaire, Bilbao and Sines (*Figure 3.9* and *Table 3.7*). The transportation of hydrocarbons is concentrated at these ports, whereas container shipping is largely controlled by Bilbao and by Leixoes-Porto and Lisbon in Portugal. These ports each handle around 2 million containers.

3.12.2 Accidents at sea

Unintentional marine pollution has a number of causes: for example, explosions, collisions, groundings, ship damage and breakdowns (CEDRE, 1998). Along the French coast in the Channel–Atlantic sector, an average of 34 accidents occurred each year between 1989 and 1993. The total number of accidents each year concerning vessels off the Spanish coast varied from 196 to 267 between 1993 and 1996. A comparison between the French and Spanish data is not possible as they are probably based on different criteria. The major accidents

Figure 3.8 **Density of litter. Source: IFREMER.**

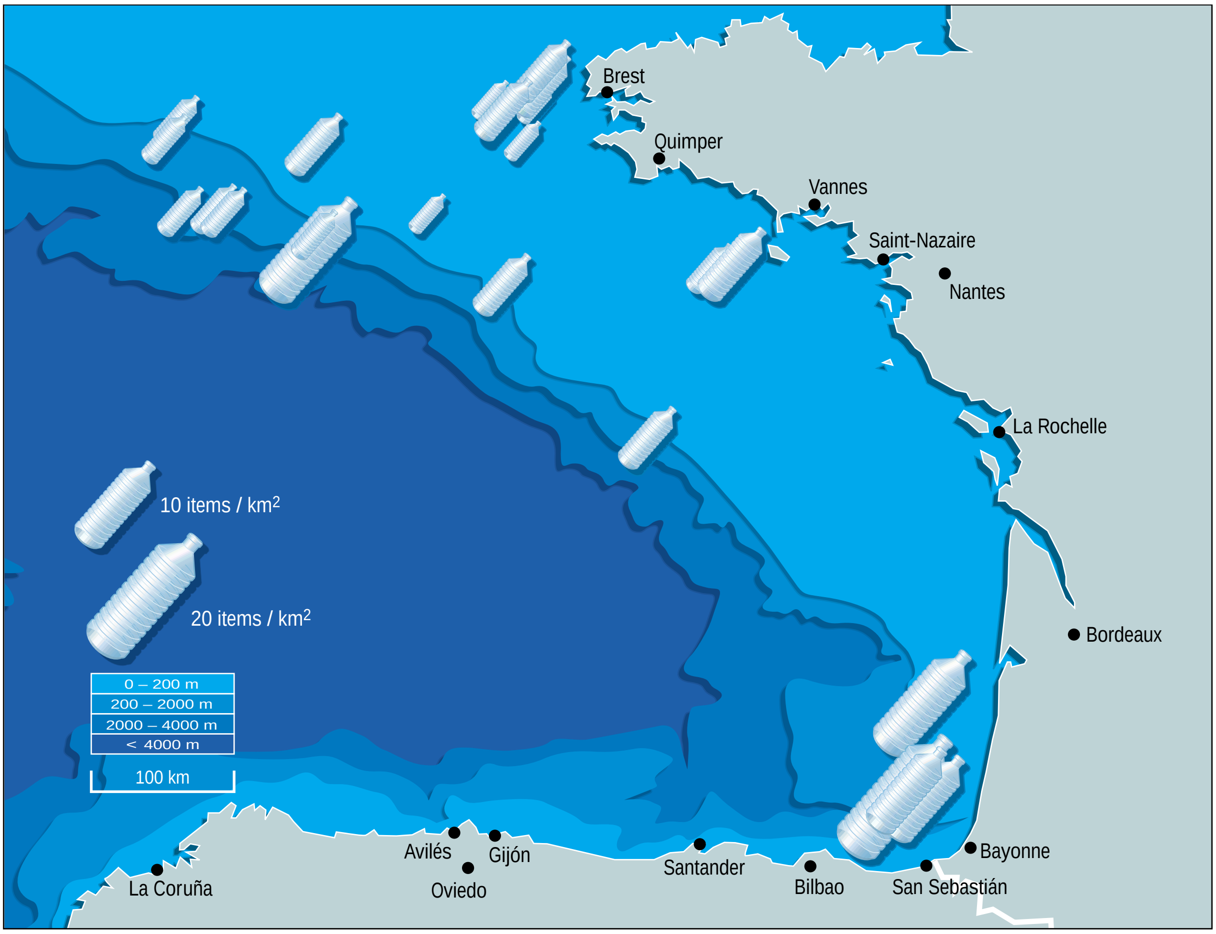


Figure 3.9 **Shipping activity 1996. Source: Journal de la Marine Marchande.**

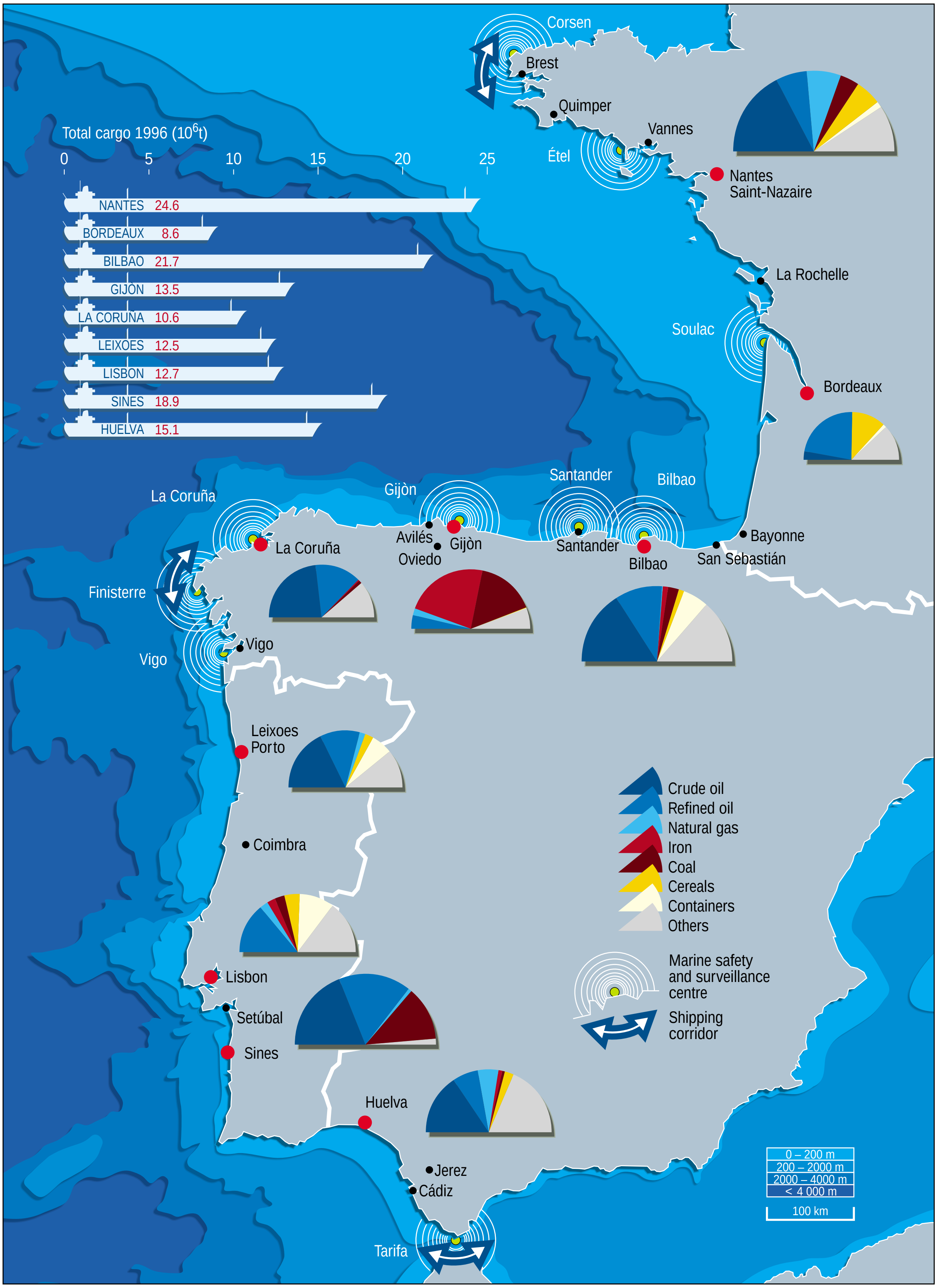


Table 3.7 Shipping activity within Region IV in 1996.

Port	Hydrocarbons* (t x 10^6)	Total freight (t x 10^6)	Containers (t x 10^3)	Passengers (no.)	Ships (no.)
France					
Lorient	0.80	2.32	-	-	461
Nantes-Saint-Nazaire	15.00	24.65	600	-	2 219
La Rochelle	-	5.53	-	-	-
Bordeaux	4.39	8.65	221	14 758	1 508
Bayonne	0.42	3.02	-	-	663
SUB-TOTAL	20.61	44.17	821	14 758	4 851
Spain					
Pasajes/San Sebastian	0.31	3.43	-	693	1 321
Bilbao	11.39	21.74	2 428	133 148	3 487
Santander	0.25	4.54	63	149 741	1 585
Gigon	1.50	13.48	53	-	844
Avilés	0.13	3.78	ns	-	1 030
Ferrol	0.33	7.18	2	138	1 015
La Coruña	7.87	10.60	7	53 180	1 057
Huelva	8.23	15.10	-	115	1 713
Sevilla	0.10	3.76	337	1 593	1 314
Cadiz	0.12	3.52	553	76 292	2 186
SUB-TOTAL	30.23	87.12	3 443	414 900	15 552
Portugal					
Leixoes-Porto	7.63	12.50	1 522	8 206	2 535
Aveiro	-	2.09	2	-	1 092
Lisbon	4.12	12.75	2 495	23 489	3 922
Setubal	0.76	4.61	11	-	1 454
Sines	13.75	18.90	ns	-	844
SUB-TOTAL	26.27	50.85	4 030	31 695	9 847
TOTAL	77.11	182.14	8 294	461 353	30 250

* includes crude oil, refined oil and natural gas; ns not significant.

resulting in unintentional oil spills along the French coast are concentrated along the north Brittany coast *(Table 3.8)*. The worst accident occurred in 1978 with the grounding of the Amoco Cadiz. The Spanish coast of Galicia has twice been affected by major oil spills; in 1976 with the grounding of the Monte Urkiola and in 1992 with the grounding and burning of the Aegean Sea.

3.12.3 Accident prevention and regulation

To reduce the risk of navigational accidents three shipping corridors have been established. In Spain the State Society for Maritime Safety and Rescue (SASEMAR) brings together the maritime security and rescue responsibilities which in France are ensured by the Regional Operational Centres for Surveillance and Rescue (CROSS), the Port Admirals, and the National Society for Maritime Rescue (SNSM).

In December 1996, the Maritime Safety Committee of the IMO approved two systems of obligatory warning for ships in the waters off Finisterre and Gibraltar. In 1997 the number of ships controlled by the traffic separation schemes was > 68 000 off Gibraltar and > 29 000 off Finisterre.

Numerous observations in France originating from customs patrols, civilian and military aircraft, ships, sightings from land and, more recently, satellites show the marine environment is also affected by accidental or unauthorised discharges. CROSS has compiled a list for the French section of the Bay of Biscay which indicates 36 incidents in 1997 *(Table 3.9)*. A significant number of observations represent ‘false alarms’. Most incidents concern nearshore or offshore oil slicks.

3.13 Coastal industries

Industries of various types are located along the coasts of Region IV *(Table 3.10)*, with a particularly high density along the northern Spanish coast. The southern parts of France, Spain and Portugal have more scattered industrial developments, while large industrial areas are located on

Table 3.8 Shipping accidents.

Location	Year	Ship	Incident	Quantity (t x 10^3)
France				
Brittany	1978	Amoco Cadiz	grounding and oil spill	223
	1997	Albion II	loss with all hands / calcium carbide spill	0.11
	1999	Erika	Oil spill	15
Bay of Biscay	1993/4	unknown	detonators washed up on shoreline	23 000 units
Spain				
Galicia	1976	Monte Urkiola	oil spill	30
	1987	Cason	chemical spill	10
	1992	Aegean Sea	oil spill	80
Portugal				
Cape St Vincent	1974	Ouranos	grounding with loss of dangerous substances	0.08
	1994	New World and Ya Mawlaya	collision and oil spill	2.5
Leixoes Port	1975	Jakob Maersk	grounding and oil spill	80
Sines	1989	Marao	collision and oil spill	4
Figueira da Foz	1992	Erika Dojer	grounding and paper pulp spill	1.5

Table 3.9 Accidental or unauthorized discharges to the French sector of the Bay of Biscay in 1997. Source of data: CROSS-SOULAC.

Hydrocarbons	23
Barrels	2
Household waste	2
Terrestrial vegetation/wood	1
Other	1
'False alarms'	7
TOTAL	36

the northern and central coasts of Portugal. Several estuaries in Region IV are under pressure from industrial activities known to be polluting, such as paper milling, petroleum refining, chlorine production, titanium dioxide production, metal plating, and the ferrous and non-ferrous metal industries. From north to south there are the Loire, Gironde, Nervion, Bessaya, La Coruña, Douro, Tajo, Tinto-Odiel. Coastal regions outside estuarine areas are also under similar pressure. For example: southern Brittany (agro-food industries), Aquitaine (paper mills, petroleum industries), Asturias (ferrous and non-ferrous metal industries), Galicia (paper mills, chlorine manufacturing, refineries, aluminium), Norte (refineries) and Alentejo (refineries, chemical industries). There are also several large shipyards in the region, including those of Nantes-Saint-Nazaire, Bilbao, Gijon, Vigo and Cadiz. Industrial installations representing significant risks to the general population and to the environment as a whole, are subject to Community Directive 'SEVESO' (Council Directive – 82/501/EEC of 24 June 1982 on the major-accident hazards of certain industrial activities). Currently, 50 such installations within the French coastal region and 30 in the Portuguese coastal region have been so designated.

3.14 Military activities

Three types of military activity, primarily undertaken by the national navies, could affect the conservation of marine environments and coastal zones: port activities, the construction and upkeep of the fleet, sea disposal of weapons and munitions, and manoeuvres and firing exercises. In France, the only military harbour in Region IV is Lorient where 5000 personnel are based.

The sea disposal of weapons and munitions has occurred at one French site and two Spanish sites. These sites are well identified, deep troughs beyond the reach of fishing gear. France disposes of 100 t/yr, although this is currently declining toward eventual elimination, in accordance with international commitments. The last disposal of obsolete munitions at sea by Spain occurred in summer 1994. In future, such wastes will be stored and destroyed on land.

3.15 Land-based activities

Industrial, municipal and agricultural land uses affect coastal waters via inputs from rivers, the atmosphere, land run-off or erosion. Diffuse inputs are difficult to quantify and data are often tentative and incomplete. There has been little success reported concerning a reduction in inputs from diffuse sources, such as from the use of fertilisers, the deposition of atmospheric contaminants (e.g. acid rain, smog) or via run-off from impermeable surfaces (e.g. roads, parking areas). However, much effort has been made toward the collection of urban and industrial wastewater and the application of appropriate levels of treatment. Nevertheless, even if households and industries are well

Table 3.10 Principal cities and major industries.

Cities	Population*	Shipping (t x 10^6)	Main industries†					
France								
Brest	201 500	1.8				d		f
Quimper	59 400		a					
Lorient	115 500	2.3						
Nantes-Saint-Nazaire	627 600	24.7	a	b	c	d		f
La Rochelle	100 300	5.5			c			
Bordeaux	696 400	8.6	a	b	c	d	e	
Bayonne	164 400	3.0						
Spain								
Pasajes-San Sebastian	176 900	3.4						
Bilbao	358 900	21.7	a		c	d	e	f
Santander	185 400	4.5	a	b	c	d	e	
Gijón	264 400	13.5	a				e	f
Oviedo	200 000							
Avilés	172 700	3.8					e	
Ferrol	83 000	7.1						
La Coruña	243 800	10.6			c		e	
Vigo	286 800		a	b	c			f
Huelva	140 700	15.1		b	c	d		
Sevilla	697 500	3.8						
Cadiz	145 600	3.5	a					f
Portugal								
Leixoes-Porto	350 000	12.5	a	b	c	d	e	
Aveiro	30 000	2.1		b	c	d		f
Coimbra	108 000							
Lisbon, Sintra, Amadora	926 000	12.8	a	b	c	d	e	f
Setubal	98 000	4.6						
Sines		18.9	a		c			

* Population: France (1990), Spain (1996); † a: food, b: wood, paper, cardboard boxes, c: chemistry, petrochemistry, petroleum, d: mechanical engineering and manufacture of metallic products, e: metallurgy of iron and steel, f: shipyards.

connected to sewage systems applying secondary or, in certain cases, tertiary treatment, exceptional rainfall during the winter or peaks in tourism during the summer could negate the effects of such treatment.

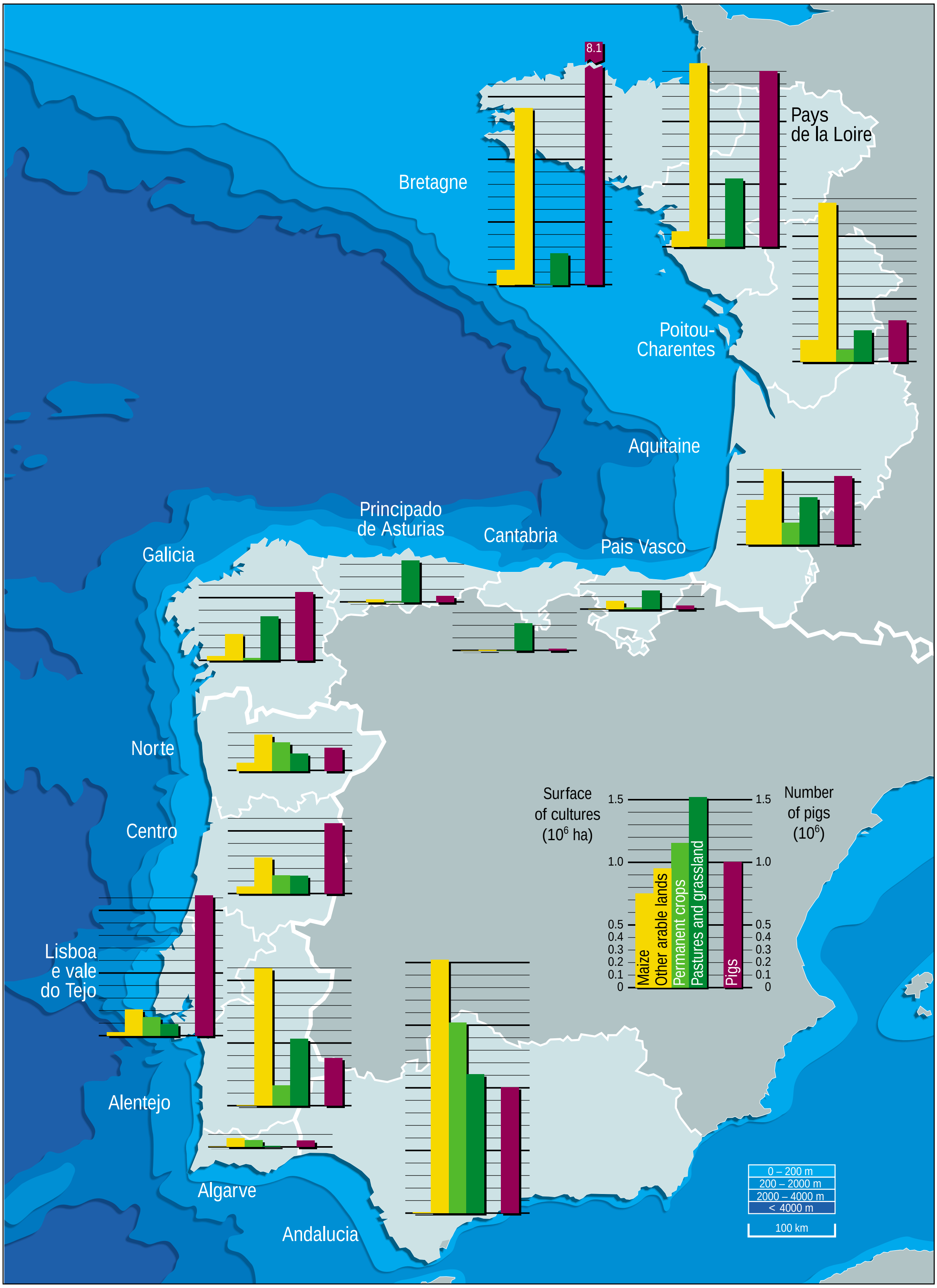
Current and historic mining activities are also a source of contamination. For example, in France a previously active mine more than 350 km upstream in the Gironde estuary, is still a significant source of cadmium and zinc due to the quantities of suspended material with which these are associated entering the freshwater system and then the estuary. Also, in the Huelva area of Spain, mining activities over many years have influenced metal concentrations in the coastal area. The Tinto and Odiel rivers discharge into the Huelva estuary after flowing through the Iberian Pyrite Belt. They drain volcanic-sedimentary formations of Palaeozoic age, containing large deposits of polymetallic massive sulphide minerals. Because of the large-scale mining and smelting operations that have occurred on the rivers banks since prehistoric times, the water is very acidic and the sediments are contaminated by sulphide-associated heavy metals (Fernandez *et al*., 1997). In April 1998, a storage dam at the Aznalcollar mine on the Guadiamar river gave way, releasing around 2 x 10^6 m^3 of sludge and 4 x 10^6 m^3 of acid water. The spill covered approximately 500 ha. In response the Spanish authorities have undertaken various activities to evaluate and minimise the impact; these are still in progress.

3.16 Agriculture

3.16.1 Arable and livestock farming

Agriculture in coastal areas is dependent on the natural characteristics of the area and varies from one section of coast to another. The distribution of the main types of agricultural activity in the region is shown in *Figure 3.10*.

Figure 3.10 **Agricultural land use, 1995. Source: EUROSTAT – EUROFARM database.**



In France, agricultural activities on land adjacent to Region IV cover a significant area. There are currently 7100 km^2 of cultivated land. This is a considerable decrease relative to 1970, with a loss of 1300 km^2 or 17% of the total; a percentage substantially higher than the national average of 1.4%. These agricultural land areas may be broken down as follows: 492 km^2 of reclaimed land (86% to the north of the Gironde Estuary) and 447 km^2 of irrigated land (92% to the south of the Loire River). The channelling of water from the river poses the risk of severely reducing flows, particularly in the summer. Livestock farming in these areas is as follows: 27.7 million chickens, 2.3 million pigs and 1.1 million cattle and sheep, with Brittany alone accounting for 84%, 98% and 61%, respectively.

In Spain, the Cantabrian coast has 614 km^2 of arable land, representing 3% of the coastal provinces and regions under consideration. Consequently, its agricultural production is small. However, the cattle sector in this area is quite significant. The coast of Galicia has a very large proportion of workers (23%) in the agricultural sector and the south coast contains arable land representing more than 30% of Huelva and Cadiz.

Agricultural activities in Portugal are carried out on approximately 9000 km^2 of coastal land, of which 5200 km^2 are arable land, 2000 km^2 are permanently under cultivation and 1720 km^2 are permanent pasture. Coastal livestock farming involves 1.4 million pigs, 0.2 million goats, 0.6 million sheep and 0.6 million cattle.

3.16.2 Fertilisers and pesticides

The use of fertilisers in Spain is low compared to other EC Member States. Spanish agriculture used 11 kg N/ha and 15 kg P_2O_5/ha in 1955, which increased to 61.7 kg N/ha and 33 kg P_2O_5/ha in 1990. Since then fertiliser use has decreased, in 1994 to 49.3 kg N/ha and 25.2 kg P_2O_5/ha. Fertiliser use in Portugal has increased in recent years, reaching 65 kg N/ha for agricultural land. This is low compared to the EU average of 126 kg N/ha.

In France, the sale of pesticides reached 92 900 t (in terms of active ingredients) in 1996 (EUROSTAT, 1998). In Spain as a whole, the sale of pesticides reached 33 230 t (in terms of active ingredients) in 1996 (EUROSTAT, 1998). With regard to the coastal region, small quantities of nematocides and insecticides are used within the Cantabrian and Galician areas, with larger quantities used in the two southern provinces. Fungicide and herbicide use both increased by more than 60% between 1985 and 1995, the use of each exceeding that of insecticides. Use is greatest in Galicia and in the two southern provinces. In Portugal, the use of pesticides, herbicides and fungicides increased between 1991 and 1996. Pesticide sales reached 12 450 t in 1996 (EUROSTAT, 1998). Over the same period, insecticide use decreased by around 12%.

3.17 Regulatory measures and future developments

The OSPAR Convention entered into force 25 March 1998. This convention has the general objective of preventing and eliminating pollution in the maritime area and ensuring that marine ecosystems remain sound and healthy, thereby protecting human health. In 1998, the OSPAR Commission adopted strategies on the protection and conservation of ecosystems and biological diversity, hazardous substances, radioactive substances and eutrophication. The OSPAR Commission also agreed that good cooperation with the European Community was very important for a number of topics. In terms of implementing its strategies, the OSPAR Commission prepared an initial list of topics of common interest and for which cooperation should be reinforced, particularly concerning its work on hazardous substances. The EC is currently drafting a Water Framework Directive which is expected, *inter alia*, to provide another link between the management of activities in catchment areas and their effects on coastal waters.

chapter 4

Chemistry

4.1 Introduction

Region IV is a large and diverse area. Water inputs originate from major river estuaries draining large catchment basins or from deep rias open to the sea. Whenever possible, information presented in this chapter has been organised according to three sub-regions, each representative of similar oceanographic conditions. Thus, from north to south: the Bay of Biscay, the western Iberian Atlantic Edge and the south Atlantic subregion. National monitoring programmes constitute the primary source of information in this chapter. Little information is available on riverine and direct inputs. Existing data are fragmentary and primarily concern inputs from the Loire River and Gironde Estuary (OSPAR, 1998a).

Unless otherwise stated, concentrations in seawater, sediments and biota are reported as follows: sea water (ng/l), sediments (mg/kg dry weight) and biota (mg/kg dry weight).

4.2 Background/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. polychlorinated biphenyls) 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 (BRCs) typical of the maritime area or parts thereof (OSPAR 1997a). *Tables 4.1* and *4.2* summarise BRCs applicable in Region IV.

Ecotoxicological Assessment Criteria (EACs) 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). These EACs are summarised in *Table 4.3*.

Table 4.2 Background/Reference Concentrations for PAHs in surface waters of the North-east Atlantic. Source: OSPAR (1997a).

	Concentration (ng/l)
Naphthalene	0.101 – 0.259
C1-Naphthalenes	0.114 – 0.286
C2-Naphthalenes	0.131 – 0.307
Acenaphthene	0.018 – 0.046
Acenaphthylene	0.002 – 0.005
Fluorene	0.023 – 0.051
Anthracene	0.001 – 0.004
Phenanthrene	0.080 – 0.205
C1-Phenanthrenes	0.045 – 0.095
Fluoranthene	0.036 – 0.054
Pyrene	0.020 – 0.033
Benz[*a*]anthracene	0.001 – 0.001
Benzo[*a*]pyrene	0.001 – 0.001
Perylene	< 0.001 –< 0.001
Indeno[1,2,3-*cd*]pyrene	0.001 – 0.003
Benzo[*ghi*]perylene	0.001 – 0.011

4.3 Heavy metals

Heavy metal inputs via rivers in particulate and dissolved form, occur predominantly through the Loire, Gironde, Adour, Miño, Duero, Tagus, Guadiana and Guadalquivir rivers.

4.3.1 Cadmium

Inputs

Riverine and atmospheric inputs are the two major sources of cadmium to the coastal environment. Upwelling and backwash to the coast represent natural sources which, in the case of cadmium, are important at the global level. However, these inputs have not been quantified at the regional level.

Table 4.1 Background/Reference Concentrations in mussel, fish and sea water. Source: OSPAR (1997a).

	Mussel (mg/kg ww)	Roundfish* muscle (mg/kg ww)	Flatfish† muscle (mg/kg ww)	Sea water (dissolved) (ng/kg)
Cd	0.07 – 0.11	-	-	5 – 25
Hg	0.005 – 0.010	0.01 – 0.05	0.03 – 0.07	0.1 – 0.4
Pb	0.01 – 0.19	-	-	5 – 20
Cu	0.76 – 1.10	-	-	50 – 100
Zn	11.6 – 30	-	-	30 – 200
Cr (VI)	-	-	-	90 – 120
Fe	-	-	-	25 – 150
Mn	-	-	-	10 – 25
Ni	-	-	-	160 – 250
Se (VI)	-	-	-	2 – 20
V	-	-	-	1250 – 1450
U	-	-	-	3000 – 3500
CB153	0.1 – 0.5‡	-	-	-
ΣPCB_7	0.35 – 1.7‡	-	-	-

* cod and hake; † dab, plaice, flounder; ‡ µg/kg

Table 4.3 Ecotoxicological Assessment Criteria. Source: OSPAR (1997b).

	Water (µg/l)	Sediment (mg/kg dw)	Fish (mg/kg ww)	Mussel (mg/kg dw)
As	1 – 10*	1 – 10†	nr	nr
Cd	0.01 – 0.1*	0.1 – 1†	fc	fc
Cr	1 – 10*	10 – 100†	nr	nr
Cu	0.005 – 0.05*‡	5 – 50†	fc	fc
Hg	0.005 – 0.05*	0.05 – 0.5†	fc	fc
Ni	0.1 – 1†	5 – 50†	nr	nr
Pb	0.5 – 5*	5 – 50†	fc	fc
Zn	0.5 – 5*	50 – 500†	nr	nr
DDE	nr	0.0005 – 0.005†	0.005 – 0.05*	0.005 – 0.05*
Dieldrine	nr	0.0005 – 0.005†	0.005 – 0.05*	0.005 – 0.05*
Lindane	0.0005 – 0.005*	nr	0.0005 – 0.005*	nr
Naphthalene	5 – 50*	0.05 – 0.5*	nr	0.5 – 5†
Phenanthrene	0.5 – 5†	0.1 – 1*	nr	5 – 50†
Anthracene	0.001 – 0.01†	0.05 – 0.5*	nr	0.005 – 0.05†
Fluoranthene	0.01 – 0.1†	0.5 – 5†	nr	1 – 10†
Pyrene	0.05 – 0.5†	0.05 – 0.5†	nr	1 – 10†
Benz[*a*]anthracene	nd	0.1 – 1†	nr	nd
Chrysene	nd	0.1 – 1†	nr	nd
Benzo[*k*]fluoranthene	nd	nd	nr	nd
Benzo[*a*]pyrene	0.01 – 0.1†	0.1 – 1†	nr	5 – 50†
Benzo[*ghi*]perylene	nd	nd	nd	nd
Indeno[1,2,3-*cd*]pyrene	nd	nd	nr	nd
$\sum PCB_7$	nr	0.001 – 0.01†	0.001 – 0.01*	0.005 – 0.05*
TBT	0.00001 – 0.0001*	0.000005 – 0.00005†	nr	0.001 – 0.01*

* firm; † provisional; ‡ this bracket is within the range of background values for natural waters. This value should be compared with the bioavailable fraction in sea water; fc for future consideration; nr not relevant to the current monitoring programme; nd no data available or insufficient data available.

Cautionary note: These assessment criteria have no legal significance and should only be used for the preliminary assessment of JMP/JAMP chemical monitoring data with the aim of identifying potential areas of concern. When applied, the fact whether an EAC is firm or provisional should be taken into account.

Total inputs from industrial sources in 1995 were estimated at approximately 0.3 t for the catchment areas draining into the French part of the Bay of Biscay.

The largest cadmium inputs to the Bay of Biscay originate from the Gironde Estuary and result from mining activities often located high upstream. Net inputs have been measured on numerous occasions owing to the high levels of contamination in this estuary. In the late 1980s, these were estimated at 12 – 20 t/yr (Elbaz-Poulichet, 1988; Jouanneau *et al*., 1990). The latest estimate is 6 t/yr.

Particulate inputs from rivers are more difficult to estimate than dissolved inputs. Jouanneau *et al*. (1990) estimated that the average mass of sediments discharged from the Gironde Estuary reaches 10^6 t/yr. Assuming a mean cadmium concentration in estuarine particulates of 0.4 mg/kg (Kraepiel *et al*., 1997), implies a net particulate input of 0.4 t Cd/yr, which is considerably lower than the dissolved input. A survey of the Loire Estuary in 1990 indicated a net flow of dissolved cadmium of 0.083 g/s, i.e. 2.6 t/yr. Assuming a mean solids export of 10^6 t/yr and a mean cadmium concentration of 0.5 mg/kg, the annual particulate flow was estimated at 0.5 t (Boutier *et al*., 1993). Direct measurements of cadmium flow were also recorded in the Charente River; an unpublished study by IFREMER reported cadmium inputs from the river to the coastal environment of < 0.05 t/yr.

According to a survey of the Tagus River in 1996, the net flow of total cadmium was estimated at 1.2 t/yr, with a mean solids export of 0.15 x 10^6 t/yr.

In the Gulf of Cadiz, the input from the Guadalquivir river was estimated at 142 kg in 1994 and 105 kg in 1995.

Atmospheric inputs to the Bay of Biscay have been the subject of very few studies. Maneux *et al*. (1996) estimated the rainwater input to the continental shelf to be 9 t/yr. Total atmospheric deposition to the Bay of Biscay and Iberian coast was estimated at 4.5 and 4.4 t in 1990 and 1995 respectively (OSPAR 1998b).

Atmospheric inputs of dissolved cadmium (i.e. cadmium dissolved in rainwater + the soluble cadmium fraction associated with aerosols) along the Brittany coastline are estimated at 0.014 – 0.02 mg/m^2/yr (Cotté, 1997), which corresponds to a total annual input of 1.4 – 2 t for a surface area of 100 000 km^2. These estimates are very tentative and it may be concluded that the atmospheric flux is of the same order of magnitude as the riverine input.

Concentrations in sea water

Cadmium concentrations at the ICES oceanic reference station (46° N; 6° W) are low at the surface (5 – 10 ng/l) and increase steadily with depth (35 ng/l at 3000 m). Unpublished studies on the Aquitaine slope revealed the presence of cadmium-enriched waters (20 ng/l) at 900 m.

On the continental shelf off the Gironde Estuary and in the Bay of Marennes-Oléron, dissolved cadmium concentrations were never higher than 15 ng/l throughout the entire water column at salinities of > 34.5, and were frequently less than 10 ng/l at salinities of > 35. Data from a survey in 1987 conducted closer to the shore indicated slightly higher concentrations of 11 – 23 ng/l at salinities of > 34.5 in southern Brittany (Boutier *et al*., 1993). Close to the Gironde Estuary concentrations can be significantly higher, but appear dependent on the river flow rate. This could partly explain the low concentrations (12 – 16 ng/l) recorded in mid-salinity waters on the continental shelf after the ‘Great Flood’ of 1995.

Cadmium concentrations in suspended particulate matter (SPM) vary greatly according to the composition of the particles. Predominantly planktonic SPMs, found mainly in the euphotic zone, have higher cadmium concentrations (2 – 3 mg/kg) than detrital SPMs from the deeper layers (< 1 mg/kg) ***(Figure 4.1)***.

Concentrations in sediments

Sediment cores were collected at various depositional sites representative of the Bay of Biscay ***(Figure 4.2)***. Cadmium concentrations in the deepest layers ranged from 0.01 mg/kg dw on the Grande Vasière mudflats to 0.15 mg/kg dw at Cap Breton. For fine sediments, concentrations around 0.1 mg/kg dw can be regarded as the regional background level (Gonzalez, 1992). Overall, the core samples showed sediments close to river mouths to be moderately enriched in cadmium. Most of the concentrations recorded were < 0.3 mg/kg and none exceeded 0.4 mg/kg. No net surface enrichment was observed in the sediments located far from the major rivers (e.g. in the Glénan Basin) or further off the coast (e.g. Grande Vasière).

A sediment survey was carried out by Spain towards the end of 1996 along the Galician coast, in the Spanish Cantabrian Sea and in the Gulf of Cadiz. Surface samples were taken at approximately 400 sites. Excluding the particularly high values found in Bilbao harbour and in the innermost part of the Ría de Pontevedra, the concentrations in total sediment were 0.013 – 0.956 mg/kg dw, with an average value of 0.162 mg/kg dw ***(Figure 4.3)***.

In the Gulf of Cadiz the highest concentrations (10.5 mg/kg dw) occurred inside the Ria of Huelva. In the mouth and surrounding coastal area of the ria concentrations were 0.6 – 1.0 mg/kg dw. The majority of the concentrations on the Huelva continental shelf area were 0.1 – 0.2 mg/kg dw, and 0.2 – 0.4 mg/kg dw in the coastal zone influenced by the ria. Near the mouth of the Guadiana river concentrations were 0.08 – 0.3 mg/kg dw and in the mouth of the Guadalquivir river the range was 0.1 – 0.3 mg/kg dw. In Cadiz Bay and on the continental shelf the concentrations were < 0.2 mg/kg dw.

Concentrations in biota

The Réseau National d’Observation de la Qualité du Milieu Marin (RNO) has been analysing contamination in mussel (*Mytilus edulis*) and Pacific oyster (*Crassostrea gigas*) on a quarterly basis at over 100 sites along the

Figure 4.1 **Mean particulate cadmium concentrations on the Aquitaine continental shelf. Source: PNOC Atlantique.**

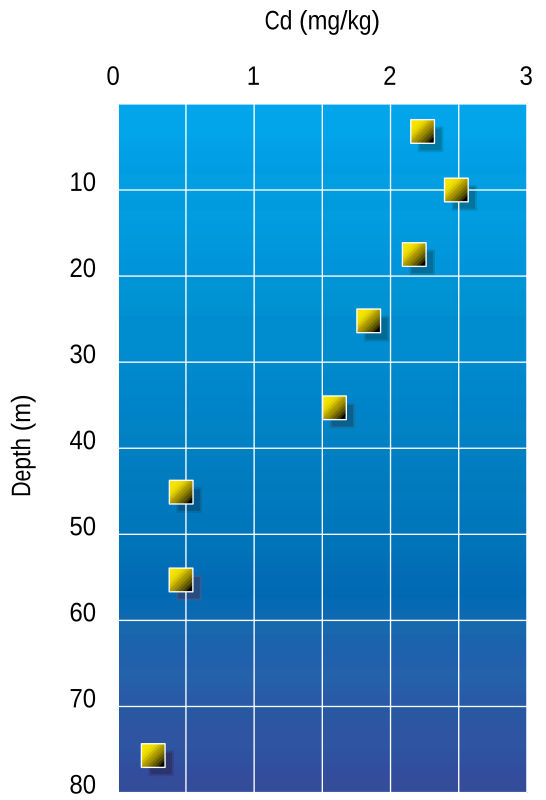
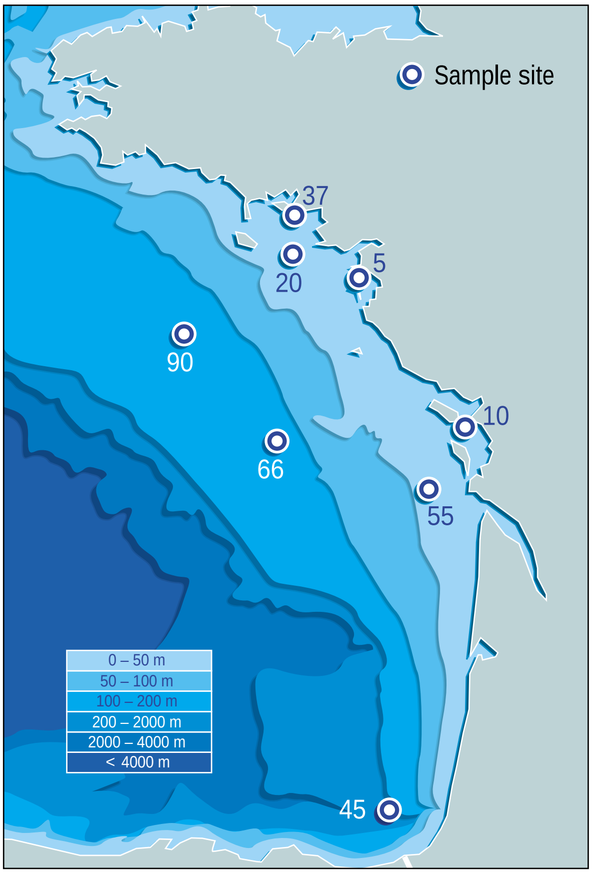


Figure 4.2 **Sample sites for sediment cores. Source: IFREMER.**



coast in the French part of the Bay of Biscay since 1979 (RNO, 1988). In oysters, the lowest concentrations occurred in the Gulf of Morbihan (1.2 mg/kg dw), in the Bay of Arcachon (1.5 mg/kg dw) and in the Nivelle (1.2 mg/kg dw); areas which do not receive any industrial inputs. *(Figure 4.4)*. Concentrations increased sharply from the Bay of Bourgneuf (1.6 mg/kg dw) to the Gironde Estuary where they reached 15 – 56 mg/kg dw. These high concentrations result from contamination by a former industrial discharge upstream (Boutier *et al*., 1989). The lowest concentrations in mussel occurred in the Bay of Vilaine; approximately 0.5 mg/kg dw, which is representative of relatively uncontaminated conditions. Mussels from southern Brittany also had low concentrations, which is in good agreement with the oyster data. Cadmium concentrations in mussels from the Loire Estuary were slightly higher. Overall, concentrations in molluscs are decreasing, whether at stations where concentrations were initially low (as in the Belon area or the Bay of Arcachon), at stations where concentrations were initially moderate (e.g. Elorn, Adour) or at sites which initially were highly contaminated, such as the Gironde Estuary.

The Spanish monitoring programme on contaminants in mussel started in 1985. In 1995, high concentrations (> 1 mg/kg dw) occurred near Finisterre cap and to the south of Galicia, although these areas are far removed from urban and industrial sites. On the other hand, the highest value (detected in Bilbao) occurred close to a busy harbour with an associated industrial area. Concentrations ranged from 0.422 to 2.28 mg/kg dw *(Figure 4.4)*. There were no temporal trends in the mussel data for 1991 to 1996.

Higher concentrations, 3.0 mg/kg dw, were observed in Portuguese oysters (*Crassostrea angulata*) from the western Gulf of Cadiz (Rio Piedras). In cockles concentrations were 0.20 – 0.35 mg/kg dw.

Cadmium concentrations in fish and shellfish from the French part of the Bay of Biscay are lower than in molluscs. Significant differences in concentration between flounder (*Platichthys flesus*) from the Gironde and Loire estuaries, are explained by the high levels of cadmium contamination in the Gironde Estuary. The mean and range in concentrations were 0.007 and < 0.004 – 0.018 mg/kg dw in the Gironde Estuary and 0.02 and < 0.004 – 0.066 mg/kg dw in the Loire Estuary. Cossa *et al*. (1992) analysed the main fish species caught along the French coastline for their contaminant concentrations. Cadmium concentrations in the fourteen species analysed ranged from 0.002 to 0.3 mg/kg dw *(Table 4.4)*.

In the Gulf of Cadiz, concentrations in common sole (*Solea vulgaris*) were 0.01 – 0.015 mg/kg dw and in the area surrounding the Guadalquivir river mouth were 0.01 – 0.07 mg/kg dw. In the fishing grounds influenced by the Ria of Huelva there was a positive correlation between cadmium concentration and the size of the fish.

4.3.2 Mercury

Mercury occurs in the marine environment in different chemical forms: as elemental, divalent inorganic, alkylated or chelated organic forms of mercury. Region IV does not appear to be contaminated by anthropogenic mercury inputs, except at a few specific sites, for example the southern part of the Bay of Biscay at the French-Spanish border, the Pontevedra ria on the Iberian Peninsula (which is affected by discharges from a chlor-alkali plant) and the mouth of the rivers Tinto and Odiel in the Gulf of Cadiz. As regards human health and seafood consumption, only those fish species at the top of the food chain occasionally exhibit contamination levels close to allowable thresholds.

Inputs

There are no specific studies on atmospheric mercury deposition to the Bay of Biscay, so the only estimates are based on models. According to Mason *et al*. (1994), deposition at this latitude should range from 10 to 15 $\mu g/m^2/yr$. The release of elemental mercury from the

Figure 4.3 **Cadmium and mercury concentrations in surface sediments from northern Spain, 1996. Source: IEO.**

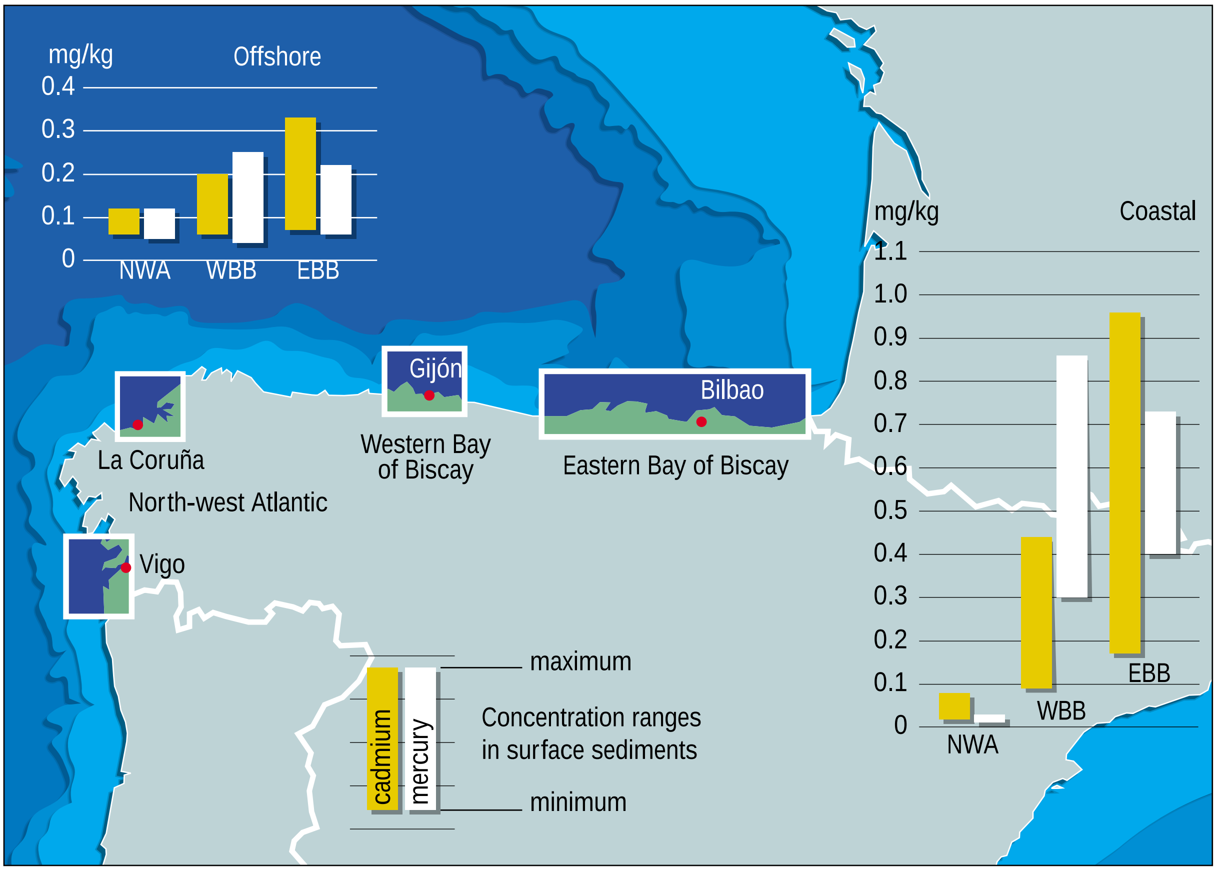
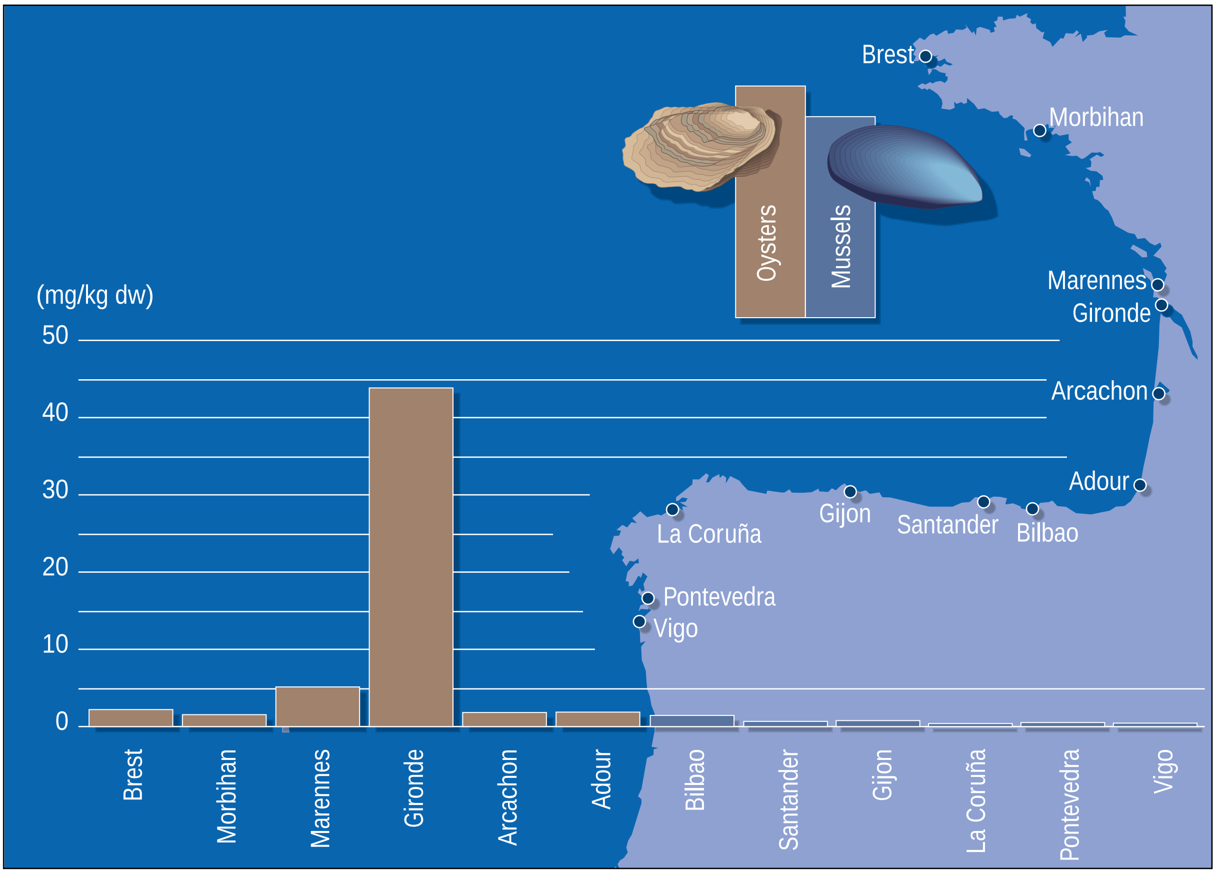


Table 4.4 Range in cadmium concentrations in fish muscle and crustaceans (mg/kg dw) for species caught in the Bay of Biscay and the Channel. Source: Cossa *et al*. (1992).

	Gulf South Oléron	Gulf North Oléron	Channel
Bib	0.002 – 0.022	0.002 – 0.013	0.002 – 0.007
Brown shrimp	0.090 – 0.670	0.034 – 0.174	-
Common prawn	0.026 – 0.068	0.068 – 0.230	-
Conger	-	0.002 – 0.025	0.002 – 0.012
Dogfish	-	0.009 – 0.339	0.014 – 0.097
Flounder	0.002 – 0.066	0.002 – 0.018	0.002 – 0.007
Hake	0.002 – 0.006	0.002 – 0.030	-
Mackerel	0.002 – 0.025	0.031 – 0.119	-
Monkfish	0.002 – 0.016	0.002 – 0.029	-
Norway lobster	0.021 – 0.695	0.022 – 0.018	-
Plaice	0.002 – 0.017	0.002 – 0.015	0.002 – 0.006
Seabass	0.002 – 0.019	0.002 – 0.020	-
Sole	0.002 – 0.020	0.002 – 0.013	0.002 – 0.008
Whiting	0.002 – 0.004	0.002 – 0.009	-

- : no information

Figure 4.4 **Cadmium concentrations in molluscs from the French and Spanish coasts, 1995. Source: RNO; Spanish monitoring programme.**



ocean surface was estimated at 4 – 22 µg/m²/yr off the Loire Estuary by Cossa *et al*. (1996). Thus, the net exchange is difficult to assess.

Spain has a total chlor-alkali production capacity of 803 x 10^3 t in total, 212 x 10^3 t of which occur in the Atlantic basin. There are nine operational plants, four within the OSPAR Convention area. There have been significant reductions in the discharges, emissions and losses of mercury from these plants since the early 1990s, owing to compliance with Paris Convention measures, particularly PARCOM Decision 90/3 in 1997. The reductions have taken place through the application of BAT-related techniques (e.g. hydrogen mercury removal, leakproof cell heads, new flooring with mercury-proof fibres, absorption of gases from cell rooms).

According to official statistics, the total atmospheric mercury discharges in France during 1990 were 16 t/yr. In addition, diffuse inputs are estimated at 15 – 30 t/yr (Cossa *et al*., 1990). The highest atmospheric inputs along the coast are linked to waste incineration in large metropolitan areas; for example approximately 85 kg Hg/yr for the city of Nantes and its surrounding area (Ministère de l'Environnement, 1996). However, westerly winds tend to predominate in this area and these are not conducive to the deposition of such emissions at sea.

Portuguese inputs to the atmosphere decreased from 440 kg in 1991 to 132 kg in 1996 (OSPAR, 1998c)

The Loire, Garonne, Dordogne, Adour and Charente rivers represent the main riverine inputs to the Bay of Biscay along the French coast. Coquery *et al*. (1997) estimated inputs from the Loire at 26 and 180 kg/yr respectively, for the dissolved and particulate fractions. Based on data recorded in the 1980s, inputs from the Gironde Estuary are estimated at 940 kg/yr, of which 93% is associated with SPM (Cossa *et al*., 1990). Inputs from the Charente River are estimated at 50 kg/yr. Direct coastal discharges from urban and industrial sources are up to 42 kg/yr (Ministère de l'Environnement, 1996).

In Portugal, total mercury discharges to water, mainly from two chlor-alkali plants situated near Aveiro and Lisbon, decreased from 284 kg in 1991 to 45 kg in 1996 (OSPAR, 1998c).

Concentrations in sea water

Concentrations in the Bay of Biscay at the ICES oceanic reference station (46° N; 6° W) were mostly 0.08 – 2 ng/l over a vertical profile of 4600 m. Concentrations peaked at the permanent thermocline, probably due to mercury remobilisation during the mineralization of particulate organic matter in the upper layers, together with desorption in the deep ocean (Cossa *et al*., 1992). Similar concentrations and a similar vertical profile were observed in the Celtic Sea (Cossa *et al*., 1996).

In the Loire and Gironde estuaries, dissolved mercury concentrations of 0.2 – 0.6 ng/l and 0.3 – 0.7 ng/l respectively, have been observed (Coquery *et al*., 1997; Cossa *et al*., 1990). Particulate mercury concentrations are highly variable, ranging from 0.1 to 1 mg/kg in the Loire Estuary (Coquery *et al*., 1997). Mercury concentrations in particulate material are often linearly related to the organic carbon content.

On the Portuguese coast, the average dissolved mercury concentrations measured during 1992–7 in estuarine waters (Tejo and Sado) and in the rias of Aveiro and Formosa were significant; of the same order of magnitude in the River Sado and the Ria Formosa (20 ng/l) and higher in the River Tejo and the Ria de Aveiro (30 ng/l). Samples from the area as a whole ranged from 10 to 70 ng/l.

Metal concentrations in the estuaries of the Rio Tinto and Odiel are high; mercury exceeding 10 ng/l (Cossa and Elbaz-Poulichet, 1999).

Concentrations in sediments

Data concerning sediments in the French part of the Bay of Biscay may be grouped according to two categories: data originating from cores obtained on the continental shelf and data concerning the coastal zone. The continental shelf sediments were sampled in 1986 and 1987 using a Reineck-type core sampler *(Figure 4.2)*: the Gulf of Cap Breton (core 45), the western Gironde mudflat (core 55), the Grande Vasière mudflat (cores 66 and 90), the Bay of Bourgneuf (core 5), the Loire Estuary (core 20) and the Bay of Vilaine (core 37). The cores were dated and analysed for their mineralogical content and mercury concentrations. Representative profiles *(Figure 4.5)* show the variation in mercury contamination over time. This peaked in the late 1970s. On the Grande Vasière mudflats, mercury concentrations are close to 0.025 mg/kg, i.e. among the lowest concentrations in a coastal environment. The surface concentrations observed on the western Gironde mudflat *(Figure 4.5)* tend to reflect an absence of any major sources of contamination. In contrast, surface concentrations in the Gulf of Cap Breton are ten times higher than the pre-industrial levels; this contamination dates back to around the 1950s (Cossa *et al*., 1990).

Concentrations in the open sea area off the Loire Estuary indicate little impact from anthropogenic inputs, while concentrations in the bays of Bourgneuf and Vilaine indicate slight contamination, with maximum concentrations of 0.18 mg/kg and 0.16 mg/kg, respectively. In the bay of Marennes-Oléron, Gonzalez (1992) recorded mean concentrations in surface sediments of 0.05 – 0.1 mg/kg. Concentrations of a similar order of magnitude occurred in the adjacent Bay of Aiguillon. Although concentrations close to 0.1 mg/kg already reflect an increase relative to natural background concentrations, the extent of the anthropogenic impact is difficult to quantify due to the effects of diagenesis on the mercury profiles. RNO data compiled by Boutier and Cossa (1988) indicate mean concentrations ranging from 0.14 mg/kg in the Bay of Vilaine to 0.85 mg/kg in the Hendaye area *(Table 4.5)*, which supports the detailed observations reported by Gonzalez (1992). In general, the coastal zone is subject only to slight mercury contamination.

The maximum concentration observed on the northern Spanish coast occurred within the Ria of Pontevedra, where values were just above 1 mg/kg, reflecting discharges from a chlor-alkali plant *(Table 4.6)*. Outside this area the average concentration in total sediment was 0.17 mg/kg *(Table 4.7)*. Concentrations were higher near sites of industrial activity, particularly on the Cantabrian coast (*Figure 4.3*).

Figure 4.5 **Mercury concentration profiles for two dated sediment cores from the Bay of Biscay. Source: IFREMER.**

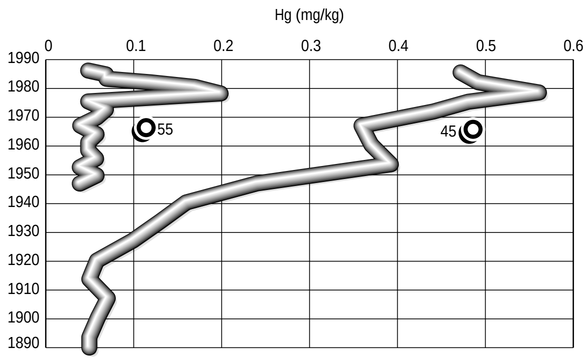


Table 4.5 Mean mercury concentrations in surface sediments (mg/kg). Source: Boutier and Cossa (1988).

Site	Mean	Standard deviation	No. samples
Port of Brest	0.51	0.23	35
Odet River mouth	0.30	0.20	8
Port of Lorient	0.44	0.21	12
Gulf of Morbihan	0.18	0.18	43
Bay of Vilaine	0.14	0.14	10
Loire Estuary	0.19	0.14	27
Bay of Marennes	0.43	0.22	41
Breton inlets	0.20	0.02	11
Gironde Estuary	0.35	0.18	38
Bay of Arcachon	0.40	0.22	42
Bay of Hendaye	0.85	0.31	5

Table 4.6 Range in metal concentrations in Spanish sediments (mg/kg dw) from the major estuaries. Source: IEO.

	Cadmium	Mercury	Lead	Copper	Zinc	Nickel	Arsenic	Chromium
Ria de Vigo								
mouth	0.02 – 0.09	0.01 – 0.08	9 – 51	2 – 20	10 – 135	2 – 37	-	5 – 40
brackish zone	0.10 – 0.25	0.07 – 0.35	58 – 136	16 – 54	102 – 201	25 – 40	-	35 – 55
close to city	0.30 – 0.78	0.37 – 0.66	125 – 268	57 – 165	184 – 350	35 – 48	-	52 – 77
Ria de Pontevedra								
mouth	0.06 – 0.20	0.02 – 0.09	14 – 50	3 – 17	25 – 100	3 – 17	-	-
brackish zone	0.13 – 0.25	0.13 – 0.82	40 – 65	12 – 25	91 – 146	13 – 22	-	-
close to city	0.50 – 1.34	1.30 – 1.94	42 – 145	20 – 90	153 – 227	16 – 29	-	-
Ria de A Coruña								
mouth	0.02 – 0.08	< 0.01 – 0.08	5 – 20	< 1 – 5	6 – 45	< 2	4 – 10	< 4 – 20
brackish zone	0.06 – 0.10	0.08 – 0.10	14 – 40	5 – 10	40 – 90	5 – 9	10 – 18	15 – 33
close to cities	0.15 – 0.52	0.20 – 0.50	43 – 78	12 – 95	75 – 320	12 – 38	15 – 25	36 – 61
Ria de Bilbao								
mouth	0.13 – 0.25	0.09 – 0.21	33 – 60	10 – 14	88 – 111	< 2	45 – 49	16 – 26
inside harbour	0.21 – 0.62	0.15 – 0.53	64 – 82	23 – 45	157 – 313	7 – 13	39 – 60	26 – 42
beside pi ers	0.74 – 1.08	0.76 – 1.12	96 – 263	46 – 99	264 – 445	19 – 35	50 – 92	50 – 108

– : no data.

Concentrations measured in Portuguese sediments ranged between 0.02 and 5.77 mg/kg over the period 1992–7. Higher average concentrations occurred in the Tejo Estuary (1.38 mg/kg) and the Ria de Aveiro (1.02 mg/kg) than the Sado Estuary (0.17 mg/kg) and the Ria Formosa (0.10 mg/kg) *(Table 4.8)*.

In the Gulf of Cadiz, a survey comprising 60 sites showed concentrations within the Ria of Huelva to range from just above 1 mg/kg dw to 9.8 mg/kg dw. In general, the highest concentrations occurred at sites near the mouths of the rivers Odiel and Tinto, which discharge into this estuary. These rivers have low flow rates and receive sewage and industrial discharges which, together with a high load of fine sediments, could explain the high mercury concentrations observed. In the stations off the estuary, the lowest concentrations were < 0.01 mg/kg and the average 0.185 mg/kg dw; the highest values (around 1 mg/kg) correspond to three stations closest to the mouth of the Huelva Estuary.

Concentrations in biota

The RNO 'Mussel Watch network' uses intertidal bivalve molluscs to monitor chemical contamination along the French coast. In 1996, mean mercury concentrations in the soft tissue of mussels and oysters from the French part of the Bay of Biscay were 0.11 – 0.26 mg/kg dw. Concentrations were generally higher in the southern Loire than in the northern Loire sector. The proportion of mercury in the methylated form varied from 21 to 74%, with the lower percentages usually associated with higher total mercury concentrations, particularly in the Bay of Marennes-Oléron *(Figure 4.6)*. Major differences occur in the mercury concentrations of fish muscle, with the highest concentrations occurring in carnivorous species (e.g. sea bass, conger and dogfish) *(Table 4.9)* and the proportion of methylated mercury ranging from 75 to 97%. Concentrations in dogfish (*Scyliorhinus canicula*) are close to half the European guideline values (Decision

Table 4.7 Range in metal concentrations in Spanish sediments (mg/kg dw) from coastal and offshore areas. Source: IEO.

	Cadmium	Mercury	Lead	Copper	Zinc	Nickel	Arsenic	Chromium
North-west Atlantic								
offshore	0.02 – 0.08	< 0.01 – 0.03	15 – 25	2 – 11	10 – 35	< 2 – 15	3 – 14	12 – 45
accumulation sites	0.06 – 0.12	0.05 – 0.12	25 – 35	10 – 18	50 – 120	13 – 23	12 – 25	50 – 96
Western Bay of Biscay								
offshore	0.06 – 0.20	0.04 – 0.25	15 – 40	< 1 – 6	15 – 80	< 2 – 14	7 – 20	5 – 52
coastal	0.09 – 0.44	0.30 – 0.86	30 – 80	8 – 26	75 – 271	9 – 37	14 – 35	45 – 250
Eastern Bay of Biscay								
offshore	0.07 – 0.33	0.06 – 0.22	22 – 58	3 – 18	60 – 130	8 – 23	16 – 47	22 – 48
coastal	0.17 – 1.40	0.40 – 0.73	50 – 240	20 – 70	110 – 300	14 – 39	22 – 150	29 – 67

Table 4.8 Average metal concentrations in sediments (mg/kg), 1992–7.

	Ria de Aveiro	Tejo River (estuary)	Sado River (estuary)	Ria Formosa
Cadmium	2.03	2.48	1.73	1.70
	(0.05 – 5.62)	(0.10 – 5.00)	(0.10 – 4.99)	(0.11 – 4.67)
Mercury	1.02	1.38	0.17	0.10
	(0.03 – 3.35)	(0.02 – 5.77)	(0.04 – 0.42)	(0.02 – 0.27)
Lead	51.21	110.06	40.11	40.20
	(12.01 – 102.54)	(30.89 – 275.94)	(16.89 – 71.90)	(6.89 – 80.97)
Copper	25.24	62.39	27.08	10.50
	(0.79 – 219.30)	(2.80 – 347.63)	(2.99 – 89.22)	(0.20 – 34.59)
Zinc	161.34	232.91	161.70	42.01
	(3.83 – 567.40)	(18.35 – 432.45)	(16.52 – 639.70)	(0.24 – 107.94)
Nickel	22.31	32.51	50.33	22.64
	(1.29 – 73.14)	(0.84 – 111.45)	(3.92 – 175.51)	(0.50 – 64.04)
Chromium	21.15	44.09	36.75	21.30
	(1.93 – 77.50)	(5.01 – 79.20)	(0.44 – 120.92)	(0.20 – 73.78)
Manganese	103.04	260.82	114.31	56.90
	(25.98 – 237.65)	(41.93 – 535.55)	(65.29 – 209.77)	(4.20 – 196.89)

EC/93/351), i.e. 1.0 mg/kg ww or *c*. 4 mg/kg dw. Mercury concentrations in Norway lobster and shrimps are generally lower than in fish and do not exceed 0.57 mg/kg dw (Cossa *et al*., 1991).

Spanish coastal monitoring surveys indicate concentrations in mussel of 0.046 – 0.664 mg/kg dw (*Figures 4.6* and *4.7*). The maximum concentration occurred within the Ria of Pontevedra due to a chlor-alkali discharge. Outside this industrial area concentrations were < 0.15 mg/kg dw, except within the bays of Gijon and San Vicente de la Barquera, where concentrations were higher at 0.263 and 0.276 mg/kg respectively. Significant decreases in concentration occurred in time series from A Coruña and Bilbao *(Figure 4.7)*.

Mean mercury concentrations in the soft tissues of bivalve molluscs (mussels, clams, oysters, cockles) along the Portuguese coast in 1997 were 0.08 – 0.48 mg/kg dw *(Figure 4.6)*. Higher concentrations occurred in oysters than mussels and clams. Concentrations were generally lower on the south coast (Ria Formosa) and slightly higher in some localised areas of the Ria de Aveiro and the Tagus Estuary where chlor-alkali plants are located. Total mercury concentrations in fish muscle for commercial species caught along the coast are below the European guideline values. Some higher concentrations are observed in carnivorous and long-lived species, such as eel, conger eel (*Conger conger*), seabass and striped mullet (*Mullus barbatus*), especially in the older/bigger individuals. Small pelagic fish (e.g. pilchard, horse mackerel, chinchard) and demersal species, such as hake and sole, have very low levels. Total mercury concentrations in crustaceans (Norway lobster, shrimps) are normally low, except in some deep-sea species on the southern Portuguese coast, probably due to the influence of Mediterranean Water.

In the Gulf of Cadiz, concentrations in oysters were > 1.2 mg/kg dw. For common sole, concentrations were higher in the Ria de Huelva area (0.4 mg/kg dw) than in the Guadalquivir area (0.15 mg/kg dw). In cockles the values were around 0.6 mg/kg dw.

Assessment

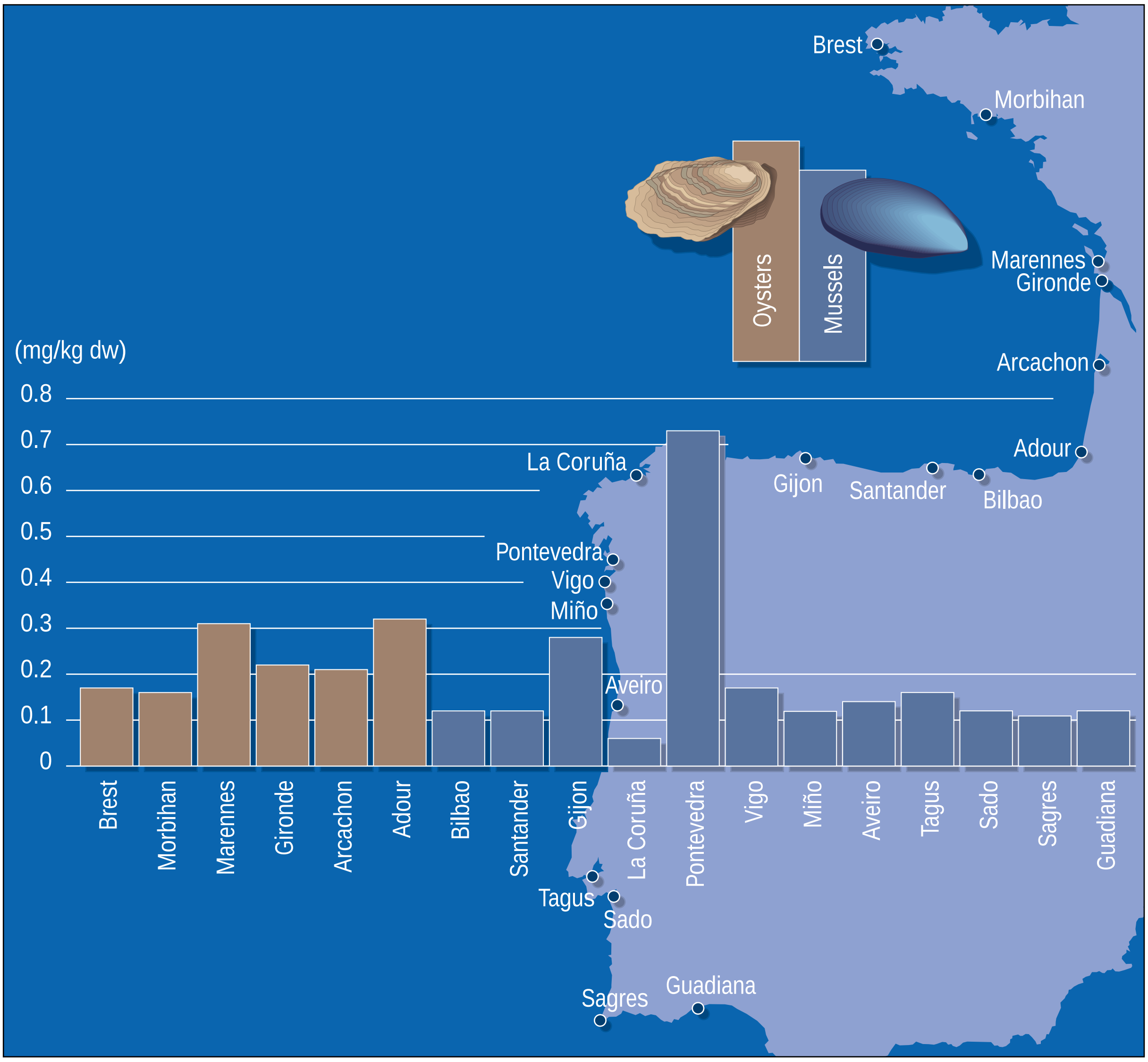
As is the case for all coastal margins, the Bay of Biscay is subject to anthropogenic mercury inputs; an effect that is now ubiquitous at a global scale. Nevertheless, the Bay of Biscay as a whole does not appear to exhibit major differences in terms of mercury contamination relative to other oceanic margins. EACs for sediments of 0.5 mg/kg dw are only exceeded in rias and estuaries to the south of Region IV.

The guideline values for seafood consumption are occasionally exceeded in fish species at high trophic levels (e.g. dogfish).

4.3.3 Lead

Lead is an extremely reactive element, quickly removed from the water column via its association with particulates and subsequent sedimentation. It is classed as a ‘scavenged element’, with dissolved concentration profiles in the marine environment exhibiting a continuous decrease between the surface and the bottom.

Figure 4.6 **Mercury concentrations in molluscs from the French, Portuguese and Spanish coasts, 1995. Source: RNO; Portuguese and Spanish monitoring programmes.**



Inputs

Total inputs from industrial sources for the catchment areas draining into the French part of the Bay of Biscay were 30 t in 1995. The data reveal a significant decrease in industrial discharges to the Loire Estuary, from 50 kg/d to 2.3 kg/d (Anon, 1990). An end to alkyl lead production in 1996, and the dismantling of the plant and site rehabilitation over the coming years, should contribute to a further reduction in discharges.

Lead behaves conservatively in the Gironde Estuary (Kraepiel *et al*., 1997); concentrations vary linearly with salinity, ranging from 60 ng/l at a salinity of 0.1 to 20.4 ng/l at a salinity of 32.1. On this basis, dissolved lead inputs from the Gironde Estuary to the continental shelf are estimated at 1.6 t/yr (Cotté, 1997). The mean lead concentration in particulates was estimated at 55 mg/kg (Kraepiel *et al*., 1997). Assuming a mean solids export of 10^6 t/yr (Jouanneau, 1982), corresponds to a flow of particulate lead of approximately 55 t/yr.

The flow of dissolved lead in the Loire River was estimated at 37 kg/d, i.e. 13 t/yr in 1990 (Boutier *et al*., 1993). This estimate is now far too high as the dissolved lead was principally derived from an industrial discharge which has since been considerably reduced. Assuming a dissolved lead concentration of 80 ng/l in freshwater (Boutier *et al*., 1993) and an average flow of 800 m^3/s in the Loire River, the gross dissolved flow is assumed to be approximately 2 t. Industrial discharges of 2.3 kg/d (in 1995) should be added to this flow, these occur primarily in the dissolved form. The dissolved lead input to the Loire

Estuary each year is thus approximately 3 t, corresponding to the upper limit for the net dissolved input to the ocean. The flow of particulate lead to the continental shelf is estimated at 90 t, based on a mean solids export of 10^6 t/yr and a mean concentration of 90 mg Pb/kg particulate matter.

Since the Loire and Gironde estuaries account for 80% of the total riverine flow reaching the French coast of the Bay of Biscay, it may be assumed that 180 t of particulate lead reach the ocean via the riverine flow, to be quickly trapped within the sediment. The annual flow of dissolved lead is estimated at < 6 t.

The flow of total lead for the Tagus River in 1996, was estimated at 18 t, with an average solids export of 0.15 x 10^6 t.

The only lead input calculated for the Gulf of Cadiz area was for the Guadalquivir river in 1995, and was estimated at 1.3 t.

Maneux *et al*. (1996) estimated that dissolved lead inputs from rainwater to the continental shelf of the Bay of Biscay reach 360 t/yr. Cotté (1997) reported a deposition rate for dissolved lead of 0.75 – 1.21 mg/m^2 i.e. 75 – 120 t for a shelf area of 100 000 km^2. These rainwater inputs are significantly greater than the dissolved lead inputs from rivers. Atmospheric deposition along the Bay of Biscay and Iberian coast was estimated at 507 t and 480 t for 1990 and 1995 respectively (OSPAR, 1998b).

Concentrations in sea water

The dissolved lead profiles observed by Cotté (1997) in the vicinity of the continental slope of the Celtic Margin to the Bay of Biscay are characteristic of a scavenged element *(Figure 4.8)*. Concentrations of 20 – 40 ng/l occur in the first 1000 m, thereafter steadily decreasing towards the bottom to reach 10 ng/l at 4500 m. A similar distribution was previously observed by Lambert *et al*. (1991) in the same area. This profile reflects both the predominance of the atmospheric input and the high reactivity of lead.

Very few data exist for the inner continental shelf of the Bay of Biscay. In the Iroise Sea, concentrations in 1985 varied from 85 ng/l ± 40 in the spring to 143 ng/l ± 70 in autumn (Riso *et al*., 1993). Along the southern Brittany coast, they ranged between 33 and 113 ng/l in 1987. Higher concentrations occurred close to estuaries, with 250 ng/l at the Vilaine mouth and 200 ng/l in the Loire. Further off the coast, and more recently in 1994, a mean concentration of 37 ng/l ± 14.55 was recorded at 70 m, near the seabed to the west of Oléron island. This is slightly lower than the mean value of 45 ng/l ± 11 observed by Tappin *et al*. (1993) in the Channel.

Particulate lead concentrations vary widely according to the nature and origin of the particles. Boutier *et al*. (1993) recorded 90 mg/kg dw in the Loire plume at a time when industrial discharges to the estuary were still significant. In the Gironde Estuary average concentrations are 55 mg/kg dw (Kraepiel *et al*., 1997). At the most downstream station, with salinity at 30.9 and SPM at 1 mg/l, particulate concentrations fall to 30 mg/kg dw. Off the coast of Oléron island on the seabed at 70 m, low concentrations (5 mg/kg dw) were recorded in biogenic SPM, while higher concentrations (30 mg/kg dw) were recorded at the bottom where the particles are mineral in nature and probably originate from the Gironde Estuary.

Along the Portuguese coast the average concentrations measured during 1992–7 ranged from 0.6 µg/l in the Ria Formosa, to 1.1 µg/l in the Tejo Estuary, to 1.2 µg/l in Ria de Aveiro to 1.3 µg/l in the Sado Estuary. The differences observed between concentrations in the surface and deep waters could imply that the source is essentially atmospheric; this is supported by data from the estuary of the river Tagus at a site near a bridge carrying heavy traffic.

Table 4.9 Mercury concentrations in fish muscle (mg/kg dw) for species caught in the Bay of Biscay. Source: Cossa *et al*. (1991).

Site	Mean	Standard deviation
Bib		
north Gascogne	0.60	0.29
south Gascogne	0.64	0.29
Conger eel		
north Gascogne	1.15	0.29
Dogfish		
north Gascogne	2.03	0.61
Flounder		
north Gascogne	0.29	0.13
south Gascogne	0.67	0.47
Hake		
north Gascogne	0.39	0.10
south Gascogne	0.30	0.06
Mackerel		
north Gascogne	0.37	0.15
south Gascogne	0.56	0.37
Monkfish		
north Gascogne	0.67	0.33
south Gascogne	0.58	0.22
Plaice		
north Gascogne	0.29	0.11
south Gascogne	0.32	0.09
Seabass		
north Gascogne	1.33	0.67
south Gascogne	1.10	0.29
Sole		
north Gascogne	0.45	0.32
south Gascogne	0.40	0.37
Whiting		
north Gascogne	0.43	0.11
south Gascogne	0.32	0.08

The mean values are based on twenty to twenty-five samples.

Figure 4.7 **Annual average mercury concentrations in mussel for 1991–96 in France and Spain. Source: RNO; Spanish monitoring programme.**

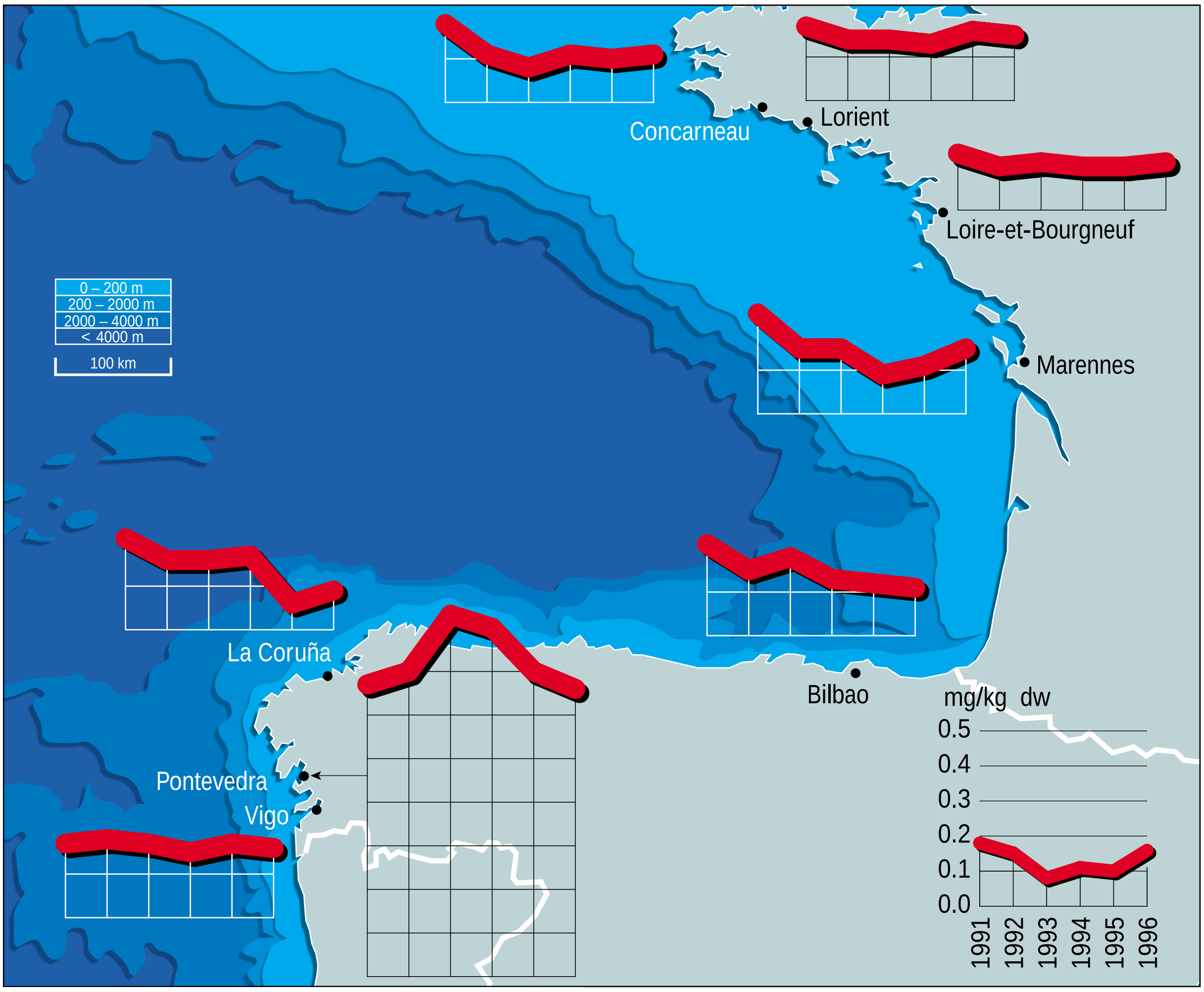
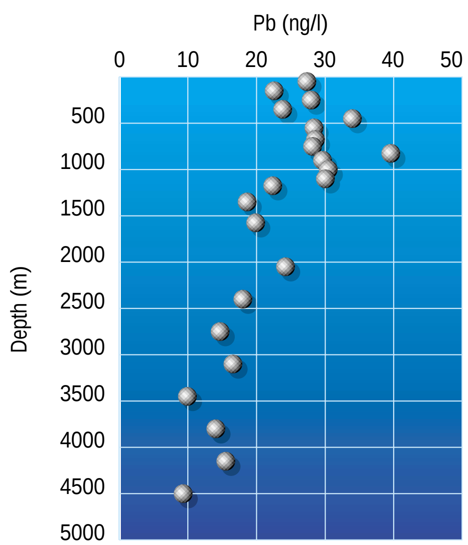


Figure 4.8 **Dissolved lead concentrations close to the continental slope of the Celtic margin. Source: Cotté (1997).**



Concentrations in sediments

Lead concentrations in cores collected from the continental shelf of the French part of the Bay of Biscay *(Figure 4.2)* were 14, 24, and 25 mg/kg in the oldest layers (100, 125 and 93 years). These concentrations correspond to the average composition of crustal rocks, i.e. 16 mg/kg. Concentrations were highest in the upper layers of the cores, indicating the influence of anthropogenic inputs: particularly in the Gulf of Cap Breton where concentrations increase from 25 to 56 mg/kg.

On the Spanish coast high concentrations occurred in areas near Bilbao Bay and within the Ria of Vigo. Concentrations ranged between 2.26 and 268 mg/kg dw, with an average of 50.8 mg/kg dw. The highest concentrations occurred in rias and coastal zones close to industrial activities.

In general, lead concentrations in the Spanish Cantabrian Sea are higher than on the Galician coast, due to the more important urban and industrial activities in that area. Concentrations in the offshore areas are all low.

Portuguese data indicate higher average concentrations in the Ria Tejo (110.6 mg/kg dw) than in the Ria de Aveiro (51.21 mg/kg dw) or the Sado Estuary and the Ria Formosa (≃ 40 mg/kg dw). Concentrations at the four sites during 1992–7 were all between 6.89 and 275.9 mg/kg dw. The highest concentrations occurred in areas affected by industrial seepage or industrial sites on the estuaries.

In the Gulf of Cadiz lead shows a similar distribution as for the other metals, with the highest concentration (700 mg/kg) in the surface sediments of the Ria of Huelva. In sediments near the mouth of the Ria of Huelva concentrations were 80 – 120 mg/kg dw. In the areas surrounding the mouths of the rivers Guadiana and Guadalquivir, concentrations were 50 – 120 mg/kg and 50 – 75 mg/kg, respectively. On the rest of the continental shelf concentrations in surface sediments were 12 – 50 mg/kg dw. In the central areas of the Gulf of Cadiz concentrations in the surface sediments were 10 – 35 mg/kg dw, during surveys carried out in 1986, 1987 and 1988.

Concentrations in biota

Along the French coast of the Bay of Biscay minimum concentrations in bivalve molluscs were generally about 1 mg/kg dw, as for example in oysters from the Etel River, the Gulf of Morbihan and the Bay of Arcachon. Median concentrations at 26 of 43 sites were 1 to 2 mg/kg dw, both in oysters and mussels *(Figure 4.9)*. Sites at which concentrations exceeded 2 mg/kg dw were very localised. The highest concentrations occurred in oysters from the Aulne River, with a median value of 7.8 mg/kg dw. A mean concentration of 10 mg/kg dw was mainly due to two extremely high values recorded in 1992. Concentrations of > 2 mg/kg dw have also been recorded at other sites: the Loire Estuary, the Gironde Estuary and at the mouth of the Bidasoa.

The mean concentrations are stable at most sites. Two notable exceptions concern the mouth of the Bidasoa, where a sharp rise in concentration occurred in oysters in 1995 and 1996, followed by a return to previous levels, and the Loire Estuary where a downward trend was observed in mussels following contamination peaks in 1991–2.

There is a large range in concentration for molluscs from the Spanish coast *(Figure 4.9)* (1.05 – 7.76 mg/kg dw). The areas closest to major urban and industrial sites have the highest concentrations, as for example in the Ria of Vigo and the bays of Santander and Gijón. The highest

Figure 4.9 **Lead concentrations in molluscs from the French and Spanish coasts, 1995. Source: RNO; Spanish monitoring programme.**

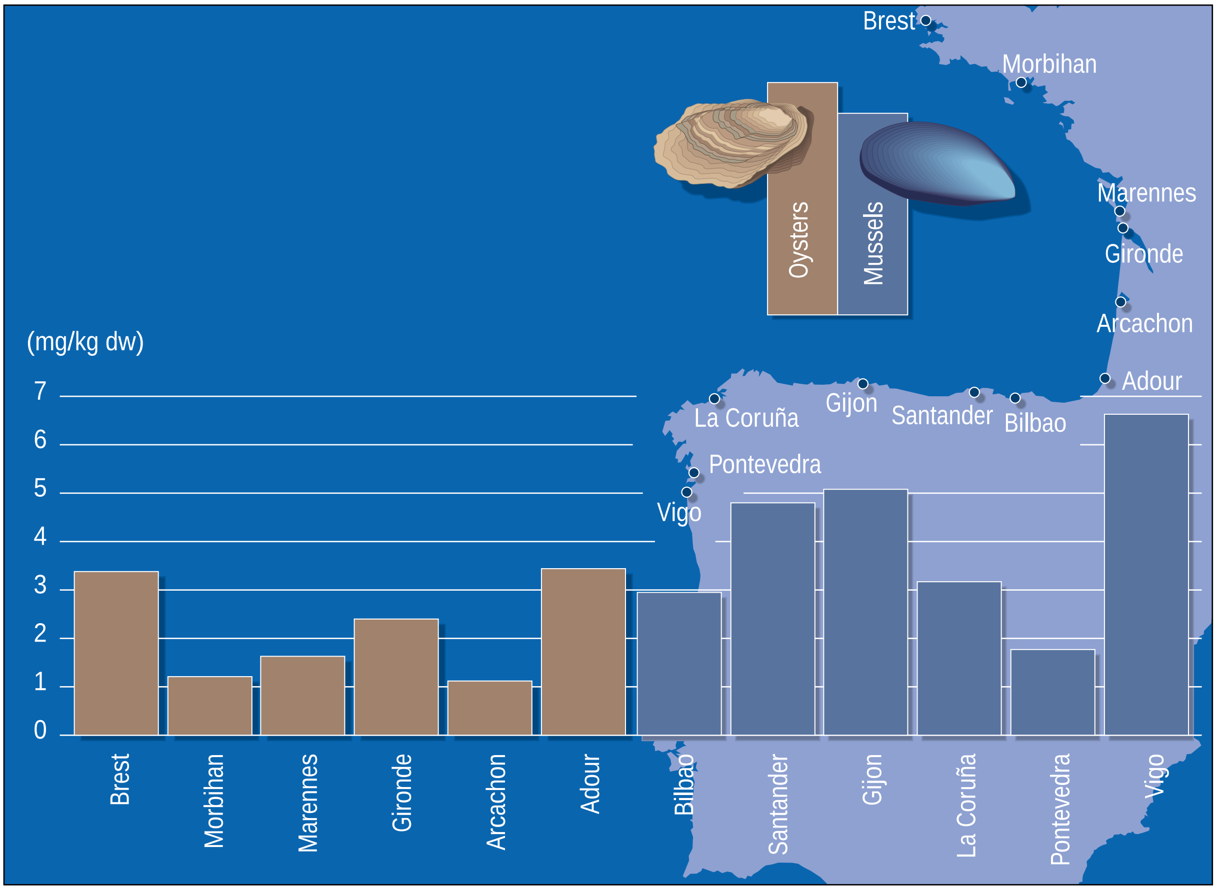


Table 4.10 Range in lead concentrations in fish muscle and shellfish (mg/kg) for species caught in the Bay of Biscay and the Channel. Source: Cossa *et al*. (1992).

	Gulf South Oléron	Gulf North Oléron	Channel
Bib	0.03 – 0.17	0.03 – 0.12	0.03 – 0.05
Brown shrimp	0.16 – 0.70	0.46 – 2.35	-
Common prawn	0.15 – 1.33	0.25 – 0.63	-
Conger	-	0.03 – 0.29	0.03 – 0.12
Dogfish	-	0.05 – 0.51	0.08 – 0.30
Flounder	0.03 – 0.19	0.05 – 0.21	0.03 – 0.06
Hake	0.03 – 0.08	0.03 – 0.10	-
Mackerel	0.03 – 0.08	0.03 – 0.15	-
Monkfish	0.03 – 0.12	0.03 – 0.10	-
Norway lobster	0.05 – 0.22	0.08 – 0.34	-
Plaice	0.03 – 0.05	0.03 – 0.31	0.03 – 0.08
Seabass	0.03 – 0.15	0.03 – 0.08	-
Sole	0.03 – 0.30	0.03 – 0.07	0.03 – 0.05
Whiting	0.03 – 0.08	0.03 – 0.34	-

- : no information.

concentration occurred in the San Sebastian area, due to the proximity of a number of different industries. Significant downward trends in concentration were observed in Pontevedra, A Coruña and Bilbao. In Vigo, Arosa and Santander no significant trends were observed.

Concentrations in different commercial fish species caught in the French sector of the Bay of Biscay, ranged from 0.03 mg/kg dw for the majority of the species to 2.35 mg/kg for brown shrimp (*Penaeus aztecus*) *(Table 4.10)*. Concentrations in common sole from the Spanish coast were 0.4 – 1.4 mg/kg dw.

Assessment

As for the entire northern hemisphere, the Bay of Biscay is subject to atmospheric lead inputs of anthropogenic origin. This is indicated via elevated surface sediment concentrations. Concentrations in fish remain low. Few data are available regarding concentrations in sea water the majority are relatively old. River inputs are significant near the shore and localised problems have been revealed by monitoring concentrations in molluscs. Nevertheless, these data do not indicate a major concern for public or environmental health.

4.3.4 Copper

The sources of copper to the Bay of Biscay are atmospheric inputs (the deposition of dust and rainwater) and riverine inputs, primarily from large rivers and estuaries (e.g. the Loire and the Gironde) but also from smaller rivers with lower flow rates such as the Vilaine, Adour or Charente. These inputs include dissolved copper in the freshwater flows, and particulate copper associated with SPM.

Inputs

The total (dissolved + particulate) copper inputs from the Loire and Gironde estuaries to the Bay of Biscay are around 225 t/yr *(Table 4.11)*. Adding this to the inputs for smaller rivers (which represent a flow equivalent to one tenth of that of the two major estuaries) the total copper inputs of riverine origin to the Bay of Biscay are thus around 250 t/yr (Boutier *et al*., 1993). On the Galician coast the total copper input from the Miño in 1994 was estimated at 21 t. In the Gulf of Cadiz the input from the Guadalquivir River was estimated at 660 kg in 1994 and 7 kg in 1995 (the location of the monitoring stations is currently being adjusted to enable a more accurate estimate).

Atmospheric copper inputs to the Bay of Biscay were estimated by Maneux *et al*. (1998) to reach 150 t/yr. However, this estimate only concerns wet deposition and should be increased to incorporate the input from dry deposition.

Concentrations in sea water

Dissolved copper concentrations in coastal waters off Brittany were approximately 160 ng/l for salinities of 35 – 35.5 in 1997. In the outer Loire Estuary, which is subject to significant dilution, dissolved copper concentrations are inversely proportional to salinity, in accordance with the equation: Cu (ng/l) = 6216 – (172 x salinity). Thus, dissolved concentrations at salinities of around 32, as frequently found in the outer Loire Estuary, are approximately 700 ng/l. Further south, in the French part of the Bay of Biscay, sea water has a mean dissolved concentration of 120 – 150 ng/l, which is similar in magnitude to that on the southern Brittany coast. The lowest concentrations occurred in the deepest, i.e. most saline, waters.

Concentrations in these deeper waters are inversely proportional to salinity according to the equation: Cu (ng/l) = 2790 – (75 x salinity). Thus, low salinity and copper-enriched waters are frequently encountered along the coast of Oléron island where concentrations of 400 ng/l have been recorded at salinities of around 32. Extrapolating the dilution curves along the plumes of the two major estuaries at a salinity of 35.5 results in concentrations of 116 ng/l, which is similar in magnitude to those reported in the literature for the North Atlantic.

Average copper concentrations in estuarine waters along the Portuguese coast ranged from 2 µg/l in the Ria Formosa to 6 µg/l in the Sado Estuary. Average concentrations in the Tejo Estuary and the Ria de Aveiro were 4 and 5 µg/l respectively. Total copper concentrations during 1992–7 deviated from those expected at stations influenced by industrial or urban effluents; a significant and sharp increase was observed in 1994. This could be associated with the severe droughts observed in 1992/3 and 1994/5.

Concentrations in sediments

Copper concentrations in sediment cores from various sites in the French sector of the Bay of Biscay were plotted as a function of particulate aluminium *(Figure 4.10)*. This showed both elements to be well correlated. It should be noted however that the regression line Cu = f(Al) does not cross the origin, indicating that the Cu/Al standardisation includes a bias which becomes significant at low aluminium concentrations, and that two data sets deviate considerably from the regression line (concentrations in the Bay of Bourgneuf are systematically below the line, while concentrations in the Gulf de Cap Breton are systematically above). Core samples with an aluminium content of > 3% and a constant vertical Mn/Al profile produce equivalent observations: i.e. copper concentrations of 7 – 19 mg/kg in the first 5 cm of the Bay of Biscay sediments. Using aluminium as the standard, *Figure 4.10* indicates Cu/Al ratios of 1.8 – 2.3 x 10^{-4} on the continental shelf, which is significantly lower than in the Bay of Bourgneuf (1.4 x 10^{-4}) and higher than in the Gulf de Cap Breton (3 x 10^{-4}). In comparison with data for other OSPAR areas sediments in the Bay of Biscay indicate relatively low levels of copper contamination.

Concentrations in the surface sediments of the Spanish coast were < 1 – 165 mg/kg, with an average of 15 mg/kg. There is little range in concentration on the Galician coast, except for locations within the estuaries. On the Cantabrian coast concentrations are generally higher than on the Galician coast. The maximum concentrations occurred near Bilbao and Gijón-Aviles. On the Portuguese coast average concentrations varied from 10.5 mg/kg dw in the Ria Formosa to 62.4 mg/kg in the Tejo Estuary. Concentrations in the Ria de Aveiro and the Sado Estuary were similar at 25.2 and 27.1 mg/kg dw respectively.

Concentrations in the Gulf of Cadiz are highest close to the coast. Concentrations on the continental shelf ranged from 4.2 mg/kg dw in the south-eastern zone near Tarifa Cape to 434 mg/kg dw in the mouth of the Ria of Huelva. Concentrations in the areas surrounding the mouths of the Guadiana and Guadalquivir rivers were 40 – 80 mg/kg dw. In the area off the Ria of Huelva, concentrations increased from 45 to 263 mg/kg dw. The maximum concentration near the mouths of the Tinto and Odiel rivers, which are affected by mining activities, was 90 mg/kg (Palanques *et al*., 1995). On the remainder of the continental shelf concentrations were around 50 mg/kg dw. The highest concentration (2100 mg/kg dw) occurred inside the Ria of Huelva. In 1988 concentrations 40 to 50 miles off the coast were 20 – 50 mg/kg.

Table 4.11 Estimated riverine inputs of copper to the Bay of Biscay. Source: Loire (Boutier *et al*., 1993); Gironde (PNOC).

	Loire Estuary	Gironde Estuary
Flow (m^3/s)	800	800
Dissolved copper in river (ng/l)	2.6	1.5
Gross dissolved copper flux (t/yr)	65	38
Solids discharge (t/yr)	1 x 10^6	2 x 10^6
Particulate copper in river (mg/kg)	71	33
Gross particulate copper flux (t/yr)	71	66
Particle deposits (t/yr)	0.5 x 10^6	0.3 x 10^6
Particulate copper in estuary (mg/kg)	42	31
Copper deposit flux (t/yr)	6	9
Total copper flux (t/yr)	130	95

Concentrations in biota

Copper concentrations have been measured on a quarterly basis in mussels and oysters along the French coast of the Bay of Biscay since 1979 *(Table 4.12)*. Major differences have been observed in the copper contents of

Figure 4.10 **Copper concentrations vs. aluminium in French coastal sediments. Source: Noël (1988).**

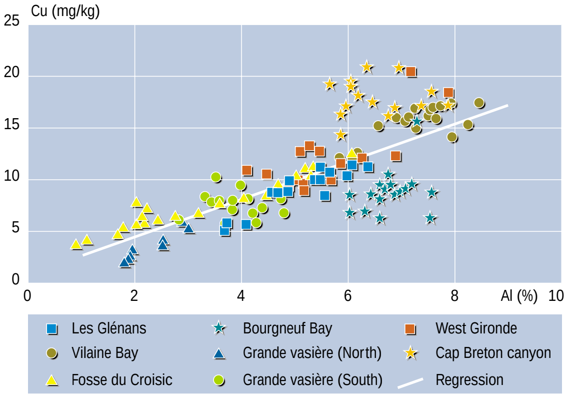


Table 4.12 **Copper concentrations in molluscs (mg/kg) from the French sector of the Bay of Biscay. Source: RNO.**

	Mussels		Oysters	
	1979–96	1994–6	1979–96	1994–6
No. samples	646	128	1903	360
Mean	7.6 ± 1.6	7.5 ± 1.4	235 ± 272	262 ± 313
Range	3.7 – 14.7	4.5 –12.2	20 – 2039	28 – 2039

oysters, with concentrations ranging from 20 to 2039 mg/kg dw according to the location, with a mean value of 235 mg/kg. In contrast, concentrations in mussels were relatively stable, with an average of 7.6 mg/kg dw between 1979 and 1996, despite seasonal variation. Significant contamination occurred in oysters from the Gironde Estuary (with a mean of ~ 1000 mg/kg), the Bay of L'Aiguillon and the northern Bay of Marennes-Oléron (with a mean of ~ 300 mg/kg), and the Basque coast (with a mean of ~ 300 mg/kg). The most significant change concerns the Bay of Arcachon, where concentrations have steadily increased since the early 1980s, with the mean value increasing from 80 to 150 mg/kg since 1990. This increase is probably due to copper-based antifouling paints which have been used since the ban on TBT-based paints in 1982 ***(Figure 4.11)***.

Along the Spanish coast, the average concentration is 5.74 mg/kg dw, with a minimum of 4.52 and a maximum of 7.75 mg/kg dw. Concentrations on the Spanish Cantabrian coast were slightly higher than on the Galician coast, where concentrations below the background level were detected. There has been a significant decrease in concentration at the Bilbao site, with non significant trends detected at various other sites.

Concentrations in fish and shellfish from the French part of the Bay of Biscay ranged between 0.2 and 105 mg/kg dw for the more contaminated species, such as Norway lobster ***(Table 4.13)***. Concentrations in common sole are similar throughout the Gulf of Cadiz, ranging from 1.5 to 1.7 mg/kg dw.

Assessment

Copper plays an active role in mussel metabolism and so its concentration is regulated by the organism itself. This explains why copper concentrations in mussel vary less in comparison with the other metals analysed.

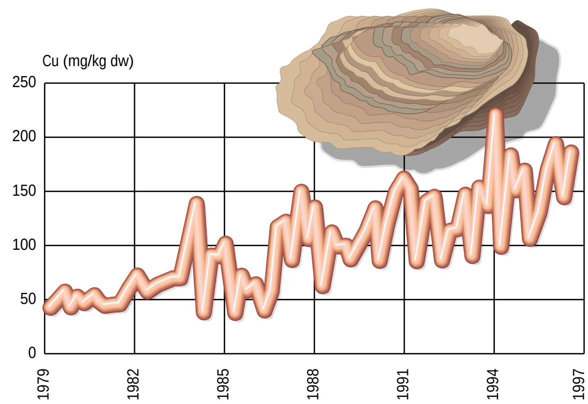
4.4 Persistent organic contaminants

4.4.1 Organotin compounds

Inputs

Antifouling paints used to protect the hulls of ships are the major source of tributyltin (TBT) and triphenyltin (TPT) in sea water. As a consequence of the negative effects observed on mariculture in Arcachon Bay, France has banned the use of TBT in antifouling paints since January 1982. TBT inputs to marinas have decreased sharply as a result. Nevertheless, monitoring indicates that marinas, harbours, shipyards and shipping routes still represent the major route of TBT input to the coastal environment. There are few data on TBT inputs to the OSPAR Maritime area.

Figure 4.11 **Copper concentrations in oysters from the RNO site at 'Les Jacquets' in the Bay of Arcachon, 1979–97. Source: RNO.**

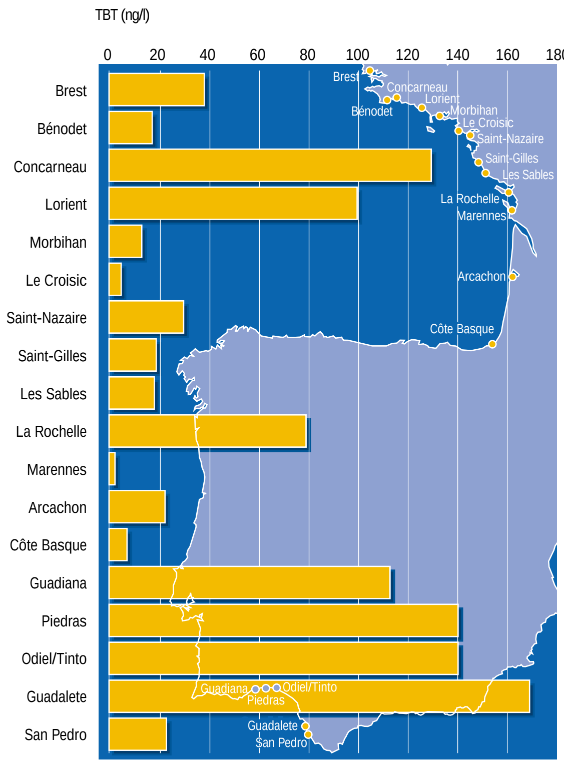


Concentrations in sea water

A survey of marinas on the French Atlantic coast conducted in 1986–7 (Alzieu *et al*., 1989) found a minimum concentration of 69 ng/l in La Trinité and a maximum concentration of 1500 ng/l in a small marina on Oléron island. A more recent survey found average concentrations of 10.4 ng/l in commercial harbours, 21.8 ng/l in marinas and 1.4 ng/l in reference coastal areas; maximum concentrations were 107.6 ng/l in marinas and 5.1 ng/l in coastal areas. A survey undertaken in 1997 ***(Figure 4.12)*** found no significant trends in concentration except at certain 'hot spots' where a sharp decrease was observed.

Concentrations in Spanish coastal waters have been studied in some detail on the south-western and north-western coasts; data for 1992 and 1996 are shown in *Figure 4.12*. In the south-western region, samples from seven estuarine and coastal areas ***(Table 4.14)*** indicated that TBT concentrations (in unfiltered water) were higher in

Figure 4.12 **TBT concentrations in French and Spanish coastal waters. Source: IFREMER; Gomez-Ariza (1997).**



Cadiz (at up to 1.22 µg/l), the largest fishing harbour, than in marinas such as those on the Guadalete Estuary or in smaller fishing harbours, such as those on the Guadiana, Carreras, Piedras, Odiel and Tinto estuaries (which had maximum concentrations of around 0.24 µg/l). TBT concentrations decreased with distance from the ports, to intermediate concentrations (0.02 – 0.12 µg/l) at estuarine sites with reduced flushing rates (such as in areas of the Sancti Petri Estuary), to undetectable levels (< 0.012 µg/l) on open beaches, such as downstream of the Doñana National Park. Dibutyltin (DBT) concentrations were generally two to five times lower than TBT concentrations but higher than concentrations of monobutyltin (MBT). Phenyltins were not detected at any of the sites.

Concentrations in sediments

In Arcachon Bay, TBT concentrations of 0.158 mg/kg dw were measured in the marina sediments, while concentrations in the central part of the bay were < 0.01 mg/kg dw. Sediment cores from the same area indicate maximum concentrations of 0.65 mg/kg in some marinas. Alzieu and Michel (1998) found homogeneous concentrations of 0.2 – 0.3 mg/kg in sediment cores representing ten years of sedimentation from La Trinité marina, this indicates a very low degradation of TBT in the sediment.

In bulk surface (10 cm depth) sediments obtained from estuarine and coastal areas in south-west Spain *(Table 4.14)* TBT concentrations were highest in harbour samples composed mainly of silt and clay (generally 0.56 – 1.46 mg/kg) and lowest at sandy downstream sites (< 0.002 – ~ 0.027 mg/kg). DBT + MBT concentrations in the most polluted samples were usually several times lower than those of the parent compound, but the difference levelled off or even reversed as the TBT concentrations decreased. Total phenyltin concentrations (TPT + degradation products) were < 0.009 to around 0.044 mg/kg, with the exception of a site in the Sancti Petri Estuary which had concentrations of up to 0.8 mg/kg total phenyltin.

Concentrations in biota

On the north-west coast of Spain, a summer survey to assess the bioaccumulation of several organotin compounds in the females of twenty dogwhelk (*Nucella lapillus*) populations can be summarised as follows: total organotin, 0.096 – 0.733 mg/kg ww; TBT, 0.029 – 0.793 mg/kg ww; DBT, 0.110 – 0.594 mg/kg ww; MBT, 0.033 – 0.191 mg/kg ww; and TPT 0.038 – 0.245 mg/kg ww. TBT and DBT occurred at all twenty sites, MBT occurred at most of the sites and TPT occurred at approximately 50% of the sites. A linear correlation occurred between TBT and all the other organotin compounds. The lowest TBT concentrations (< 0.07 mg/kg ww) occurred in dogwhelk from the exposed shores of the northern coast, and the highest (> 0.35 mg/kg ww) in dogwhelk from industrial bays and some sheltered areas of mussel cultivation within the southern estuaries. The percentage of TBT with respect to the total TBT + DBT concentrations also varied widely (16 – 60%), but increased as the TBT concentrations increased. Similarly, the percentage of TPT with respect to TBT ranged from 11 to 52%, but was not correlated with the TBT concentration.

Table 4.13 Copper concentrations in fish and shellfish (mg/kg) from the French sector of the Bay of Biscay. Source: Cossa *et al.* (1990).

	ICES Zone VIIIa	ICES Zone VIIIb
Bib	0.6 – 1.8	-
Brown shrimp	34 – 94	37 – 99
Conger	0.4 – 1.2	-
Dogfish	1 – 2	-
Flounder	0.4 – 1.1	0.8 – 2.4
Hake	0.5 – 1.1	0.5 – 1.0
Mackerel	1.4 – 4.4	-
Norway lobster	19 – 105	12 – 42
Plaice	0.2 – 1.1	-
Seabass	0.7 – 1.6	1.4 – 2.9
Sole	0.4 – 0.9	0.4 – 2.8
Whiting	0.6 – 3.0	-

- : no information.

TBT concentrations in the tissues of filter-feeding bivalve molluscs (cockles, mussels and oysters) from seven estuarine and coastal areas of south-west Spain were less variable than in sea water or sediment, and higher than those of DBT + MBT; increasing from 0.041 mg/kg ww on open beaches with undetectable organotin concentrations in sea water to > 0.244 mg/kg ww at sites affected by harbours.

Assessment

The harmful effects of TBT on the coastal environment were first observed in the Bay of Arcachon. Regulatory measures adopted by France in 1982 helped to return oyster production levels to normal by 1984.

The 1996 survey in north-west Spain also examined the impact of imposex in 37 dogwhelk populations *(Table 4.15)*. Imposex is the superimposition of male sexual characteristics, including a penis, onto the females of certain gastropod species. Values for the Relative Penis Size Index (RPSI), the Vas Deferens Sequence Index (VDSI) and the percentage of sterile females were 6 – 59, 3.2 – 4.6 and 0 – 54, respectively. Since these indices are based logarithmically on the TBT concentration in female tissues, the spatial distribution of imposex generally agrees with the spatial variability in TBT concentration. Although most samples included females which had effectively been sterilised by TBT, there are no populations currently considered to be at risk of extinction since the proportion of reproductive females in even the most affected populations is around 50% (Ruiz *et al*., 1998). The TBT concentrations in the tissues of molluscs from south-west Spain (up to 0.31 mg/kg ww) are not considered to result in adverse effects, but are probably affecting the fitness of the local adult populations (Gomez-Ariza *et al*., 1997).

4.4.2 Polychlorinated biphenyls

Polychlorinated biphenyls (PCBs) are a well studied group of contaminants which are commonly determined in pollution monitoring programmes. They are lipophilic, resistant to degradation, persistent and toxic. Concentration data in this chapter are expressed either as PCBs (which refers to a technical mixture) or in terms of individual chlorinated biphenyls (CBs), in which case the

Table 4.14 Organotin concentrations in water (µg Sn/l), sediment (mg Sn/kg dw) and bivalve molluscs (mg Sn/kg ww) from estuarine and coastal areas of south-west Spain. Source: based on Gomez-Ariza *et al.* (1997).

	MBT	DBT	TBT
Guadiana and Carreras Estuaries			
sea water (8)	< 0.005 – 0.050	0.007 – 0.020	0.009 – 0.080
sediments (21)	0.002 – 0.100	0.002 – 0.300	0.001 – 0.130
bivalve molluscs (6)	0.010 – 0.047	0.017 – 0.047	0.050 – 0.117
Piedras Estuary			
sea water (7)	< 0.005 – 0.013	< 0.005 – 0.020	< 0.005 – 0.100
sediments (15)	0.002 – 0.015	0.002 – 0.030	0.001 – 0.020
bivalve molluscs (4)	0.002 – 0.013	0.013 – 0.018	0.067 – 0.107
Odiel and Tinto Estuaries			
sea water (11)	< 0.005 – 0.040	< 0.005 – 0.100	< 0.005 – 0.100
sediments (20)	0.003 – 0.120	0.002 – 0.200	0.003 – 0.200
bivalve molluscs (3)	0.005 – 0.010	0.005 – 0.023	0.017 – 0.100
Guadalete Estuary			
sea water (7)	< 0.005 – 0.025	< 0.005 – 0.040	< 0.005 – 0.120
sediments (5)	0.020 – 0.130	0.020 – 0.500	0.027 – 0.600
San Pedro Estuary			
sea water (6)	0.007 – 0.014	< 0.005 – 0.014	0.009 – 0.016
sediments (13)	< 0.001 – 0.006	0.001 – 0.009	< 0.001 – 0.011
bivalve molluscs (2)	0.011 – 0.028	0.031 – 0.046	0.117 – 0.127
Cadiz Bay			
sea water (11)	< 0.005 – 0.040	< 0.005 – 0.070	< 0.005 – 0.500
sediments (13)	0.001 – 0.030	0.001 – 0.050	0.002 – 0.230
Sancti Petri Estuary			
sea water (12)	< 0.005 – 0.030	< 0.005 – 0.040	< 0.005 – 0.060
sediments (25)	0.001 – 0.550	0.001 – 1.200	0.001 – 17

MBT monobutyltin; DBT dibutyltin; TBT tributyltin.

data are expressed in terms of the International Union for Pure Applied Chemistry (IUPAC) number.

Inputs

Inputs to the River Tagus for the sum of the seven congeners with the IUPAC numbers, 28, 52, 101, 118, 138, 153, 180 ($\sum PCB_7$) were estimated during the period 1992–5. Total inputs, excluding industrial discharges, were extremely variable ranging from 9.8 kg in 1992 to 84 kg in 1994.

Concentrations in sea water

There are relatively few data on PCB concentrations in estuarine waters discharging into Region IV, although some reliable data are available for PCBs associated with particulate matter. In the Loire Estuary, Saliot *et al*. (1984) found PCB concentrations in SPM to vary within the range 55 to 437 µg/kg, whereas Pierard (1995) found lower concentrations in fluid mud and SPM from the Gironde Estuary; around 1 – 3 µg/kg for CB153 and

Table 4.15 Imposex and organotin concentrations (mg Sn/kg ww) in female dogwhelk from estuaries and coastal areas of north-west Spain. Source: based on Ruiz *et al*. (1998).

Site	RPSI	VDSI	% st	MBT	DBT	TBT	TPT
Ribadeo	9	3.2	0	< 0.003	0.081	0.017	< 0.003
Foz	10	4.2	18	-	-	-	-
Viveiro	45	4.2	23	-	-	-	-
Barqueiro	33	4.3	25	-	-	-	-
Cariño	19	4.2	16	< 0.003	0.084	0.050	< 0.003
Cedeira	21	4.1	7	-	-	-	-
Prior	9	3.2	3	-	-	-	-
Mugardos	45	4.3	33	0.112	0.303	0.234	0.083
Centroña	24	4.0	17	0.043	0.115	0.081	0.031
Perbes	13	3.9	11	-	-	-	-
Sada	37	4.1	10	-	-	-	-
Veigue	22	4.1	9	-	-	-	-
Mera	37	4.2	25	0.129	0.259	0.235	0.055
Bastiagueiro	59	4.5	40	0.110	0.196	0.185	0.050
Sta. Cristina	51	4.5	46	0.111	0.245	0.262	0.066
Dique	21	4.1	21	0.059	0.120	0.107	< 0.003
Langosteira	7	3.3	0	< 0.003	0.081	0.026	< 0.003
Malpica	6	3.6	0	0.025	0.063	0.012	< 0.003
Laxe	32	4.1	9	-	-	-	-
Muxia	33	4.2	26	-	-	-	-
Corcubion	18	4.3	28	0.022	0.056	0.018	< 0.003
Louro	18	3.9	6	-	-	-	-
Muros	38	4.3	28	-	-	-	-
Creo	57	4.6	54	0.057	0.216	0.325	< 0.003
Ribeira	39	4.3	29	0.045	0.143	0.093	< 0.003
Vilagarcia	28	4.5	44	0.043	0.153	0.146	0.018
Cambados	18	4.0	15	-	-	-	-
A Toxa	43	4.3	33	0.026	0.110	0.075	< 0.003
Sanxenxo	28	3.8	11	-	-	-	-
Poio	30	4.5	50	0.059	0.139	0.140	0.037
Marin	41	4.3	40	-	-	-	-
Rande	47	4.6	53	0.038	0.140	0.174	0.023
Bouzas	36	4.4	36	0.066	0.190	0.151	0.052
Samil	41	3.5	10	< 0.003	0.107	0.037	0.019
Canido	32	4.3	29	-	-	-	-
Baiona	35	4.0	6	-	-	-	-
A Garda	43	4.4	46	< 0.003	0.091	0.113	0.013

RPSI Relative Penis Size Index; VDSI Vas Deferens Sequence Index; % st percentage of sterile females; MBT monobutyltin; DBT dibutyltin; TBT tribulytin; TPT total phenyltin; - no information.

10 – 20 µg/kg for ΣPCB_{22}, which approximates to 15 – 30 µg/kg in terms of the technical mixture equivalent. On the basis of these data, Pierard (1995) estimated that approximately 31 kg of the annual PCB input to the Gironde Estuary resulted from PCBs adsorbed onto riverine borne SPM. PCB concentrations in SPM from the Loire and Gironde estuaries are considerably lower than those currently found in the Seine Estuary. This estuary is considered highly contaminated by PCBs, with concentrations of around 400 – 900 µg PCBs/kg, and 20 – 45 µg CB153/kg (Abarnou, 1988; Munschy *et al.*, 1996).

Concentrations in sediments

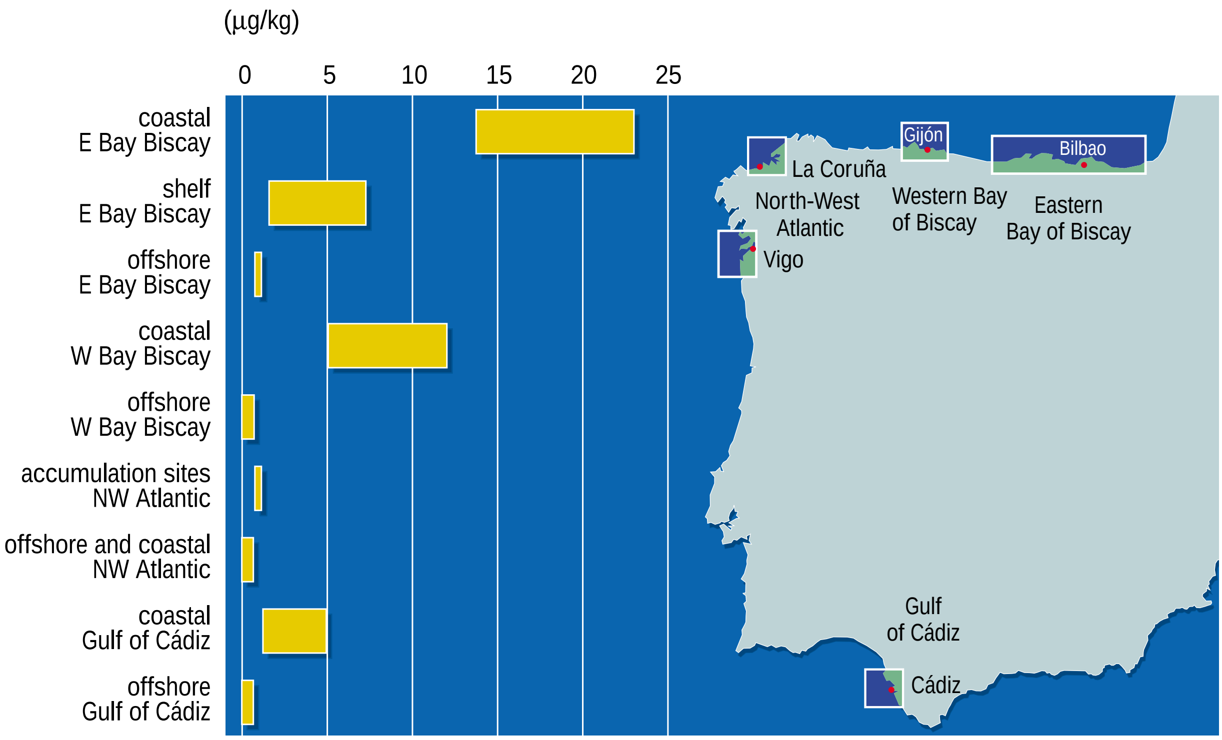
Polychlorinated biphenyl concentrations at various sites on the French Atlantic coast have been found to vary from 10 to 100 µg/kg, which indicates low to moderate contamination. In the Bay of Arcachon, Pierard (1995) found concentrations in the harbour area (CB153: 24 µg/kg) to be two orders of magnitude higher than at other sites in the bay (CB153: 0.3 – 0.7 µg/kg).

In the eastern Spanish section of the Bay of Biscay a gradient in ΣPCB_7 concentrations occurs, with concentrations low offshore, 0.6 – 1.4 µg/kg, increasing gradually across the continental shelf to reach maximum levels of 10 – 20 µg/kg at the coastal sites closest to land. This is due to the high population levels in this area, and major industrial sites along this coast. These concentrations are considered to indicate low to moderate levels of contamination. ΣPCB_7 concentrations are low in the western Spanish section of the Bay of Biscay ranging from 0.03 to 0.6 µg/kg offshore and on the continental shelf. Gradients in concentration were not observed although some sites close to populated cities (Gijón and Avilés), and with mining and industrial activities in the vicinity, had higher concentrations of 5 – 10 µg/kg. Nevertheless, these concentrations are considered low.

ΣPCB_7 concentrations in total sediment from offshore areas and the continental shelf of north-west Spain ranged from 0.03 to 0.6 µg/kg *(Table 4.16; Figure 4.13)*. Gradients in concentration were not observed, although concentrations of around 1 µg/kg occurred at two sites close to the Ría de Pontevedra. All concentrations were very low. In contrast, gradients in concentration were observed within the estuaries (the rias of Vigo, Pontevedra and A Coruña), with the maximum concentrations closest to the cities *(Table 4.17)*. On average concentrations were 1 – 40 µg/kg, which are considered low to moderate.

Along the south-western Spanish coast ΣPCB_7 concentrations are lowest in offshore areas (0.05 – 0.6 µg/kg) and in those areas which are not affected by the cities of Cádiz and Huelva. Closer to the coast, concentrations increase in the vicinity of the estuaries. Concentrations close to the Cádiz Estuary were 1 – 2.6 µg/kg, and in front of the Huelva Estuary a gradient occurred towards the mouth of the river, with concentrations ranging from 1.4 to 4.9 µg/kg.

Figure 4.13 **ΣPCB_7 concentrations in Spanish surface sediments, 1996. Source: IEO.**



Concentrations in biota

The French monitoring programmes currently determine PCB concentrations in mussels and oysters as total PCB and in terms of individual congeners. Because the PCB ‘fingerprints’ in mussels and oysters are identical at all the sites, the spatial distribution of the contamination may be described by any quantification method. The average PCB concentration for the 37 sampling sites between 1980 and 1996, and between Fouesnant in western Brittany to Hendaye on the river Bidasoa, is 290 µg/kg dw. These relatively low concentrations reflect the moderate levels of urbanisation on the French Atlantic coast. Higher concentrations generally occur near the estuaries of the larger rivers, such as the Loire (~ 600 µg PCB/kg dw) and to a lesser extent the Gironde (~ 500 µg PCB/kg dw). Elevated levels in the Lorient may reflect local sources of contamination, whereas the high concentrations currently found in the Basque region may be due to the residual circulation in the Bay of Biscay ***(Figure 4.14)***. A decrease in the PCB concentrations has been observed at most of the sampling stations. Seasonal trends are very similar, with slightly lower concentrations in summer.

The spatial distribution of $\sum PCB_7$ concentrations in mussel at various sites along the Spanish coast in 1995 was extremely variable with concentrations ranging from 1.15 to 46 µg/kg ww. Lower concentrations occurred at Corrubedo and Leira, 1.15 and 1.67 µg/kg ww respectively, which are below the background concentration of 1.7 µg/kg ww.

The maximum concentrations occurred in the bays of A Coruña (46 µg/kg ww) and Orio (44 µg/kg ww), and are four times higher than the EAC of 10 µg/kg ww. In A Coruña bay the high values reflect a local input near the sampling zone in 1991. Concentrations at this site are decreasing and were 50% lower in 1997 than in 1995. On the basis of this study three categories of data are observed:

- concentrations of < 5.15 µg/kg ww, representative of most of the coast, i.e. for areas with low population densities and no industrial activity;
- concentrations of 9 – 18 µg/kg, i.e. around the EAC level, corresponding to areas of moderate industrial activity, such as Vigo, Gijón and Mundaka; and
- high concentrations, corresponding to areas of moderate to high levels of industrial activity, such as A Coruña, Santander, Bilbao and Orio. In such areas concentrations are three to four times higher than the EAC.

CB contamination can vary at a local level, as illustrated by the Santander data, where concentrations vary by a factor of three between two relatively close sites (33 and 10 µg/kg ww respectively). A decrease in concentration occurred in mussels between 1991 and 1996 at Bilbao, with no significant trends at Vigo, Pontevedra, Arosa, A Coruña or Santander.

Table 4.16 CB concentrations in surface sediments (µg/kg) from Spanish coastal and offshore areas. Source: IEO.

Site	$\sum PCB_7$	CB28	CB52
Eastern Bay of Biscay			
offshore	0.6 – 1.0	< DL – 0.1	< DL – 0.1
mid coastal	1.4 – 7.2	0.1 – 0.5	0.1 – 0.5
inshore	13.6 – 23.0	0.6 – 1.4	0.6 – 1.7
Western Bay of Biscay			
offshore	0.03 – 0.6	< DL – 0.05	< DL – 0.08
coastal	5.0 – 12.0	0.06 – 1.0	0.09 – 0.5
North-west Atlantic			
offshore and coastal	0.03 – 0.6	< DL – 0.03	< DL – 0.03
accumulation sites	0.6 – 1.0	0.03	0.07 – 0.1
Gulf of Cadiz			
offshore	0.05 – 0.6	< DL – 0.03	< DL – 0.1
coastal	1.0 – 4.9	0.05 – 0.13	0.1 – 0.15

DL detection limit.

Table 4.17 CB concentrations in surface sediments (µg/kg) from Spanish estuaries. Source: IEO.

Site	$\sum PCB_7$	CB28	CB52
Ria de Vigo			
mouth	0.3 – 7.6	< DL – 0.06	< DL – 0.2
brackish zone	10 – 37	0.2 – 0.4	0.2 – 0.5
area closest to city	42 – 88	0.4 – 0.8	0.8 – 3.5
Ria de Pontevedra			
mouth	0.5 – 3.1	< DL	< DL
brackish zone	6.3 – 13	< DL – 0.02	< DL – 0.03
area closest to city	21 – 36	0.1 – 0.2	0.1 – 0.3
Ria de A Coruña			
mouth	0.07 – 0.6	< DL	< DL – 0.03
brackish zone	1.0 – 3.7	< DL	< DL – 0.03
areas closest to cities	4.5 – 33	0.2 – 0.3	0.2 – 0.7
Ria de Bilbao			
mouth	8.6 – 13	0.3 – 0.4	0.3 – 0.5
inside harbour	24 – 74	0.8 – 2.1	1.5 – 1.8
beside piers	94 – 122	3.5 – 5.7	2.6 – 3.9
Ria de Huelva	9.6 – 16	0.06 – 0.09	0.2
Cádiz Bay	0.9 – 1.5	0.02 – 0.03	< DL – 0.1

DL detection limit.

In a range of commercial fish species from the Bay of Biscay average total PCB concentrations ranged from 132 – 1020 µg/kg *(Table 4.18)* (Cossa *et al*., 1990). Benthic species such as flounder and sole were the most contaminated.

The range in concentration for $\sum PCB_7$ in fish muscle from the Galician and Cantabrian coast in 1990 was 5.9 µg/kg ww for hake to 8.2 µg/kg ww for pilchard, and in the Gulf of Cadiz in 1990 average concentrations were 4 – 6 µg/kg ww for sole and 11 – 15 µg/kg ww for striped

CB101	CB118	CB138	CB153	CB180
< DL – 0.1	< DL – 0.1	< DL – 0.13	< DL – 0.1	0.02 – 0.11
0.2 – 1.0	0.2 – 0.9	0.2 – 1.4	0.2 – 1.8	0.2 – 1.7
1.2 – 3.6	1.0 – 2.3	2.0 – 5.2	2.5 – 5.7	2.6 – 6.4
< DL – 0.04	< DL – 0.07	0.02 – 0.14	< DL – 0.11	0.02 – 0.12
0.2 – 1.0	0.6 – 0.7	0.2 – 2.0	0.2 – 2.4	0.16 – 2.7
< DL – 0.05	< DL – 0.04	< DL – 0.06	< DL – 0.05	< DL – 0.05
0.12 – 0.14	0.07 – 0.1	0.08 – 0.14	0.1 – 0.19	0.08 – 0.14
< DL – 0.1	< DL – 0.1	< DL – 0.1	< DL – 0.08	< DL – 0.15
0.1 – 0.3	0.1 – 0.3	0.2 – 0.7	0.2 – 0.7	0.5 – 1.2

CB101	CB118	CB138	CB153	CB180
< DL – 0.3	0.06 – 0.3	0.07 – 1.0	0.1 – 1.3	0.1 – 1.0
0.6 – 2.4	0.5 – 1.5	1.7 – 8.0	2.1 – 7.3	1.5 – 8.1
3.0 – 7.0	2.1 – 4.2	10 – 20	10 – 22	10 – 29
< DL – 0.2	0.02 – 0.2	< DL – 0.04	0.1 – 0.3	0.1 – 0.4
0.2 – 0.5	0.2 – 0.5	0.1 – 3.5	0.5 – 4.5	0.4 – 3.8
1.0 – 3.0	1.1 – 1.5	4.0 – 7.7	5.0 – 6.8	5.0 – 6.9
0.05	0.03 – 0.05	0.2	0.1	0.1
0.09 – 0.2	0.1 – 0.5	0.3 – 1.3	0.2 – 1.5	0.2 – 1.6
0.3 – 2.4	0.5 – 1.8	2.0 – 7.6	1.9 – 9.3	3.5 – 13
1.0 – 1.5	0.6 – 0.7	1.8 – 2.8	2.3 – 3.5	2.1 – 3.5
2.1 – 3.0	1.5 – 2.1	5.3 – 7.4	5.7 – 9.0	5.9 – 9.6
7.0 – 10	3.3 – 5.3	17 – 29	21 – 35	22 – 36
0.9 – 1.3	0.5 – 0.8	2.4 – 4.0	3.0 – 4.5	2.6 – 5.5
0.05 – 0.2	0.05 – 0.1	0.2 – 0.3	0.3 – 0.4	0.3 – 0.4

mullet. The average concentration for hake in the Gulf of Cadiz was 8 µg/kg ww.

Higher concentrations and greater variability in the levels of contamination are observed in the higher predators, such as marine mammals. PCB concentrations in the fatty tissues of dolphins from the Atlantic were in the range 100 – 10 000 µg/kg *(Table 4.19)*. For ΣPCB_7 the concentrations were 1500 – 75 000 µg/kg depending on the reproductive status of each individual *(Table 4.20)*. Such concentrations result in a bioconcentration of around $10^8 – 10^{10}$. The accumulation of such contaminants, resulting in a whole body burden of ~ 100 mg for an individual animal, results from the consumption of contaminated prey.

Assessment

All the data for total PCB concentrations in mussels from Region IV are lower than the natural background values of 0.35 – 1.7 µg/kg ww.

4.4.3 Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are a diverse group of organic planar compounds containing two or more fused aromatic (benzene) rings. A large number of individual environmentally relevant PAHs exist, ranging in molecular weight from naphthalene (molecular weight 128,16) to coronene (molecular weight 300,36).

Inputs

There is no information available on the sources and their emission rates for PAHs in Region IV.

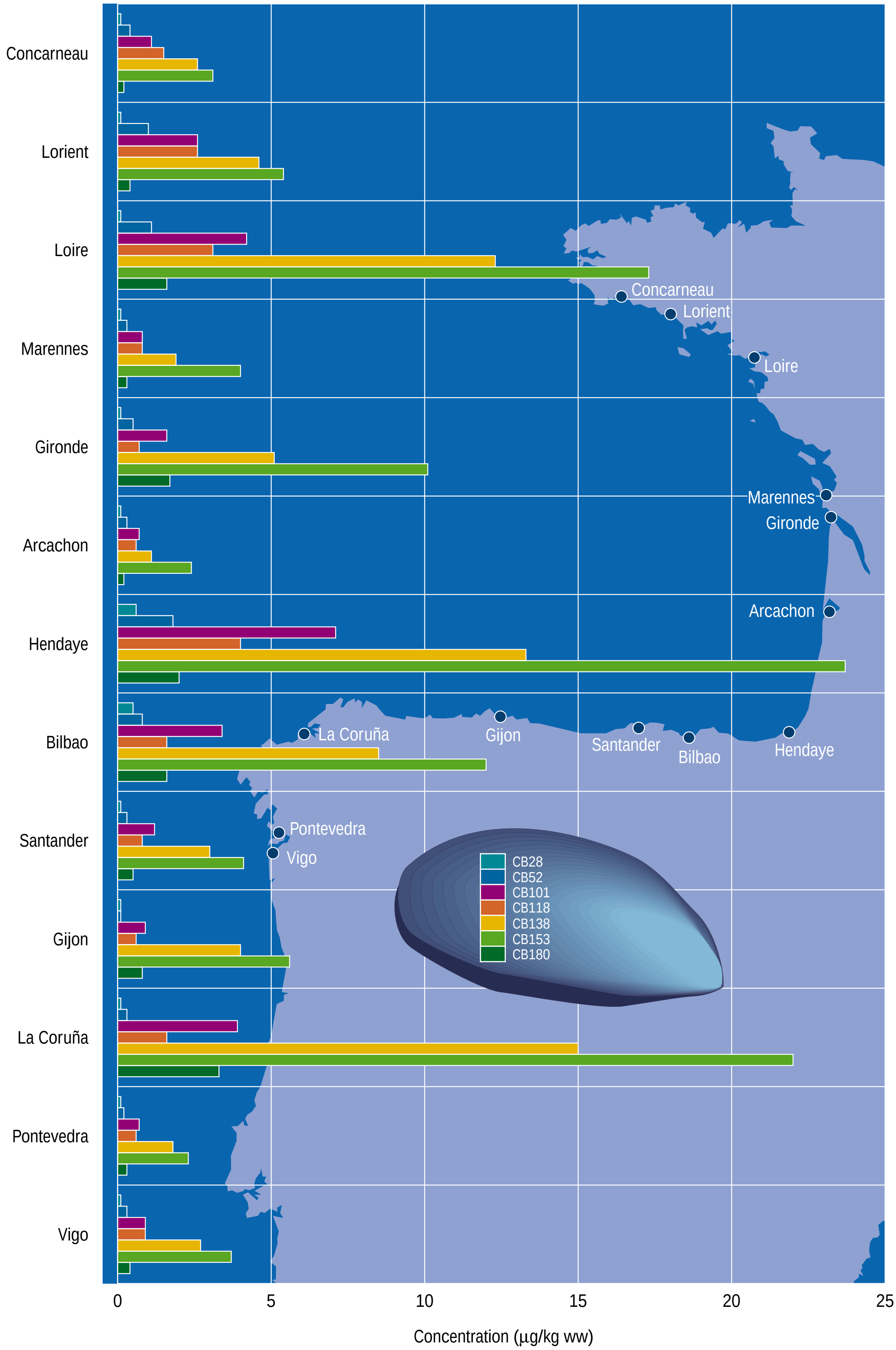
Concentrations in sea water

The lowest PAH concentrations occur in the Atlantic, ranging from 300 pg/l for the more water-soluble, lower molecular weight PAHs (i.e. those with two and three rings) to < 1 pg/l for the high molecular weight PAHs (i.e. those with five or more rings) (OSPAR, 1997c).

Concentrations in sediments

Concentrations of pyrene, benzo[*a*]pyrene and ΣPAH (the sum of concentrations for the individual PAH compounds) in surface sediments along the French coast are shown in *Table 4.21*. These concentrations represent three distinct geographical areas: Atlantic deep sea sediments (615 – 1040 m) from the Cap-Ferret Canyon, shallow coastal sediments (42 – 133 m) from the Gulf of Cap Breton and the depositional area offshore of the Gironde Estuary, and estuarine and lagoon sediments from the Loire Estuary, the Gironde Estuary and Arcachon Bay. he surface sediment concentrations ranged from 9 to 4888 µg/kg dw for ΣPAH, from 2 to 551 µg/kg dw for pyrene and from below the detection limit to 508 µg/kg dw for benzo[*a*]pyrene. The range in PAH concentrations reflects the wide range of sediments analysed. For example, in the Gironde Estuary ΣPAH concentrations in sandy sediments were significantly lower than in muddy sediments, at 19 – 252 µg/kg and 622 – 4888 µg/kg, respectively (Budzinski *et al.*, 1997). The majority of the ΣPAH concentrations in the sediments and SPM of the central and southern Bay of Biscay, offshore, on the continental shelf and in estuarine and lagoon sediments were < 2000 µg/kg. A few higher concentrations were observed resulting from local sources of PAH contamination.

Figure 4.14 **Concentrations of individual CBs in mussels from the French and Spanish coasts, 1995. Source: RNO; Spanish monitoring programme.**



Total PAH concentrations in Spanish coastal sediments vary widely, but are generally low to moderate, except at a few localised sites subject to industrial and urban inputs. Higher concentrations tend to occur in the Bilbao area than around Vigo on the north coast or Huelva in the Gulf of Cadiz (where one site had a concentration fifteen times higher than the average for the area). Nevertheless, the concentrations observed decrease sharply with distance from the sources *(Table 4.22)*.

In the Bilbao area concentrations of phenanthrene, anthracene and pyrene are higher than the respective EACs. The maximum phenanthrene and anthracene concentrations correspond to the inner ria and that for anthracene to the coastal station. The average $\sum PAH_{13}$ (anthracene, phenanthrene, pyrene, chrysene, benzo[*e*]pyrene, benzo[*k*]fluoranthene, dibenz[*ah*]-anthracene, benzo[*ghi*]perylene, indeno[1,2,3-*cd*]pyrene, fluoranthene, benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*a*]pyrene) concentration in the estuary and adjacent coastal area is 5.2 µg/kg dw.

Concentrations in biota

Concentration data for biological samples are scarce. The most recent data (1994–6) for individual PAH concentrations in blue mussel, Mediterranean mussel (*Mytilus galloprovincialis*) and Pacific oyster in French coastal and estuarine areas are available via the national monitoring network. In the French section of the Bay of Biscay $\sum PAH_{12}$ concentrations are 30 – 404 µg/kg dw (with an arithmetic mean of 148 µg/kg dw for the 43 sites over the period 1994–6). Concentrations of pyrene and benzo[*a*]pyrene were 2 – 106 µg/kg and < 1 – 6 µg/kg dw respectively. Slightly higher concentrations of $\sum PAH_{11}$ were reported in mussels caged for three months in Arcachon Bay; 238 – 428 µg/kg dw with one concentration of 2108 µg/kg dw. The distribution of PAH concentrations in molluscs along the French coast indicate that the high concentrations are related to urbanised and estuarine areas.

Table 4.18 PCB concentrations in commercial fish species (µg/kg) from the Bay of Biscay. Source: Cossa *et al.* (1992).

	CB153	PCB
Seabass		
off the Gironde Estuary	38.4 ± 7.4	578 ± 156
	(27.5 – 52.8)	(351 – 891)
off southern Brittany	37.0 ± 7.2	500 ± 170
	(17.5 – 47.6)	(129 – 794)
Flounder		
off the Gironde Estuary	124.5 ± 123	1017 ± 1064
	(6.8 – 419.2)	(58 – 3697)
off the Loire Estuary	29.3 ± 14.6	25 ± 137
	(4.0 – 51.0)	
Mackerel		
off the Gironde Estuary	39.0 ± 26.8	312 ± 263
	(4.9 – 104.8)	(37 – 928)
off Vendée	3.2 ± 22.7	225 ± 155
		(72 – 677)
Lesser spotted dogfish	16.0 ± 7.9	132 ± 62
off Vendée	(4.5 – 32.7)	(39 – 298)

4.4.4 Other persistent organic compounds

Inputs

There are many different types of organochlorine compound but they are all characterised by their

Table 4.19 CB153 concentrations in fatty tissue (melon fat) (µg/kg) from dolphins. Source: IFREMER.

	Common dolphin			Striped dolphin		
	No. samples	mean	min – max	No. samples	mean	min – max
Newborn (< 1 yr)	1	1640		2	2565	2310 – 2820
Immature and pubescent (1 – 5 yr)	3	960	500 – 1200	12	1800	910 – 3860
Female adult (> 5 yr)	3	400	40 – 1090	5	450	200 – 1110
Male adult (> 5 yr)	2	6710	6680 – 6740	3	5500	5040 – 6200

Table 4.20 CBs in dorsal subcutaneous fatty tissue (µg/kg ww) of common dolphins stranded on the Galician coast. Source: IEO.

		CB153		$\sum PCB_7$	
	No. samples	mean	min – max	mean	min – max
Non-mature females	5	2 366	1 258 – 3 960	6 386	3 148 – 10 300
Non-mature males	10	7 031	1 244 – 29 006	18 172	3 664 – 76 139
Mature females	8	10 997	553 – 29 246	29 750	1 633 – 74 574
Mature males	11	10 538	2 553 – 26 511	25 104	6 577 – 61 580

$\sum PCB_7$ IUPAC numbers 28, 52, 101, 118, 138, 153, 180.

Table 4.21 PAH concentrations in surface sediments (µg/kg dw) along the French coast.

	Date	Pyrene	Benzo[a]pyrene	∑PAH
Bay of Biscay				
Gironde deposition area	1987–8	4 – 29	5 – 53	156 – 694
Cap Ferret canyon	1988	24 – 47	nd – 188	141 – 2070
Cap Breton abyss	1984	90 – 105	108 – 178	1430 – 2027
Arcachon Bay	1985–6	10 – 238	12 – 488	116 – 3655
Arcachon Bay	1995	4 – 551	3 – 312	32 – 4120
Gironde Estuary*	1993	2 – 387	nd – 508	19 – 4888
Loire Estuary	1983–4	304 – 421	134 – 270	1213 – 2700
Arctic Ocean/Iceland†	ni	2 – 6	1 – 4	ni

* Budzinski *et al.* (1997); † OSPAR (1996); nd not detected; ni no information.

persistence in the marine environment. They are usually widely dispersed within the environment. The only data available on other persistent organic compounds are limited to lindane and DDT, both of which have been banned since the 1970s. Inputs of quantitative lindane discharged into the estuary of the River Tagus were, excluding industrial inputs, estimated at 9.8 kg in 1992, 6.8 kg in 1993, 15 kg in 1994 and 2.8 kg in 1995.

Concentrations in biota

Due to their high potential for bioaccumulation, levels of marine contamination may be estimated by monitoring concentrations in bivalve molluscs. There are no data on concentrations in water or sediments.

Along the French coast, average lindane concentrations in oysters and mussels were < 5 – 20 µg/kg dw during 1979–93. Comparisons between data for 1993 and 1989 indicate a general decrease in concentration. The highest concentrations (20 µg/kg dw), which were found in the Charente area, were due to the use of this pesticide for agricultural purposes or to protect houses against termites. Along the Spanish coast mussel concentrations tended to increase from Galicia to Cantabrico. In 1995, concentrations were low; 0.05 µg/kg ww in Vigo and 0.37 µg/kg ww in Santander-Pantalan. In Punta Insua, Muxia and Corme concentrations were below the detection limit.

As consequence of the 1972 ban on DDT as a pesticide in agriculture, concentrations in molluscs along the French coast had decreased significantly by the middle of the 1980s. During 1979–93 the total DDT concentration in oysters from the Bay of Arcachon, an area which had been particularly contaminated, had decreased by a factor of 900 *(Figure 4.15)*. As a general trend, concentrations are higher to the south of the River Loire than to the north. On the northern Spanish coast DDT concentrations in 1995 were 0.22 – 0.35 µg/kg ww, with the lowest values in Oia and Vivero and the maximum value in A Coruña Bay (0.61 µg/kg). Degradation products were around 0.1 – 2.09 µg/kg for DDE and 0.11 – 1.18 µg/kg for DDD.

Assessment

Monitoring programmes indicate low levels of lindane and DDT and its degradation products within the coastal environment. However, despite DDT concentrations being below the EAC, significant regional variations in concentration are apparent, with many areas having considerably higher concentrations than in the past.

4.5 Multiple chemical inputs

There is no information on multiple chemical inputs to Region IV.

Table 4.22 Spatial variability in PAH concentrations in sediments (µg/kg dw) from the area around Vigo. Source: IEO.

		Benzo[a]pyrene		ΣPAH_6		ΣPAH_{13}	
	No. samples	median	min - max	median	min – max	median	min – max
Harbours	18	306	34 – 979	1956	271 – 6576	3693	505 – 13 949
Estuary	23	95	4.0 – 250	652	35 – 1713	1196	65 – 3 248
Coastal	5	5.1	3.6 – 7.7	43	32 – 63	81	59 – 121
Offshore	3	1.4	1.3 – 1.6	14	15 – 26	28	27 – 30

ΣPAH_6 fluoranthene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, benzo[*ghi*]perylene, indeno(1,2,3-*cd*)pyrene. ΣPAH_{13} ΣPAH_6 + phenanthrene, anthracene, pyrene, chrysene, benz[*a*]anthracene, benzo[*e*]pyrene, dibenzo[*ah*]anthracene.

4.6 Oil

Inputs

The transport and use of petroleum and petroleum products are the main sources of hydrocarbon inputs to Region IV.

Concentrations in sea water

Concentration data for non-polar hydrocarbons are available for surface waters in various Portuguese estuaries. Concentrations in the Ria Aveiro show little variability between 1992 and 1996 and were generally around the detection limit, i.e. < 0.05 mg/l. In the estuaries of the Tagus and Sado rivers, concentrations were also generally below the detection limit, except for sites affected by anthropogenic activities, where concentrations were higher. Within the Ria Formosa concentrations rarely exceeded the detection limit.

Concentrations in sediments

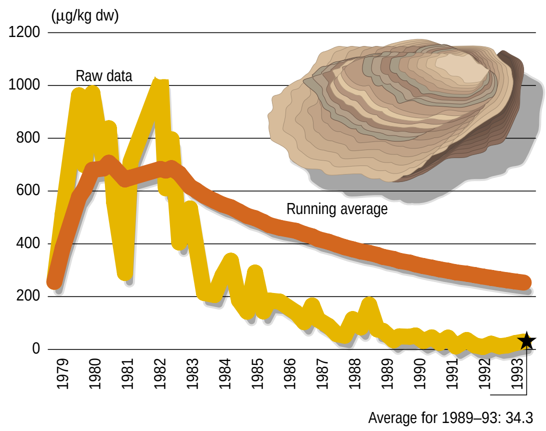
Concentrations in sediments from the Ria Aveiro during 1992 to 1996 were variable, with the highest concentrations occurring at sites affected by industrial activities or urban effluents. Similarly, in the estuary of the River Tagus, higher concentrations occurred at sites close to urban effluent discharges, while upstream the concentrations were considerably lower. Hydrocarbon concentrations in sediments of the Ria Formosa between 1992 and 1996 appeared to vary randomly, but with higher concentrations observed near a landing site.

4.7 Radionuclides

Inputs

The Spanish nuclear facilities discharging liquid radioactive effluents to rivers flowing into Region IV include four power reactors and a fuel fabrication plant. The total annual discharges for the period 1991–4 were 5'11E11 – 7'06E13 Bq for tritium activity and 2'46E08 – 1'76E10 Bq for the remaining. Total discharges of α-emitters varied from 2'36E07 to 4'447E07 Bq. Tritium emissions ranged from below the detection limit to 6'97E12 Bq.

Figure 4.15 **$\sum$DDT concentrations in oysters from Arcachon Bay, 1979–93. Source: RNO.**



Concentrations in biota

Radioactivity in biota within the Bay of Biscay is primarily due to natural ^{40}K. However, ^{228,230,232}Th and U concentrations have been found in molluscs from the Bay of La Rochelle near industrial inputs and some locally restricted concentrations of Ra and U have been detected in the Bay of Piriac (to the north of the River Loire). Concentrations of artificial radionuclides in biota from the Bay of Biscay were below the detection limits for ^{60}Co, ^{90}Sr, ^{106}Ru and ^{137}Cs.

4.8 Nutrients and Oxygen

4.8.1 Nutrients

Nutrients comprise a series of elements in their mineral forms, which occur in solution and are essential for the growth of aquatic life. Agriculture is the main source of nutrients in rivers which discharge to the Bay of Biscay. Another source is urban sewage which is discharged to rivers after treatment. In terms of cities with $>$ 10 000 inhabitants, the overall contribution to the nitrogen and phosphorus inputs is equivalent to 4.6 million inhabitants in the Adour-Garonne area and 7.9 million inhabitants in the Atlantic section of the Loire-Bretagne area. About 70% of this urban sewage is collected, and then subject to average removal rates for nitrogen and phosphorus at treatment plants of 44% and 32% respectively in the Adour-Garonne area and 46% and 54% respectively in the Loire-Bretagne area.

Inputs

The total discharges of nitrates and phosphates from the River Tagus in 1992–5 were 416 – 4771 t N/yr for nitrates and 235 – 1100 t P/yr for phosphates. These values have been estimated by default, partly because there is no information on contributions of fluvial origin, but also because there are still no reliable estimates for industrial effluent discharges. These data indicate considerable variability from year to year.

Nutrient fluxes for the Brittany coast (which extends from the Pointe du Raz to the Vilaine Estuary) have been computed using 1985–91 data (AELB-SEE, 1992). A slight positive trend was observed in nitrate concentrations, with concentrations $>$ 50 mg/l present in 3% of observations in 1990 and 6% of observations in 1994. Steady state conditions were observed for phosphate. Ammonia concentrations in rivers discharging to the Bay of Biscay are generally decreasing, while nitrate concentrations are slightly increasing. This was observed by two French water agencies (AEAG-DIREN, 1997). The riverine nitrogen flux is linked to river flow and increases during rainy years. For example, the mean annual nitrate flux from the Loire river doubled during 1988 which was a rainy year (APEEL, 1996).

Direct inputs represent a very small component of the riverine inputs, both in terms of nitrogen and phosphorus, and so potential impacts associated with these inputs are relatively localised. The Loire and Gironde account for 70 – 80% of nitrogen and phosphorus inputs along the French Atlantic coast *(Table 4.23)*. The phosphorus input from the Gironde is larger than from the Loire due to twice the amount of SPM in the Gironde relative to the Loire.

Because of the large tidal range on the French Atlantic coast (up to 7 m), the estuaries are very turbid; the mean concentration of SPM is rarely $<$ 100 mg/l and often $>$ 1 g/l (APEEL, 1996). So, despite high nutrient concentrations, primary production tends to be relatively insignificant within the estuaries, tending to occur in the more saline, but less turbid, coastal waters.

The continental shelf off north and north-western Spain is a dispersive area with strong hydrodynamics. The mesoscale distribution and the temporal variability in the biological productivity of the area is associated with upwelling. The nutrient distribution patterns reflect these oceanographic characteristics. However, the situation is different in the estuaries where higher nutrient concentrations occur.

Nutrient concentrations on the Portuguese coast from 1992–7, reflect the locations of the sample sites, with sites close to areas affected by industrial and urban effluents having significantly higher concentrations. Nitrate and nitrite concentrations have decreased over recent years, although abnormally high concentrations occurred in 1994. No significant trends in phosphate, silicate or ammonia were observed over 1992–7, and the concentration data were relatively variable. As a generalisation nutrient concentrations in surface waters increased, although lower concentrations occurred in the deeper, more saline water.

The oceanographic characteristics of the Gulf of Cadiz are determined by the exchange of water between the Mediterranean and the Atlantic, nevertheless concentrations of 1 mg at of P-PO_4/l can be found in the Gulf of Cádiz and levels of up to 100 mg at of P-PO_4/l in the Ría of Huelva.

4.8.2 Oxygen

Dissolved oxygen in aquatic systems is essential for marine life. The concentration of dissolved oxygen, also known as the oxygen saturation, depends on physical factors (such as air-sea exchanges at the water surface), chemical factors and biological factors (such as microbial respiration and oxidation). It is generally the biological processes which are of most significance in terms of levels of oxygen saturation.

Concentrations in sea water

Apart from one period of exceptional anoxia in the Bay of Vilaine in 1982, anoxic conditions have not been observed in French coastal waters. Low oxygen concentrations occur in the large estuaries, in the zone of maximum turbidity, when river flow is low (i.e. July – October). The oxygen depletion is due to nitrification and oxidation of the SPM. As oxygen concentrations are related to the resuspension mechanism, they are a function of tidal

Table 4.23 Annual nitrogen and phosphorus fluxes along the French Atlantic coast.

		Nitrogen flux (t/yr)				Phosphorus flux (t/yr)		
	Basin area	riverine	riverine	urban to sea	industrial to sea	riverine	urban to sea	industrial to sea
	(km² x 10³)	(NO_3-N)	(TKN)	(total-N)	(total-N)	(total-P)	(total-P)	(total-P)
Southern Brittany	6	16 500	ni	230	-	900	130	-
Vilaine	11	14 500	ni	-	-	800	-	-
Loire	118	100 000	33 000	1 100	220	9 000	180	-
Vendée coast	8	6 000	ni	280	3 700	600	70	26
Charente	10	24 000*	ni	30	-	1 400*	20	-
Gironde†	85	70 000	35 000‡	520	-	12 000	130	-
Landes coast	4	3 000*	300*	1 000	-	100*	160	-
Adour	17	15 000*	ni	200	-	2 000*	110	-
TOTAL		250 000	90 000§	3 400	4 000	27 000	800	26
(incl. urban part)		(50 000)				(13 000)		

* approximate data based on concentration ranges for water quality and population density within the catchment area (after AEAG-DIREN, 1997); † Garonne plus Dordogne rivers; ‡ range 30 – 45 x 10³ t/yr from various sources (AEAG, 1994); § based on 30% of TKN relative to nitrate for missing data; ¶ according to average sewage treatment data within the watershed (RNDE, 1996); ni no information.

amplitude; in the Loire Estuary the water column can become almost anoxic (APEEL, 1996), whereas in the Gironde Estuary 30% saturation appears to be the minimum level likely. Recent data support these values.

Significant decreases in oxygen concentration along the Iberian Peninsula only occur in very restricted areas which receive large inputs of organic matter. Areas with oxygen concentrations of < 2 mg/l occur in the Nervion Estuary at intermediate salinities and, in summer, low oxygen concentrations (i.e. < 4 mg/l) occur in salt marshes within the Cantabrian rias Mundaka and Ribadeo. Within the Galician rias, hypoxia only occurs within the water in direct contact with the sediment surrounding mussel rafts (Garcia and Iglesias, 1982). The pelagic system is always well oxygenated.

With regard to the Portuguese coast, the average annual concentrations of dissolved oxygen within the Ria Aveiro showed little variability in the 1992–7 period. At the sites considered, percentage saturation was > 80% in 1992 and 1993, where saturation values of < 75% due to industrial effluents had previously been observed. In the Tagus and Sado estuaries, dissolved oxygen concentrations were normal for 1992–7 except at a few sites where concentrations were lower, probably associated with the effects of industrial discharges or with the low rainfall in 1994 and 1995. Dissolved oxygen concentrations in the Ria Formosa were generally lower than in the estuaries of coastal Portugal. This could result from higher water temperatures throughout the year, together with less turbulence and thus less reoxygenation at the water surface. There has been a gradual decrease in the average annual concentrations of dissolved oxygen along the Portuguese coast in recent years, particularly since 1994.

chapter 5

Biology

5.1 Introduction

Within the context of the general ecosystem structure, which results from the major climatic, topographical and evolutionary characteristics of the oceans and continental land masses, biogeographic areas and subareas with common biotic and abiotic features can be defined according to the patterns of the composite flora and fauna. For example, on the European continental margin of the Atlantic Ocean, there is a sharp north to south temperature gradient, which restricts the distribution of many species and leads to a biogeographic subdivision of the eastern Atlantic into two provinces: the boreal Atlantic province and the subtropical Lusitanian province *(Figure 5.1)*.

Region IV corresponds to the Lusitanian province, which extends from the western coasts of the Iberian Peninsula to Brittany. Owing to major differences in the climatic characteristics and communities of animal and plant species, the Lusitanian province has been subdivided into the subtropical subprovince (Strait of Gibraltar to Finisterre) and the subtropical/boreal transition subprovince (Finisterre to Brittany).

Within the subtropical area, the coastline open to the ocean (Finisterre to Cape San Vicente) can be distinguished from the subregion of the Gulf of Cádiz, which represents an area of transition between the Mediterranean Sea and the Atlantic Ocean.

In the subtropical/boreal transition subprovince the fauna are mixed, with groups of boreal and subtropical origin. This area may also be subdivided into the eastern subregion, which exhibits the oceanographic characteristics of the Bay of Biscay, and the Atlantic-influenced subregion (Cape Finisterre to Cape Estaca de Bares and then to the south of Brittany). The characteristic fauna and flora of the latter result in part from the position occupied by the Iberian Peninsula at the beginning of the Tertiary Period, i.e. folded in towards France, with the Bay of Biscay practically closed, in such a way that Galicia and Brittany were very close together.

In addition to biogeographical affinities, the communities in a given area reflect the nature of substrate. In this respect Region IV is highly diverse, having many different types of coastal habitat, such as rocky cliffs, shingle, rocky shores, sandy and muddy shores, coastal lagoons and estuaries.

5.2 Overview of the ecosystem

5.2.1 Bacteria

The abundance of benthic bacteria reflects the concentration of organic matter in the sediments. On the Galician shelf the highest numbers occur in regions close to areas with high population densities and with high levels of organic matter in the sediments. In continental shelf sediments from Cape Finisterre to the River Minho, bacterial abundance increases southwards along the Galician coast with the highest numbers occurring in sediments off the Rías Bajas, mainly off the Ría of Vigo (2 – 32 x 10^8 cells/g dw). The number of bacteria decreases offshore where less organic matter is present in the sediment.

The abundance of pelagic bacteria varies in relation to river inputs, site, depth and seasonality. Vertical profiles of heterobacteria and cyanobacteria on the continental shelf of the Cantabrian Sea during periods of upwelling, show that cyanobacterial abundance is associated with the chlorophyll maximum. In Santander Bay, the annual abundance of pelagic bacteria varies between 7.3 and 24.6 x 10^8 cells/l, with cyanobacteria ranging from 1.2 to 46 x 10^6 cells/l and autotrophic nanoflagellates from 3.8 to 19.7 10^6 cells/l.

In the Ría of Arosa with its intensive mussel culture, the annual numbers of planktonic bacteria vary between 4.5 and 20.8 x 10^8 cells/l. These numbers are a consequence of the organic matter released from mussel rafts. After an upwelling event, abundance varies over depth and time, ranging from 2.5 to 12 x 10^8 cells/l. In the neighbouring Ría of Vigo (which has a high population density), abundance ranges from 5.3 to 35.2 x 10^8 cells/l, with cyanobacteria ranging between 0.4 and 102.1 x 10^6 cells/l, autotrophic nanoflagellates between 0.5 and 15.2 x 10^6 cells/l and heterotrophic nanoflagellates between 0.8 and 2.6 x 10^6 cells/l.

5.2.2 Phytoplankton

At least 1000 species of phytoplankton have been identified in Region IV ***(Table 5.1)***. For most of the year diatoms dominate the phytoplankton community, particularly during periods of upwelling, while coccolithophorids dominate during winter. Small dinoflagellates dominate warmer stratified waters offshore. In the northern and eastern waters of the Bay of Biscay, the influence of upwelling events is weaker and a predominance of dinoflagellates is likely in summer. In the coastal area between the Loire and Gironde estuaries, *Rhizosolenia*

Table 5.1 Numbers and types of phytoplankton identified in Region IV.

	No. species
Bacillariophyceae (diatoms)	533
Dinophyceae (dinoflagellates)	315
Prymnesiophyceae (coccolithophorids)	86
Raphidophyceae	3
Euglenophyceae	9
Chlorophyceae	27
Prasinophyceae	15
Crysophyceae	4
Dictyochophyceae	9
Cryptophyceae	10
Cyanophyceae	6
Ebriideae	1

Figure 5.1 **Biogeographical subdivisions of Region IV.**

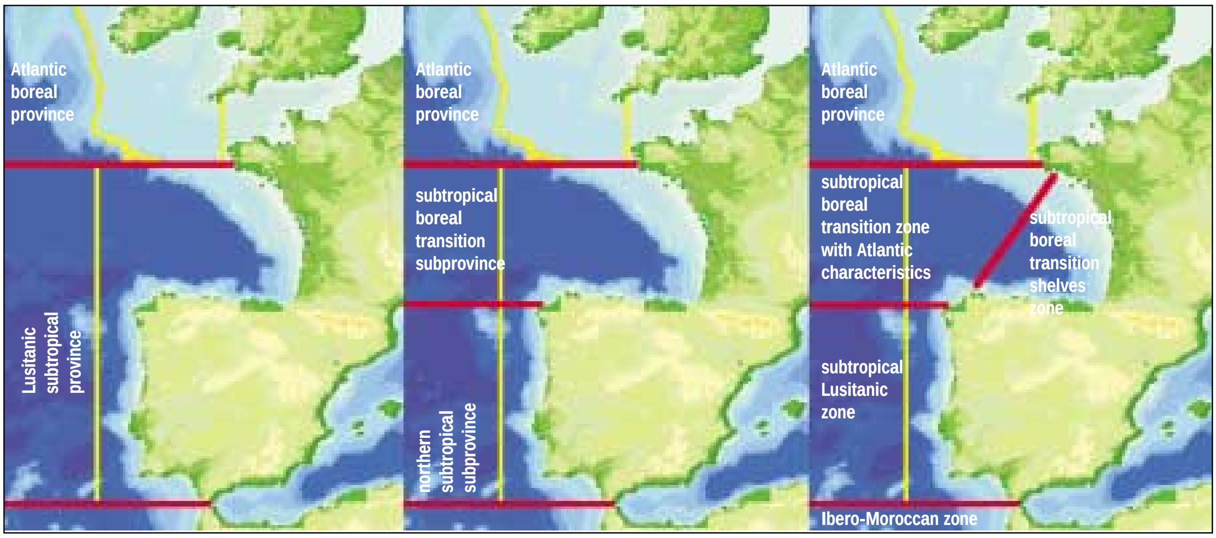


Table 5.2 Dominant phytoplankton species at a coastal site near A Coruña on the Galician coast.

Stage	Species	Comments
Blooms	*Chaetoceros socialis* *Lauderia borealis* *Thalassiosira fallax* *Schroederella delicatula* *Chaetoceros dydimus* *Rhizosolenia setigera*	Microflagellates, chain-forming and large diatoms
Stratification	*Leptocylindrus danicus* *Chaetoceros affinis* *Dinophysis acuminata* *Dinophysis acuta* *Rhizosolenia delicatula* *Gyrodinium spirale* *Protoperidinium bipes*	Microflagellates, small and large diatoms and dinoflagellates
Summer upwelling	*Chaetoceros socialis* *Rhizosolenia fragilissima* *Pseudo-nitzschia* spp.	Small chain-forming diatoms
Winter mixing	*Skeletonema costatum* *Nitzschia longissima* *Pseudo-nitzschia* spp. *Distephanus speculum* *Solenicola setigera* *Gyrodinium glaucum* *Gyrodinium spirale* *Paralia sulcata*	Perennial species, small diatoms, dinoflagellates and microflagellates Resuspended phytobenthos

and *Skeletonema* are ecological dominants in spring; *Navicula* in spring, summer and autumn; *Coscinodiscus* and *Leptocylindrus* in summer, autumn and winter; *Fragilaria* in winter and *Melosira* and *Paralia* throughout the year. The dominant phytoplankton species occurring in the Galician area during the main oceanographic stages are listed in *Table 5.2*. Species composition is similar in the Cantabrian Sea, even though the importance of dinoflagellates increases during summer, especially in the eastern Bay of Biscay.

The annual phytoplankton cycle in Region IV shows the pattern typical for a temperate sea characterised by a winter mixing period followed by a stratification phase during summer. Phytoplankton blooms during the transition periods (i.e. in spring and autumn) are characterised by an almost absolute dominance of diatoms. During summer stratification, nutrient concentrations drop and phytoplankton biomass decreases to low levels. In winter, mixing and low light levels prevent phytoplankton growth despite high nutrient concentrations. Phytoplankton biomass within Spanish coastal waters under various oceanographic conditions is given in *Table 5.3*.

Rivers discharge large volumes of freshwater into the sea forming river plumes. The continuous input of nutrients from the run-off of large rivers (such as the Loire, Gironde, Minho, Tejo and Douro) enhances and maintains ‘new’ primary production. Owing to the haline stratification which maintains phytoplankton cells in a very thin layer of water, phytoplankton production can start very early in the less turbid part of the plumes. These winter blooms are relatively short-lived however, as they soon become phosphorous-limited. Lower river run-off and a much narrower continental shelf off the northern Iberian Peninsula together make buoyant plumes much less persistent along the Cantabrian coast. In Portugal, seasonal differences in river discharge can give rise to both river plumes and to lenses of lower salinity. These lenses are particularly rich in phytoplankton and are characterised by the near absence of coccolithophorid species during summer between the Minho and Douro rivers.

Filaments and fronts associated with high salinity water of subtropical origin (Eastern North Atlantic Water,

Table 5.3 Mean (± 1 standard deviation) of chlorophyll concentrations for the main oceanographic stages within Spanish estuaries, rías and coastal waters.

	Bloom	Stratification	Upwelling	Winter
Estuaries and rias on the Spanish coast*				
Zarauz-Fuenterrabía	2.51 ± 1.85	0.89 ± 0.54	-	0.50 ± 0.27
Deva-Zumaya	1.85 ± 0.97	0.23 ± 0.12	-	0.48 ± 0.23
Ría of Ferrol	3.83 ± 1.11	-	3.03 ± 0.59	0.52 ± 0.12
Ría of Ares-Betanzos	3.30 ± 1.20	1.75 ± 0.75	2.05 ± 0.85	0.42 ± 0.09
Ría of A Coruña	2.51 ± 1.55	1.70 ± 0.71	2.15 ± 0.15	0.68 ± 0.30
Ría of Corme-Laxe	2.23 ± 1.12	1.03 ± 0.15	1.66 ± 0.20	0.32 ± 0.15
Ría of Camariñas	1.20 ± 0.05	0.50 ± 0.05	-	-
Ría of Muros-Noya	2.83 ± 0.54	1.71 ± 0.72	1.71 ± 0.72	0.35 ± 0.05
Ría of Arousa	2.85 ± 0.89	1.57 ± 0.85	4.52 ± 1.56	0.52 ± 0.29
Ría of Pontevedra	2.01 ± 0.70	1.05 ± 0.61	2.65 ± 1.31	0.38 ± 0.02
Ría of Vigo	2.70 ± 0.72	1.74 ± 0.84	2.60 ± 0.81	0.35 ± 0.04
Ria of Huelva	3.41 ± 3.35	2.01 ± 1.62	-	2.72 ± 2.15
Continental shelf close to the Galician and Asturian coast†				
Asturias	49.33 ± 19.29	25.33 ± 10.85	40.72 ± 14.32	15.64 ± 7.52
Rias Altas	67.68 ± 49.49	37.55 ± 24.44	57.84 ± 41.86	15.64 ± 3.80
Rias Bajas	32.84 ± 10.50	35.53 ± 20.45	87.11 ± 34.04	–
coastal	43.13 ± 21.23	33.21 ± 21.26	62.36 ± 36.40	15.33 ± 8.79
mid-shelf	82.70 ± 52.23	32.25 ± 19.39	65.09 ± 55.29	15.17 ± 4.19
outer-shelf	37.35 ± 12.33	28.66 ± 16.04	60.76 ± 19.30	18.03 ± 6.10

* mg Chla/m^2; † mg Chla/m^2, integrated over the euphotic zone (25 – 40 m); – no information.

also known as the ‘Navidad’ Current) are important along the Iberian margin. During winter and spring, the Navidad Current results in a convergent front at the boundary between coastal and oceanic water. When saline intrusion is weak, the development of fronts and the formation of a seasonal thermocline is enhanced, leading to phytoplankton blooms. When saline intrusion is intense, strong vertical mixing occurs and prevents phytoplankton growth in spring. Along the Portuguese coast coccolithophorids act as tracers for this current.

Upwelling of North Atlantic Central Water and even Eastern North Atlantic Water is a common feature along the Portuguese and Galician coasts and in the western Cantabrian Sea, especially in summer. Upwelling affects the thermal stratification/mixing cycle and may have important consequences for phytoplankton growth. Upwelling pulses during the summer prevent the formation of a permanent and deep surface layer, thus enhancing phytoplankton growth. Under conditions of moderate upwelling, the inner 25 km of coastal water are about ten times more productive than offshore waters, and upwelling centres approximately twenty times more productive. Along the Landes coast, mainly in summer, weak upwelling events are induced by northerly winds. Their effects on plankton production are unknown.

Toxic dinoflagellates and diatoms are regular components of the marine phytoplankton community and can render shellfish toxic at concentrations as low as 10^2 – 10^3 cells/l, well below those causing water coloration (i.e. > 10^6 cells/l). Their maximum concentrations exhibit interannual variations determined mainly by changes in the upwelling regime, river run-off, inoculum size and other environmental parameters. Cape Finisterre constitutes a biogeographic boundary for the proliferation of toxic species, such as *Gymnodinium catenatum, Dinophysis acuta* and *D. acuminata*. Different toxic outbreaks are delimited in time and space according to the species-specific niche requirements of the causative agents. *Table 5.4* lists the phytoplankton species that have been associated with toxic outbreaks on the Galician and Portuguese coast and their associated toxins.

5.2.3 Zooplankton

The zooplankton community of Region IV is very rich in terms of taxonomic groups and species. The main holoplanktonic and meroplanktonic groups and their relative abundance are shown in *Figure 5.2*. Copepods are the most important group in terms of species richness, persistence, abundance and ecological significance. At least 268 species of pelagic copepod have been recorded in Region IV since 1967. Nevertheless, despite this diversity only seven species of copepod characterise the region, accounting for 90% of the total abundance *(Figure 5.2)*.

Table 5.4 Species associated with shellfish toxicity on the Galician and Portuguese coasts.

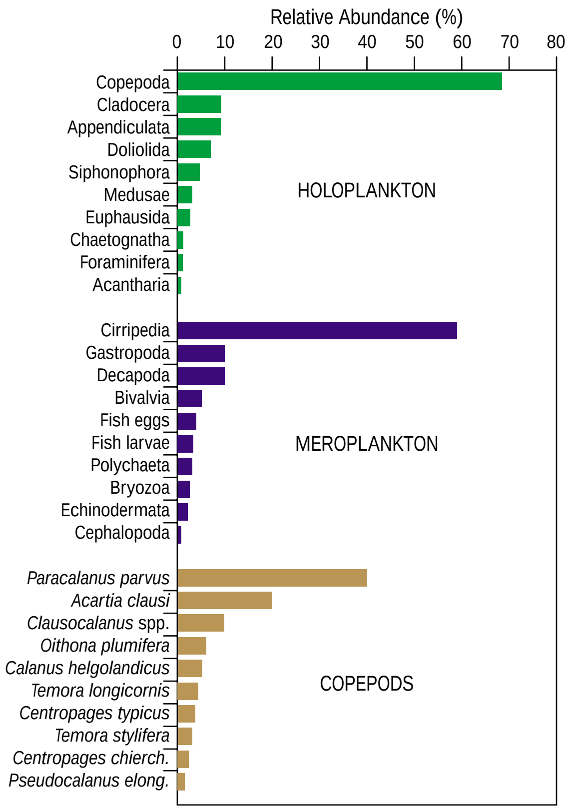
	Rías Altas	Rías Bajas	Portuguese coast
Paralytic Shellfish Poisoning			
Gymnodinium catenatum	-	+	+
Alexandrium minutum (=lusitanicum)	+	+	+
Diarrhetic Shellfish Poisoning			
Dinophysis sacculus	+	-	-
D. acuminata complex	+	+	+
D. acuta	-	+	+
D. caudata + *D. tripos*	+	+	+
Amnesic Shellfish Poisoning			
Pseudo-nitzschia australis	-	+	+

Toxicity was determined using High Performance Liquid Chromatography on monoalgal cultures or single cell isolation (except for *D. sacculus* and *D. tripos*).

+ toxicity occurred in shellfish when this species was present; - species present in very low numbers and below the threshold required to render shellfish toxic.

Nyctiphanes cochii and *Meganyctiphanes norvegica* are the most abundant euphausiids. Seven of the nine species of marine cladoceran are found in Region IV (*Podon intermedius, P. polyphemoides, P. leuckarti, Evadne nordmanni, E. spinifera, Pseudevadne tergestina* and *Penilia avirostris*). At least eight species of chaetognath have been recorded; *Sagitta decipiens, S. lyra* and *S. friderici* being the most abundant. The Appendicularia *Oikopleura dioica* and *Fritilaria pellucida* are also very common in coastal and neritic areas of Region IV.

Figure 5.2 **The relative abundance of the ten major groups and species of holoplankton, meroplankton and copepods.**



Copepods are present throughout the year, whereas other holoplankton and meroplankton groups have a marked seasonal distribution; cladocerans are abundant in late spring and summer, and chaetognaths are mainly present in summer. Fish larvae and meroplankton are abundant during the spawning and breeding seasons of the species concerned.

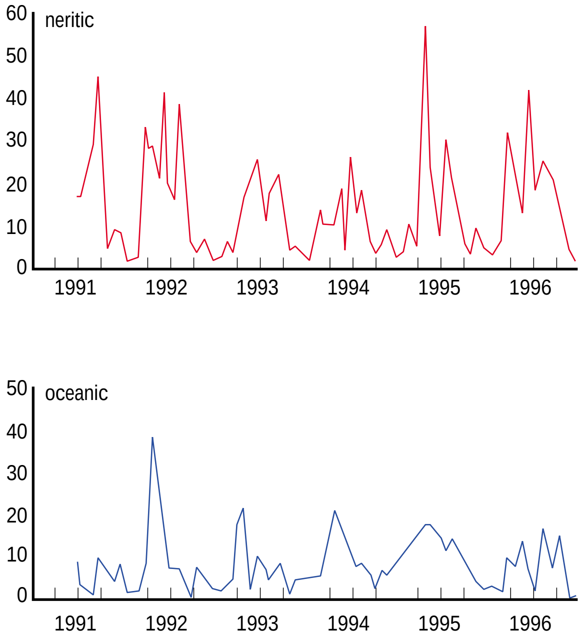
Zooplankton composition, abundance and distribution is highly variable spatially, varying across the shelf with respect to latitude and coastal topography. For example, in terms of variations with latitude 95 species of copepod have been identified in the southern Bay of Biscay (accounting for 71.9% of the total zooplankton abundance), 85 species in Galician waters (62.9% of abundance), 89 species in northern Portuguese waters (63% of abundance), 144 species in southern Portuguese waters (30% of abundance) and 174 species in the Gulf of Cádiz.

Topography and cross-shelf gradient are major causes of variability. Some species such as *Acartia discaudata* and *Podon polyphemoides* are restricted to enclosed areas, such as the Rías Bajas and the Ría of A Coruña, while others are indicative of oceanic water (e.g. *Rhincalanus nasutus* and *Sagitta lyra*). Cross-shelf gradients in species composition and abundance are enhanced by the presence of meroplanktonic species in shallow waters. A gradient in meroplankton species occurs in the southern Bay of Biscay, with relative abundances of 15%, 9% and 2.5% in coastal, neritic and oceanic waters respectively. An inverse pattern is observed for copepods, with relative abundances of 70%, 90% and 92% respectively. On the western Iberian coast in areas subject to seasonal upwelling events, zooplankton are more abundant over the mid-continental shelf.

There are two peaks in the annual cycle of zooplankton abundance and biomass in Region IV. These occur in spring and autumn and correspond to, although lag behind, pulses of phytoplankton production. In coastal zones, the seasonal variation in mesozooplankton abundance ranges from a maximum of around 3000 ind/m^3 in spring to around 250 ind/m^3 in winter. In the oceanic sector of Region IV the annual cycle of zooplankton abundance and biomass is typical of oligotrophic areas, with only slight variations throughout the year and a single period, generally in April, when communities reach their annual peak *(Figure 5.3)*.

Superimposed upon this general scheme are features associated with the spatial topography and hydrodynamics of the region. The main deviations from the general scheme occur in estuaries and shallow coastal areas, where tidal action and winds force water column mixing. Nutrient inputs to such areas are almost constant and both phytoplankton and zooplankton are likely to be abundant, with several pulses of production throughout the year. In the neritic region of the Cantabrian, Galician and Portuguese coast upwelling is particularly important; this occurs episodically between May and September and results in favourable conditions for zooplankton during summer, which is the opposite of what generally happens in temperate seas.

Figure 5.3 **Zooplankton biomass (dry weight, mg/m^3) at neritic and oceanic sampling stations off Santander, 1991–6. Source: after Valdés and Moral (1998).**



to the south in cold water areas (i.e. the Galician coast and to the north of the River Douro in Portugal).

The Cantabrian area mainly comprises rocky shores and the algal communities show great similarity to those of the Mediterranean. A distinctive characteristic is the scarcity of Laminariales (which are totally absent from the Basque Country) and the abundance of Rhodophyceae, some of which (e.g. *Gelidium sesquipedale*) form large stands 5 – 15 m deep, and which have been subject to industrial exploitation since the 1950s *(Figure 5.4)*. The rocky littoral zone of the Basque Country is characterised by communities of a caespitose habit. The Cantabrian–Asturian area is one of transition towards more northern communities and stands of *Laminaria ochroleuca* and *Sargassum polyschides* appear more often. The infralittoral zone is dominated by *G. sesquipedale*.

The Atlantic area from Cape Peñas to the River Minho is characterised by estuaries and rías, and is the most diverse, rich and complex of the habitats along the Iberian Peninsula. Western Asturias and northern Galicia have a mixture of southern and northern species and are characterised by an abundance of Fucales and other brown algae. In the infralittoral zone, *G. sesquipedale* populations are substituted towards the west by others, such as *Laminaria hyperborea* which forms dense stands. From

5.2.4 Benthos

Macrophytobenthos

Marine plants include algae and some flowering plants. Algae live on rocky substrates extending from the coastline to depths of up to 20 – 30 m. The Atlantic coast of Region IV shows a zonal distribution changing from localised northern species in French coastal waters and along the west coast of Galicia, to southern forms extending eastwards (Bay of Biscay) and southwards (Portuguese coast and the Gulf of Cádiz).

The morphology of the coastal environment is very heterogeneous in terms of habitats and mesoscale processes. Consequently, algal biodiversity is high, with the overlapping of different species and the presence of island-like zones. Species characteristic of northern regions, such as *Laminaria* and *Saccorhiza*, advance and retreat together with a group of species in a general trend in which large populations of brown algae decrease from north to south.

Southern Brittany is the southernmost distribution limit for northern populations *(Table 5.5)*. Some species, which disappear to the south of the River Loire, reappear

Table 5.5 Main seaweed species in Region IV.

	Species	Comments
Southern Brittany	*Laminaria digitata, Alaria esculenta, Phycodrys rubens, L. saccharina, Himanthalia elongata, Palmaria palmata.*	Southern limit of cold water populations
Cantabrian zone		
Basque country	*Caulacanthus ustulatus, Corallina elongata, Gelidium latifolium.*	Rocky littoral with communities of a caespitose habit
	Stypocaulon, Cladostephus, Dictyota.	Protected and sandy areas
	Cystoseira, Sargassum flavifolium.	Infralittoral
eastern Cantabria – Asturias	*L. ochroleuca, S. polyschides.*	Transition towards more northern communities
	G. sesquipedale, Cystoseira baccata, Halidris siliquosa, Laminaria spp.	Infralittoral
Atlantic zone		
western Asturias – northern	*Fucus serratus, Chondrus crispus* (var. *filiformis).*	Mixture of southern and northern species
Galicia	*G. sesquipedale, Cy. baccata*	Infralittoral. Substituted towards the west by others (e.g. *L. hyperborea*)
Cape Ortegal – River Minho	*L. saccharina, S. polyschides, H. elongata, Ascophyllum nodosum.*	Settlement of northern species favoured by seasonal upwelling of cold water
	S. muticum, Undaria pinnatifida.	Non-indigenous species in the inner part of the Rias Bajas
Portugal	*L. saccharina, L. hyperborea, F. serratus, Pelvetia canaliculata, A. nodosum, H. elongata, Ch. crispus, P. palmata, Ceramium shuttleworthianum.*	Most southern European distribution in Portugal
	Cy. barbata, Zonaria tournefortii, Amphiroa beauvoisii, Griffithsia opuntioides, Ulva linearis, Valonia utricularis.	Meridional and Mediterranean species with their northern limit in Portugal
Gulf of Cadiz	*Ca. ustulatus, Gelidium spathulatum, G. microdon, Chondracanthus acicularis, Ce. ciliatum, Co. elongata.*	Abundant caespitose plurispecific communities
	Phyllophora heredia, G. sesquipedale, Caliblepharis ciliata.	Infralittoral
	Cy. tamariscifolia, Cy. baccata, S. flavifolium.	Laminarians very scarce
	F. spiralis limitaneus, F. vesiculosus.	Fucales representative of large estuaries
	Sphacelariaceae, Dictyotaceae, *Halopitys incurvus, Cryptonemia lomation.*	Protected sandy areas

Cape Ortegal to the River Minho, cold water from the seasonal upwelling events favours the settlement of northern species. Fucales are particularly abundant in the inner part of Rías Bajas which supports intensive mussel and oyster cultivation and facilitates the proliferation of blooms of other algae (e.g. Ulvales). Nevertheless, this appears to be a local imbalance, rather than a significant alteration in community structure.

The Portuguese coast is orientated north to south and algal species can be grouped in two assemblages; northern species tend to occur between the rivers Minho and Tejo, while more southern species are found to the south of the River Tejo. More than 40 species have their southernmost European distribution in Portuguese coastal

Figure 5.4 ***Gelidium sesquipedale*** **is an important natural resource for the local economy of northern Spain.**

waters, and the northern limits of more than twenty southern and Mediterranean species occur primarily along the Algarve coast.

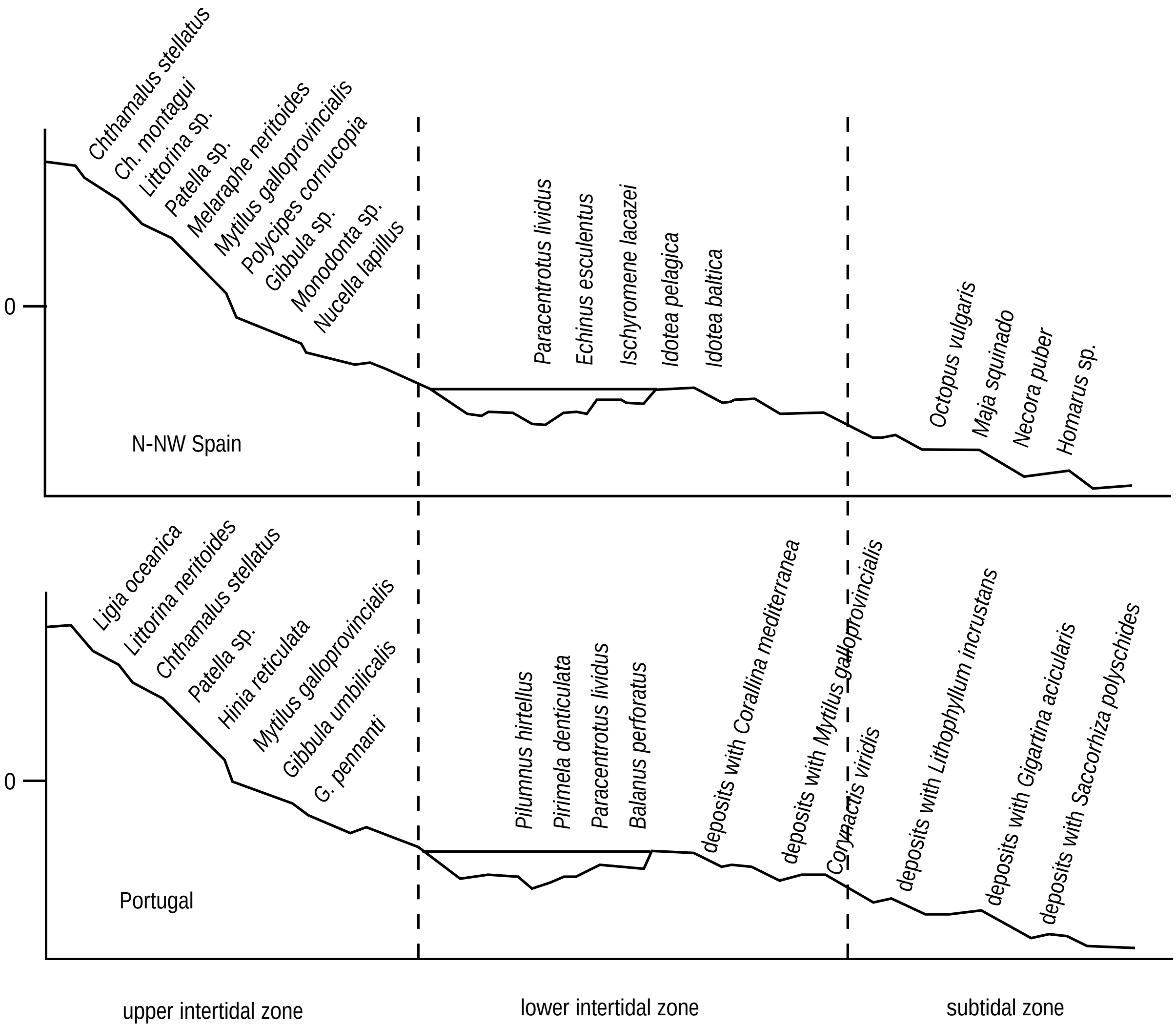
Algae in the Gulf of Cádiz are very similar to those of the Basque country. Caespitose plurispecific communities occur in the littoral zone, Laminarians are very scarce, and the Fucales are represented by *Fucus spiralis limitaneus* and forms of *F. vesiculosus* in the large estuaries *(Table 5.5)*.

Macrofauna on hard substrates

Intertidal and shallow subtidal macrofauna (> 1 mm in size) communities follow the ecological zonation described for European shores. Upper intertidal zones are dominated by sessile and slow-moving macrofauna while deeper zones are dominated by mobile macrofauna.

Hard substrates are the dominant habitat in shallow northern and north-western Spanish waters. The upper intertidal zone is characterised by a mixed community comprising barnacles, limpets, littorinids and topshells *(Figure 5.5)*. The dogwhelk is common in the north-west, scarce in central regions and almost absent from the east. Mussels occur in patches in the Bay of Biscay but are more frequent to the north-west. Natural oyster beds are restricted to rocky outcrops inside rías and estuaries. The stalked barnacle, *Pollicipes cornucopia*, lives in very exposed locations. Lower intertidal and subtidal environments are dominated by dense stands of macroalgae interspersed with barren areas dominated by sea urchins (*Paracentrotus lividus* and *Echinus esculentus*). *Paracentrotus lividus* populations are intensively exploited and populations are now restricted to tide pools and comprise small-sized individuals. There is a diverse faunal community associated with intertidal and subtidal macroalgal stands, comprising prosobranchs, amphipods and isopods. Herbivores are the dominant trophic group. Southern species (e.g. *Idotea pelagica*) are more

Figure 5.5 **The main macrofaunal species on the rocky shores along the north and north-western coasts of Spain and Portugal.**



abundant to the east while northern species (e.g. *Idotea baltica*) are more abundant to the west. The large macrofauna comprise octopuses, crabs and lobsters and these are all intensively exploited.

On the Portuguese coast the upper intertidal fringe is characterised by the same groups as along the coast of north to north-west Spain, but with some northern species being replaced by southern species *(Figure 5.5)*. Abundance varies according to the rate of exposure to desiccation and to wave action. Polychaetes, crabs and the cirriped *Balanus perforatus* are present in the lower intertidal area and the sea urchin *Paracentrotus lividus* occurs in small pools. In more exposed areas a facies of *Corallina mediterranea* occurs between the surface and 2 m followed by a facies of Mediterranean mussel (2 – 12 m). In the subtidal area over 300 species are present, comprising polychaetes, sipunculids, isopods, amphipods, decapods, polyplacophores, gastropods, bivalve molluscs, echinoderms, sponges, hydrozoans, anthozoans, ascidians and bryozoans. The zone from 12 to 42 m is characterised by species of coralligenous biocoenosis (i.e. sponges, anthozoans and bryozoans).

Finally, three communities have been identified on hard bottoms between 350 and 4500 m. The first group, of bathyal affinities, includes madreporarians (*Flabellum chunii, Lophelia pertusa*), polychaetes (*Lumbrineris flabellicola, Phyllodoce madeirensis*), crustaceans (*Bathynectes superbus, Dorhynchus thomsoni*), bivalve molluscs (*Bentharca pteroessa, Chlamys bruei*), the ophiuroid *Amphilepis norvegica* and the echinoid *Cidaris cidaris*. The second group shows abyssal affinities and includes the cnidarians *Amphianthus dohrnii* and *Antomastus agaricus*. The third group is the dominant group and has a wide bathymetric distribution. The main species are the madreporarians *Desmophyllum cristagalli* and *Flabellum alabastrum* and the echinoderms *Ophiactis abyssicola* and *Phormosoma placenta*.

Macrofauna on soft substrates

Species distribution is strongly related to grain size, depth and the organic matter content of the sediment. In the intertidal and shallow subtidal zones of the north and north-west Spanish coasts, two major communities predominate: the reduced community of *Macoma* (which occurs on intertidal muddy sediments at the bottom of rías) and the Lusitanian boreal community of *Tellina* (which occurs at medium to low tidal levels on fine to medium sandy sediments). Species composition and abundance for both communities are given in *Figures 5.6* and *5.7*.

The inner subtidal sediments of the Ría of A Coruña, which are muddy and occasionally hypoxic, are dominated by a very dense *Thyasira flexuosa* community. Subtidal sediments in the mid and outer part of the ría comprise fine sand and are inhabited by a *Tellina fabula–Paradoneis armata* community (*Figures 5.6* and *5.7*).

Figure 5.6 **Relative abundance of the main species occurring in muddy sediment communities. Source: Lopez-Jamar *et al*. (1995); Tenore et al. (1984); Viéitez (1976).**

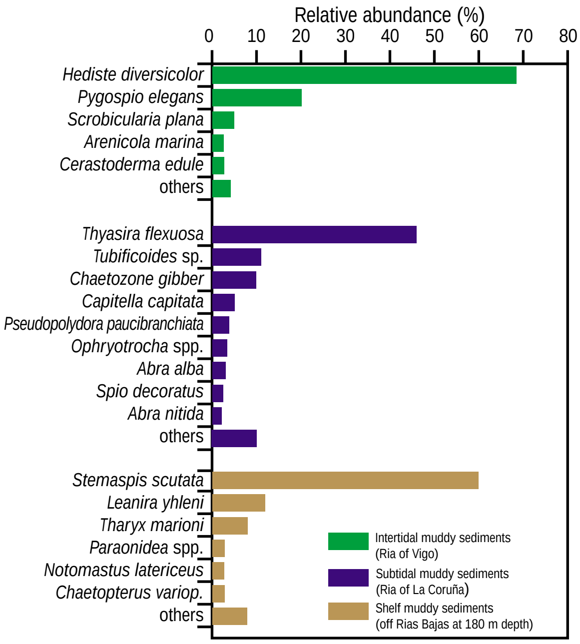
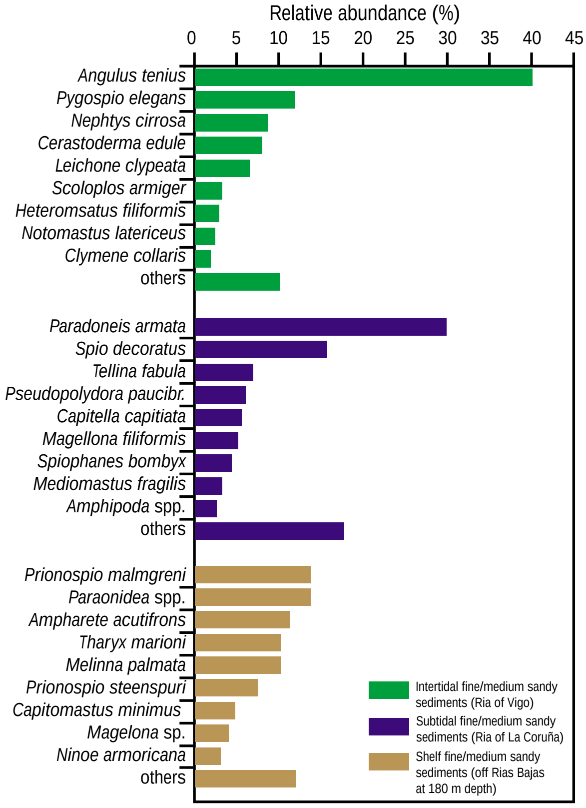


Figure 5.7 **Relative abundance of the main species occurring in fine/medium sandy sediment communities. Source: Lopez-Jamar *et al*. (1995); Tenore *et al*. (1984); Viéitez (1976).**



On the northern Galician shelf, where seasonal coastal upwelling results in benthic enrichment, small surface-feeding and fast-growing polychaetes are dominant. The fauna on the western shelf mainly comprises subsurface deposit-feeding polychaetes and relates to the organic matter exported from the Rías Bajas to the shelf (*Figures 5.6* and *5.7*). Polychaetes, molluscs, cnidarians, echinoderms and crustaceans are the most abundant groups on the Cantabrian shelf and slope (31 – 1400 m).

In the subtidal zone, the large macrofauna is dominated by decapods, fishes (mainly Gobiidae), echinoderms and coelenterates. The greatest abundance occurs in shallow waters. Ten species account for 92% of abundance and 70% of biomass. Crustaceans are the most abundant group, corresponding to 83% in terms of numbers and 59% in terms of biomass.

Over 70% of the intertidal zone along the Portuguese coast is composed of sand substrates with low faunal densities. The main species are listed in *Table 5.6*. In the subtidal zone (about 30 m deep), fine sand is characterised by the bivalve *Chamelea striatula*. The bivalve molluscs *Dosinia exoleta* and *Spisula solida* are very abundant in medium to coarse sand. As the percentage of gravel in the sediment increases the cephalochordate *Amphioxis lanceolatus* becomes more common. From the lower infralittoral limit to 200 m, the faunal community reflects the increase of mud in the sediments. Polychaetes are the most common group in sediments with up to 10% fines, although molluscs, crustaceans and sipunculids are also important. Other communities corresponding to mixed sediments, silt sediment and muddy bottoms are shown in *Table 5.6*.

Soft substrates predominate in the Gulf of Cádiz. Large macrofauna communities are related to depth and sediment type *(Table 5.6)*: shallow muddy bottoms off the River Guadalquivir (15 – 30 m) are characterised by prawns, mantis shrimp, crabs, and common cuttlefish; the middle continental shelf (31 – 100 m) is characterised by bivalve molluscs, gastropods, cephalopods and crustaceans; the outer continental shelf (101 – 200 m) is characterised by a high abundance of the prawn *Parapenaeus longirostris*; the upper portion of the slope (201 – 500 m) is dominated by shrimps and crabs; areas deeper than 300 m are dominated by Norway lobster.

Portuguese and Gulf of Cádiz macrozoobenthos include several commercially important species; mainly crustaceans (rose shrimp, red shrimp, brown shrimp, common prawn, Norway lobster, edible crab (*Cancer pagurus*), green crab and swimming crab) and molluscs (surf clam, razor clam, wedge shell, carpet shell, mussel, cockle, octopus and cuttlefish).

Meiofauna

Meiofauna are those 1 – 0.06 mm in size. Despite their importance in benthic trophic dynamics, meiofauna are still the least studied group of benthic fauna. Spatial distribution is related to the grain size, depth and organic matter content of the sediment.

In the Galician rías of Muros, Arosa and in the estuary of the Foz (the Ría of Vigo), nematodes dominate, followed by harpacticoid copepods. Diversity of taxa is moderate. The Comesomatidae dominate in the Ría of Arosa, with *Sabatieria pulchra* and *Metacomesoma punctatum* indicating high levels of organic matter. In the Ría of Muros the Desmodoridae are the dominant family, comprising 43% of total biomass. In the Ría of Ferrol, characterised by coarse sands of *Amphioxus*, the dominant groups are polychaetes, followed by Tardigrada and Mistacocarida.

On the continental shelf off the Rías Bajas of Galicia, an area of high oxygenation and low bioturbation of the sediments, meiofauna densities are 10 to 100 times greater than in the rías. Nematodes predominate, representing 78% of total biomass, and the Comesomatidae are the most abundant family. *Sabatieria pulchra* and *S. ornata* are the dominant species on the inner and outer shelves respectively.

At sites 2000 and 4400 m deep in the southern Bay of Biscay, the organic content of the sediment is not a limiting factor for meiofauna abundance, suggesting that in abyssal environments meiofauna may be more dependent on microbial activity, hydrodynamics and sediment stability. Abundance and species richness are lower at the deeper station, and the Monhysteridae dominate at both. At a site 5300 m deep near the Galician coast, nematodes comprise > 95% of the meiofauna.

Along the Portuguese coast, studies are limited to estuaries (such as the Sado estuary) and some deep-sea sites. The estuarine meiofauna is dominated by nematodes (representing > 50% in abundance), followed by copepods (up to 35%) and a group formed by turbellarids, polychaetes and ostracods (10%). The deep-sea meiofauna exhibits strong similarities to the meiofauna of the continental margins of the temperate North-east Atlantic. Major decreases in abundance are observed between 500 and 1500 m. Between 2000 and 4000 m the decrease in density is not significant. The dominant groups are nematodes (up to 92%), followed by copepods and nauplii (up to 8%).

5.2.5 Fish

The fish of Region IV are well known from a descriptive point of view. Of the 1098 species described for the North-east Atlantic and the Mediterranean, around 700 occur in Region IV. In terms of biogeography, many species reach their southern or northern limits of distribution in the Bay of Biscay. The boundary for the cold temperate species is around 47° N *(Table 5.7)*. The shelf break in the Bay of Biscay is a major spawning area for species with a wide

Table 5.6 Main species of benthic macrofauna in soft substrates along the Portuguese coast and in the Gulf of Cadiz.

Portuguese coast	Species	Gulf of Cadiz	Species
Intertidal	*Talitrus saltator*	River mud (15 – 30 m)	*Penaeus kerathurus*
sand	*Tylos europeus*		*Squilla mantis*
	Eurydice pulchra		*Medorippe lanata*
	Spio filicornis		*Calappa granulata*
	Nephtys cirrosa		*Sepia officinalis*
	Haustorius arenarius		
	Urothoe brevicornis	Littoral mud and mud-sand	*Chamaelea gallina*
	Bathyporeia guilliamsoniana		*Donax* sp.
	Pontocrates arenarius		*Tapes* sp.
	Donax trunculus		*Venerupis* sp.
	Tellina tenuis		
		Middle shelf (30 – 100 m)	*Atrina pectinata*
Subtidal			*Circomphalus cassinus*
fine sand	*Chamelea striatula*		*Cymbium olla*
coarse sand	*Dosinia exoleta*		*Loligo vulgaris*
	Spisula solida		*Alloteuthis* sp.
gravel	*Amphioxus lanceolatus*		*Sepia* sp.
			Octopus vulgaris
Infralittoral			*Eledone moschata*
up to 10% fines	*Jasmineira caudata*		*Alpheus glaber*
	Eunice pennata		*Pontocaris* sp.
	Pista cristata		*Liocarcinus depurator*
	Corbula gibba		*Goneplax rhomboides*
	Maera othonis		*Dardanus arrosor*
	Liocarcinus pusillus		
	Aspidosiphon muelleri	Outer shelf (100 – 200 m)	*Parapenaeus longirostris*
			Plesionika heterocarpus
mixed sediment	*Calappa granulata*		*Dardanus arrosor*
	Thyone inermis		*Homola barbata*
	Labidoplax digitata		*Inachus* sp.
	Petrosia ficiformis		*Macropodia*
	Chloeia venusta,		*Eledone cirrhosa*
	Eunice vittata		*Sepia elegans*
	Eunice harassii		*Illex coindetii*
	Euthalenessa dendrolepis		
		Upper slope (200 – 500 m)	*Solenocera membranacea*
25 – 50% silt	*Dasybranchus caducus*		*Chlorotoccus crassicornis*
	Aglaophamus malmgrenis		*Plesionika* sp.
	Mysta picta		*Pasiphaea* sp.
	Glycera rouxi		*Processa* sp.
	Leanira yhleni		*Munida intermedia*
	Lumbrineris impatiens		*Macropipus tuberculatus*
	Sternaspis scutata		
		Bottom > 300 m	*Nephrops norvegicus*
deep mud	*Dentalium agile*		Sepiolidae
	Siphonodentalium quinquangulata		
	Abra longicallus	Deep samples (500 – 700 m)	*Aristeomorpha foliacea*
	Sternaspis scutata		*Aristeus antennatus*
	Ampharetidae		*Plesionika martia*
	Terebellidae		*Bathynectes superbus*
	Glyceridae		*Nephrops norvegicus*

geographical distribution (e.g. blue whiting (*Micromesistius poutassou*), mackerel, horse mackerel and hake).

Pelagic fish

Although fifteen pelagic species are common in Region IV, only sardine, anchovy, mackerel, horse mackerel, albacore and bluefin tuna (*Thunnus thynnus*) are important in terms of abundance and commercial interest. *Figure 5.8* shows the distribution of the small and medium-sized pelagic species over the French continental shelf.

The sardine has a wide geographic distribution, from Mauritania to the British Isles. The Ibero-Atlantic and Bay of Biscay populations coexist in Region IV. There are two main spawning areas and seasons: early winter in Galician/Portuguese waters and early spring in the Cantabrian Sea. Sardine spawning appears coupled to the normal wind regime, avoiding periods when the retention processes are lower. Recruitment occurs in the second half of the year. Two anchovy populations coexist in Region IV; one along the Atlantic coast of the Iberian Peninsula and the other in the Bay of Biscay. Spawning occurs in waters near the large rivers (i.e. the Garona and Guadalquivir rivers), in spring in the Bay of Biscay and in winter in the Gulf of Cádiz. In the Bay of Biscay, juveniles remain near the coast while adults make feeding and spawning migrations.

Horse mackerel is distributed from Norway to Cape Verde. Adults live near the bottom and are usually found in continental shelf waters, while juveniles display more pelagic habits. Spawning occurs over the mid continental shelf, beginning in winter in Portugal, continuing towards the Bay of Biscay to the North Sea where it reaches a peak in summer. Mackerel also has a wide distribution and in contrast to horse mackerel, undertakes long spawning and feeding migrations. Feeding and wintering areas occur in northern European waters, mainly the Norwegian Sea. Around February there is a migration towards the spawning grounds, located mainly in the Bay of Biscay near the slope. Juveniles do not seem to follow this migration and their abundance is higher in southern waters.

Albacore and bluefin tuna live in subtropical areas of the western Atlantic and make annual migrations to the Bay of Biscay. Juvenile schools (from one to four years) move eastwards at the beginning of spring and reach their maximum concentration in the Bay of Biscay in summer. Large bluefin tuna adults pass through the Gulf of Cádiz when entering or leaving the Mediterranean Sea during their spawning migrations.

Demersal fish

Demersal species comprise the majority of the fish species occurring in Region IV. The species present are related to bottom topography and the adults and recruits usually have different areas of distribution. Some species are sedentary (e.g. sole, megrims, dogfish and skates), while others are migratory (e.g. hake, red seabream, blue whiting). Many deep-water species have an extensive geographical distribution owing to the small environmental variations in their habitat. Communities are described according to depth and to the main sectors of the continental shelf.

Table 5.7 Cold temperate and warm temperate fish species with their southern and northern limits of distribution on the French shelf of the Bay of Biscay. Source: Quéro *et al*. (1989).

Cold temperate species	Warm temperate species
Butterfish	Axillary sea bream
Cod	Bogue (*Boops boops*)
Dab	Bogue (*Sarpa salpa*)
Echiodon drummondi	Couch's sea bream
Great silver smelt	Drum (*Umbrina canariensis*)
Greater sandeel	Gilt-head sea bream
Haddock	Long-finned gurnard
Herring	Mediterranean horse mackerel
Lemon sole	Scorpionfish (*Scorpaena loppei*)
Nilsson's pipefish	Sea spotted bass
Norway pout	Seahorse
Norwegian topknot	Spanish mackerel
Saithe	Spanish sea bream
	Thickback sole

Data obtained in autumn 1973 and spring 1976.

With regard to the eastern Bay of Biscay, a total of 191 species were recorded during the French groundfish surveys on the Armorican and Aquitaine shelves at depths of 15 – 600 m. Abundance varied widely with around ten species *(Table 5.8)* making up over 80% of the total demersal catches. Six communities were identified in the Bay of Biscay; three located in the coastal area (15 – 60 m), one on the muddy bottom of 'La Grande Vasière' (with hake as its main species), one over the outer shelf and one comprising deep-water species along the shelf edge *(Table 5.9)*.

The southern Bay of Biscay has a mixture of typically temperate fauna, with groups of boreal and subtropical affinity. Species richness and the distribution of fish populations are determined by the narrowness and topography of the continental shelf. This is very irregular with a reduced or even absent sediment cover in many areas. More than 80% of the demersal fish biomass is accounted for by seven species, in order of importance: blue whiting, horse mackerel, dogfish, hake, monkfish (*Lophius piscatorius*), silvery pout (*Gadiculus argenteus*) and megrim. Five communities characterise the area, corresponding to shallow coastal waters, the mid shelf, the outer shelf, and the shelf break and slope *(Table 5.9)*.

Figure 5.8 **Distribution of the main pelagic fish species on the continental shelf to the east of the Bay of Biscay. Source: after Massé (1996).**

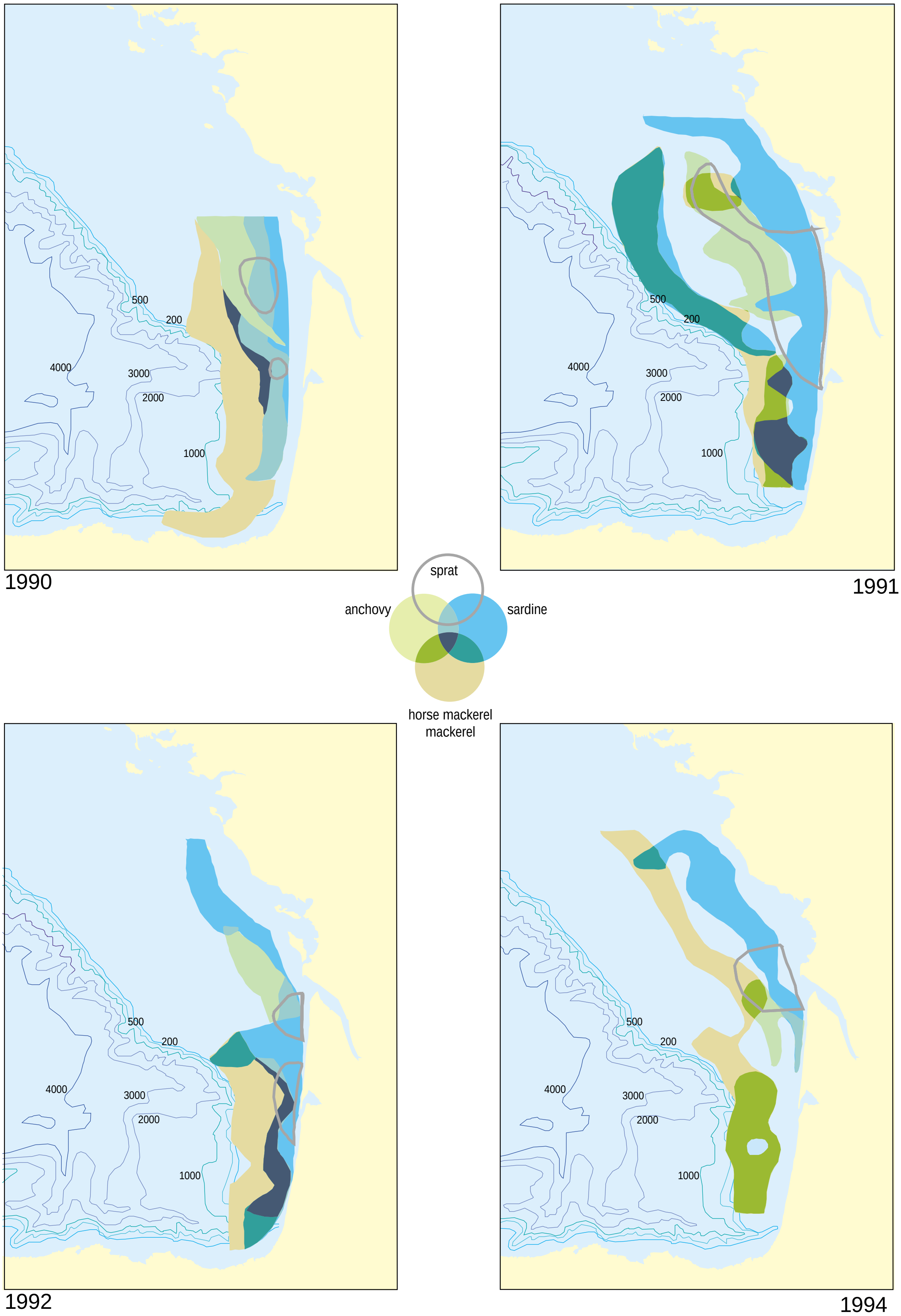


Table 5.8 The most abundant fish species in the Bay of Biscay, 1987–95.

Demersal species	Relative abundance in demersal catches (%)	Pelagic species	Relative abundance in pelagic catches (%)
Poor cod	27	Horse mackerel	56
Boar fish	17	Blue whiting	30
Bib	13	Greater argentine	2
Hake	12	Mackerel	2
Lesser spotted dogfish	4	Mediterranean horse mackerel	2
Anglerfish	3	Pilchard	2
Thornback ray	2	Sprat	2
Whiting	2	European anchovy	1
Spurdog	2	Common ling	1
Cuckoo ray	2		
Red gurnard	2		
Megrim	2		

The top ten species within Portuguese waters are snipefish (*Macroramphosus scolopax*), boarfish (*Capros aper*), blue whiting, horse mackerel, mackerel, axillary seabream (*Pagellus acarne*), hake, jack mackerel (*Trachurus picturatus*), chub mackerel (*Scomber japonicus*) and dogfish. These account for 75% of total biomass *(Table 5.9)*.

Important estuaries and coastal marshes at the mouths of large rivers draining into the Gulf of Cadiz further enhance the physiographical diversity of the region. Shallow muddy sediments off the mouth of the River Guadalquivir are characterised by fish of estuarine influence, similar to the coastal community of Sciaenidae at subtropical and tropical latitudes. Species groups are shown in *Table 5.9*.

Gregarious and highly abundant species such as blue whiting and silvery pout, which serve as a food source for other species, occur between 100 and 300 m. Predatory species of commercial interest are forced to occupy these areas in order to exploit an abundant food source and as a consequence this zone is the most intensively fished. Large predators such as hake, monkfish and sole, and the forage fish blue whiting, are particularly important in terms of the transfer of energy through the ecosystem.

The shelf break area appears to be the preferred region for hake spawning which is particularly intense during the first quarter of the year in the Bay of Biscay. Hake nursery grounds are located off northern Galicia, in the western Cantabrian Sea and Grande Vasiere, mainly in the range of 80 – 150 m. A new cohort is present in these areas as early as the May following spawning and high numbers of age group 0 are found during autumn. Young hake remain in nursery grounds until spring, one year after spawning, and then scatter over the continental shelf.

Monkfish (both *L. piscatorius* and *L. budegassa*) are distributed throughout Region IV from shallow waters to waters of at least 800 m depth. The smaller fish live in shallow waters moving to deeper waters as they grow. The spawning season is mainly between October and March and age at first maturity is estimated at over eight years.

The spatial aspects of the sole life cycle in the Bay of Biscay are well established. Spawning occurs in late winter and spring on the continental shelf (50 – 80 m), with post-larvae and young juveniles arriving at coastal nurseries in May to June, where they remain for about two years.

Blue whiting are distributed near the bottom, mainly between 200 and 500 m. Fish length increases with depth and larger individuals (> 25 cm) concentrate at 500 – 750 m. At 200 to 400 m, their distribution enters the oceanic zone in which they exhibit diurnal vertical migrations. Blue whiting are the main prey for large predators.

5.2.6 Birds

The Iberian Peninsula is at a strategic geographical position regarding the migratory behaviour of seabirds and, together with the high biological production of coastal areas in the Gulf of Cádiz and along the Galician coast, gives rise to large seabird populations. Seabirds are grouped in terms of pelagic species (e.g. yelkouan shearwater (*Puffinus yelkouan*), Leach's petrel (*Oceanodroma leucorhoa*), northern gannet (*Morus bassanus*) and razorbill (*Alca torda*)), coastal species (e.g. shag (*Phalacrocorax aristotelis*), terns (*Sterna* spp.) and common scoter (*Melanitta nigra*)) and gulls, with coastal or fishing ground distribution. For descriptive purposes, seabird populations are divided in terms of nesting and wintering populations.

The seabird community is dominated by the yellow-legged gull (*Larus cachinnans*), which until recently was considered the same species as the herring gull (*L. argentatus*), and which makes up 70% of the total

Table 5.9 Main demersal fish species in Region IV.

Eastern Bay of Biscay		Southern Bay of Biscay		Portugal		Gulf of Cadiz	
15 – 60 m	greater weaver	35 – 90 m	common sole	< 100 m	scad	15 – 30 m	meagre
	sandeel		greater weaver		black sea bream		*Umbrina canariensis*
	black sea bream		axillary sea bream		common two-banded sea bream		*Spicara flexuosa*
	sprat		Spanish sea bream		greater weaver		transparent goby
	whiting		red mullet		Spanish sea bream		*Halobatrachus didactylus*
	sand goby		tub gunard		striped mullet		thick-back sole
	bib		Atlantic John Dory		axillary sea bream		*Dentex* sp.
	thin-lip grey mullet		solenette		brown comber		*Pagrus* sp.
	red mullet				little scorpionfish		*Diplodus* sp.
	common sole	90 – 150 m	bib				*Pagellus* sp.
	bogue (*Boops boops*)		boarfish	100 – 200 m	snipefish		
			hake		large-scaled gurnard	30 – 100 m	brown comber
60 – 120 m	*Lesueriogobius friesii*		anglerfish		boarfish		little scorpionfish
	hake		megrim		chub mackerel		long-finned gurnard
	red bandfish		dragonet		hake		*Mullus* sp.
	scaldfish		dogfish		bib		*Leseurigobius sanzoi*
	wedge sole				scad		scaldfish
	Enchelyopopus cimbrius	150 – 250 m	four-spot megrim		dogfish		wedge sole
	Maurolicus muelleri		black-bellied angler		bogue (*Boops boops*)		*Citharus linguatula*
			blue whiting		Couch's sea bream		
120 – 250 m	blue whiting		wedge sole			100 – 200 m	boarfish
	silver pout		silver pout	200 – 600 m	blue whiting		snipefish
	lesser silver smelt				blue-mouth		dogfish
	spotted dragonet	250 – 400 m	*Malacocephalus laevis*		four-spot megrim		
	dogfish		*Bathysolea profundicola*		greater forkbeard	200 – 500 m	silver pout
	megrim		ratfish		silver pout		blue whiting
	boarfish		black-mouthed dogfish		anglerfish		greater forkbeard
			greater forkbeard		black-mouthed dogfish		hake
250 – 600 m	black-mouthed dogfish		*Antonogadus macrophthalmus*		black-bellied angler		*Antonogadus megalokinodon*
	greater forkbeard				velvet belly		black-spot grenadier
	ratfish	400 – 600 m	*Notacanthus bonapartei*		hake		*Malacocephalus laevis*
	four-spot megrim		*Deania calceus*		*Benthodesmus elongatus*		
	greater silver smelt		velvet belly		European conger	500 – 700 m	ratfish
	Malacocephalus laevis		*Trachyrhynchus trachyrhynchus*		scabbardfish		*Deania calceus*
	Notoscopelus kroeyerii		*Lepidion eques*		*Nezumia sclerorhynchus*		gulper shark
					dogfish		velvet belly
							black-mouthed dogfish

number of seabirds. It is a littoral species and its main food sources are fish discards and rubbish dumps which, together with the protection of their colonies, explains their strong demographic growth in recent decades. In Galicia, the population has grown fivefold since the end of the 1970s, and the 46 000 nesting pairs account for up to 94% of total seabird numbers and 90% of biomass in the area. In the Cantabrian Sea and the Gulf of Cádiz there are estimated to be 10 000 and 1800 breeding pairs respectively. The very similar lesser black-backed gull (*L. fuscus*) established itself in the 1970s and there are now some 300 pairs in Sisargas, with many more in Cíes and parts of Vizcaya and Guipúzcoa.

Other nesting seabirds of importance are the shag (2200 pairs), European storm-petrel (*Hydrobates pelagicus*, 1300 pairs), kittiwake (*Rissa tridactyla*, 185 pairs) and guillemot (*Uria aalge*, < 15 pairs). The kittiwake and the guillemot both reach the southernmost points of their distribution on the northern Iberian Peninsula. Up to 3000 pairs of little tern (*Sterna albifrons*) were counted in the coastal area of the Odiel marshes in 1993 and more than 200 in the Gulf of Cádiz.

The nesting seabird community is very poor in comparison with other European Atlantic areas, both in terms of numbers and biomass. Nevertheless, it improves appreciably during migrations and in winter. Of particular importance is the autumn passage, visible from coastal points such as the Cape Estaca de Bares and Cape Peñas, where large numbers of common scoter, Cory's shearwater (*Calonectris diomedea*), sooty shearwater (*Puffinus griseus*), Balearic shearwater (*Puffinus mauretanicus*), northern gannet and different species of skua (*Catharacta skua* and *Stercorarius* spp.) and tern (*Sterna* spp.) are seen. Among the wintering populations the great cormorant (*Phalacrocorax carbo*) reaches significant numbers (2500 individuals in the Rías Bajas). Also important is the black-headed gull (*Larus ridibundus*), common gull (*L. canus*), Mediterranean gull (*L. melanocephalus*), great black-backed gull (*L. marinus*), razorbill, guillemot and Atlantic puffin (*Fratercula artica*).

In the Gulf of Cádiz the greatest number of species and individuals occurs during winter and in migratory periods. The wintering population of razorbill has been estimated at 4000 individuals for the coasts of Cádiz and Huelva, although it may actually be twice as high. In Atlantic waters, Leach's petrel is an abundant wintering species (as shown by the large number of dead specimens which occur along the coast following storms), other abundant species during migrations and winter are gannet and yelkouan shearwater. Some species of seaduck and tern are also abundant in the Gulf of Cádiz during winter.

5.2.7 Marine mammals

Information on the presence of marine mammals is based on past whaling activities, strandings on coasts and systematic and opportunistic sightings. A large variety of species, both boreal and temperate, have been reported in the Bay of Biscay and Iberian Atlantic waters, including seven species of mysticeti, twenty-three species of odontoceti and seven species of pinnipeds. The main habitats and status of these species is summarised in *Table 5.10*. Detailed information on distribution and migratory patterns is restricted to the most common species.

Cetaceans

Of the baleen whales, which are all migratory, only fin whales (*Balaenoptera physalus*) are common within Region IV. The northern right whale (*Eubalaena glacialis*) was a common species along the northern and western Spanish coast during the Middle Ages, supporting a seasonal coastal fishery for more than 500 years, but over the last 30 years has only been reported on very exceptional occasions.

Sperm whales (*Physeter macrocephalus*) are a common feature of the cetacean fauna of Region IV. They tend to aggregate in summer over the continental slope, feeding on cephalopods. The common dolphin (*Delphinus delphis*) is the species most frequently observed at sea *(Figure 5.9)* and also represents about 50% of all strandings in the area. Groups of bottle-nose dolphins (*Tursiops truncatus*) are resident in several inshore bays from Brittany to Portugal. Harbour porpoise (*Phocoena phocoena*) was considered one of the most common species in the area, but sightings and strandings are now common only in certain areas, for example the western Galician and northern Portuguese coasts.

Concerns regarding the conservation of cetacean populations in Region IV are similar to those expressed for other regions, and relate to issues such as the alteration of ecosystem structure and the impact of fisheries.

Figure 5.9 **The common dolphin is the most abundant cetacean within Region IV.**

Table 5.10 Status of marine mammal species in the Bay of Biscay and Atlantic Iberian waters.

	Habitat	Status*
Mysticeti		
minke whale	pelagic, continental shelf	rare, frequent
sei whale	pelagic	exceptional
fin whale	pelagic	frequent
blue whale	pelagic	exceptional
Bryde's whale	pelagic	exceptional
humpback whale	pelagic	rare
northern right whale	pelagic	exceptional
Odontoceti		
rough-toothed dolphin	pelagic	exceptional
bottlenose dolphin	coastal, continental shelf	frequent
striped dolphin	pelagic	frequent
Atlantic spotted dolphin	pelagic	rare
common dolphin	pelagic, continental shelf	frequent
white-beaked dolphin	continental shelf	exceptional
Atlantic white-sided dolphin	continental shelf	exceptional
Risso's dolphin	pelagic, continental shelf	frequent
false killer whale	pelagic	exceptional
long-finned pilot whale	pelagic, continental shelf	frequent
short-finned pilot whale	pelagic, continental shelf	exceptional
killer whale	pelagic	rare
harbour porpoise	coastal	rare, frequent
white whale (beluga)	continental shelf	exceptional
sperm whale	pelagic	frequent
pygmy sperm whale	pelagic	exceptional
dwarf sperm whale	pelagic	exceptional
Cuvier's beaked whale	pelagic	rare
northern bottlenose whale	pelagic	exceptional
True's beaked whale	pelagic	exceptional
Gervais' beaked whale	pelagic	exceptional
Sowerby's beaked whale	pelagic	exceptional
Blainville's beaked whale	pelagic	exceptional
Pinnipeda		
walrus	coastal	exceptional
harbour seal	coastal	exceptional
ringed seal	coastal	exceptional
harp seal	coastal	exceptional
grey seal	coastal	rare
bearded seal	coastal	exceptional
hooded seal	coastal	exceptional

* 'frequent' implies a species considered to be abundant or frequently sighted within the area; 'rare' implies a species within its main area of distribution but which is not abundant; 'exceptional' implies a species that has been observed in the area but which is outside its distribution range or is within its supposed range of distribution but which is extremely scarce.

Pinnipeds

Pinnipeds cannot be considered part of the fauna of Region IV, although specimens appear regularly in the Bay of Biscay and on the Atlantic Iberian coast. The species most commonly seen are the grey seal (*Halichoerus grypus*) and the harbour seal (*Phoca vitulina*) *(Table 5.10)*. The presence of the grey seal is related to the dispersion of young individuals from breeding colonies on the British Isles.

5.2.8 Turtles

Sea turtles are mostly tropical or subtropical, although some species undertake long migrations using the Gulf

Stream. A few vagrants therefore arrive in Region IV each year. The majority are leatherback turtles (*Dermochelys coriacea*) and loggerhead turtles (*Caretta caretta*), but green sea turtles (*Chelonia mydas*), hawksbill sea turtles (*Eretmochelys imbricata*) and Kemp's ridley turtles (*Lepidochelys kempii*) are also seen.

5.2.9 Ecosystem functioning

Region IV corresponds to a temperate sea whose dynamics are governed by climate and tides. As is the case for the entire North-east Atlantic, Region IV undergoes a seasonal climatic rhythm resulting from changes in sunlight, heat input and mechanical forcing on the water surface due to wind. These produce a regular pattern in hydrographic conditions throughout the year characterised by winter mixing and summer stratification, with phytoplankton blooms occurring during the transition periods. The spring bloom, generally March to early April, occurs when sunlight exposure is intense and long enough for net photosynthesis. This seasonal pattern has a significant effect on the dynamics of the pelagic ecosystem.

Temporal variability is manifest at the seasonal, inter-annual and decadal scale. Spatial variability reflects vertical and horizontal water movements, which are particularly diverse in Region IV and include coastal run-off and river plumes, internal waves and tidal fronts, coastal upwelling, shelf break currents, cyclonic and anticyclonic gyres, jet filaments, fronts and large scale low frequency oscillations. Most of these are mesoscale processes, which are typically the most energetic. They represent major perturbations of the system and have a dramatic impact on ecosystem productivity and the transport and fluxes of biological material.

There are no regional budgets for matter or energy, or any trophic models for the ecosystems of the area as a whole. However, a preliminary comparison between the Galician shelf, which is subject to strong upwelling, and the Cantabrian Sea, where upwelling on the shelf is of lesser significance, indicates higher phytoplankton biomass on the Galician shelf compared to the Cantabrian Sea, attributed to export from the rías, while primary production levels are the same in both areas.

The average value of annual primary production for the Galician shelf is 410 g C/m^2/yr, while that of the Cantabrian Sea is 428 g C/m^2/yr. Annual carbon budgets computed from the values in ***Table 5.11*** and export production rates indicate that a large fraction of primary production in Galicia is exported to the bottom as particulate organic matter ***(Figure 5.10)***. Total primary production values were increased by 30% to account for the production of dissolved organic matter by phytoplankton. The contribution of zooplankton to export is relatively small in both areas, although its relative importance is higher in the Cantabrian Sea. About 65% of primary production is available for export in Galicia, while in the Cantabrian Sea export is only 17% of production.

The pelagic ecosystem in the Cantabrian Sea is more dependent on recycled nutrients than that on the Galician shelf. This mostly occurs within the water column, as indicated by the higher availability of primary production to bacteria, and supports the results from studies on oxygen consumption. The large amount of export production on the Galician shelf is important to the benthic ecosystems and the demersal fish. The proportion of primary production available to pelagic fish is similar in both areas, at 3% in the Cantabrian Sea and 4% on the Galician shelf.

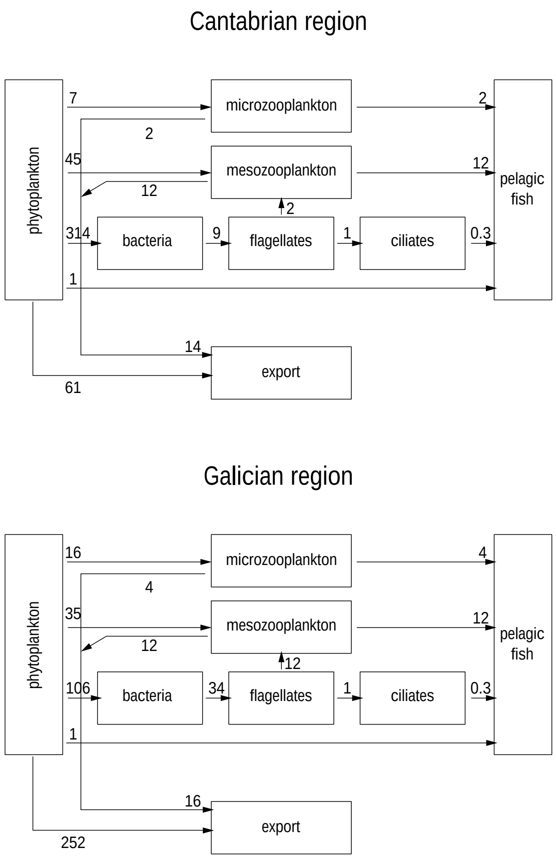
Trophic studies on the role of invertebrate megabenthos in the diet of demersal fish indicate that decapod crustaceans are the main food items for the juveniles. Molluscs and echinoderms are accidental prey items or are selected by specialist predators. Benthic fish are more selective than demersal fish in terms of their prey items. Demersal fish have a more general diet. When the predator populations reach a certain size, the benthic fauna are not sufficient to satisfy their food requirements and the diet must be supplemented by catching nektonic organisms.

Table 5.11 Mean biomass (mg C/m^2) and daily production rates (mg C/m^2/d) for the main compartments of the Cantabrian and Galician pelagic shelf ecosystems.

	Cantabrian shelf		Galician shelf	
	biomass	production	biomass	production
Phytoplankton	1638*	903*	2714*†	863*†
Bacteria	753‡	631‡	652†§	701⊥
Heterotrophic flagellates	3¶	9⊥	11§	33⊥
Ciliates	2¶	0.7⊥	2§	0.7⊥
Microzooplankton	53¶	5⊥	105**	11⊥
Mesozooplankton	315¶	32⊥	319**	32⊥

* averaged from data in Bode *et al*. (1996); † averaged from data in Tenore *et al*. (1995); ‡ data from Barquero et al. (1998); § based on unpublished data; ⊥ computed using formulae in Bode and Varela (1994); ¶ averaged from data in Bode (1995); ** averaged from data in Valdés *et al*. (1991).

Figure 5.10 **Carbon fluxes (g C/m^2/yr) from the phytoplankton to the pelagic fishes in the Cantabrian and Galician regions of the Bay of Biscay.**



5.2.10 Key habitats

Owing to their role in the transformation and transfer of material from land to sea, estuaries are the most productive and dynamic of the coastal ecosystems. Estuaries are also the most vulnerable to sea level rise and are subject to intense human pressures. On the basis of their geomorphology, the estuaries of Region IV fall into three categories: coastal plain estuaries, rías and bar-built estuaries.

Coastal plain estuaries

Coastal plain estuaries formed when sea level rose and drowned existing river valleys. Most northern estuaries belong to this category. Coastal plain estuaries are small meso-macrotidal shallow areas with relatively extended tidal flats. On the Atlantic coast of France tides may reach more than 7 m in many places. In the lower estuary the period of active growth by the phytoplankton may be more prolonged than in adjacent coastal waters due to the supply of riverine nutrients. The main habitat types, in addition to the pelagic system, are marshes and intertidal and subtidal mudflats and sandflats. Many of the marshes on the northern estuaries, such as those of Santoña and Urdaibai, are important wintering areas for birds. Several of these estuaries have been severely threatened by pollution, dredging and land reclamation. Aquaculture sites are located in some, mainly producing shellfish and turbot.

Rías

Rías, located on the north-western Iberian Peninsula, formed in river valleys affected by both tectonic land subsidence and a rise in sea level. Rías are relatively deep and extensive in relation to their catchment area. Planktonic productivity within rías is mainly driven by the intrusion of nutrient-rich Atlantic water from coastal upwelling, which may last several months during the warmer seasons. Intertidal and subtidal fauna, which are largely dependent on planktonic productivity, play a major role in the productivity of rías. In addition to turbot, aquaculture within Galician rías produces significant quantities of shellfish, mainly mussels, oysters and several species of clam.

Bar-built estuaries

Most Portuguese estuaries are shallow areas with extended intertidal sediments; the small coastal lagoons of the Ría of Aveiro, the Ría Formosa and the Tejo and Sado estuaries being the most representative. These estuaries are subject to considerable hydrological variability and have prolonged dry periods. They mostly have important ecological and economic roles. The Guadiana and Guadalquivir are the main estuaries in the Gulf of Cádiz. These areas are a complex mixture of wetlands, salt marshes and sand dunes protected from the sea by a barrier dune and connected to groundwater mainly through small lagoons located in both the dunes and marshes. They are largely used for shellfish and finfish aquaculture as well as for salt-ponds. Doñana, a national park within the Guadalquivir estuary, is one of the largest over wintering areas for birds in Europe.

The main physical perturbations are the loss of estuarine habitats, mainly wetlands, salt marshes and sand dunes, due to land reclamation, salt and sand extraction, rice production and aquaculture. In addition, estuarine sediments often accumulate organic and inorganic pollutants, from mining and industrial activities for example, and this is the case for the Odiel and Tinto estuaries which are contaminated by metals from erosion and mining.

5.2.11 Key species

The accurate selection of key species for a given area depends on a good understanding of the ecosystem. There are two main sources of environmental change:

effects derived from global warming and effects due to fishing activities. On this basis, a pelagic invertebrate and several demersal vertebrates are proposed as key species for Region IV.

Over the last fifteen years the pelagic copepod *Temora stylifera* has shown a clear increase in spatial coverage, abundance and persistence in Region IV. This species is subtropical, highly abundant in southern waters and because of its strong relationship with surface water temperature and its accurate identification, it is proposed as a key species for monitoring oceanographic change within the Bay of Biscay.

The warming trend indicated by *Temora stylifera* is also likely to be responsible for the appearance of tropical fish species throughout Region IV; temperatures were observed to increase by about 2 °C from 1972 to 1992 in the northward slope current and by 1.4 °C from 1972 to 1993 in surface waters on the southern Bay of Biscay shelf. The first recorded observations of tropical fish in Region IV were along southern Portugal in 1963 and in the Bay of Biscay in 1968 for *Cynopsis roseus*, in 1970 for American John Dory (*Zenopsis conchifer*) and in 1980 for *Sphoeroides pachygaster (Figure 5.11)*.

As with the common European skate (*Raja batis*), which is negatively affected by fishing activities in the North Sea and Irish Sea, the thornback ray (*Raja clavata*) has decreased since 1995 along the north and northwestern coasts of Spain *(Figure 5.12)*.

Dogfish may be a good indicator species for monitoring change in exploited systems, as its natural diet is modified by discards from fishing activities. It also shows a high survival rate (of up to 90%) when discarded. Both factors are responsible for its increasing abundance since 1995 *(Figure 5.12)*.

5.3 Impact of non-indigenous species and harmful algal blooms

5.3.1 Non-indigenous species

The introduction of non-indigenous species carries the risk of introducing pests and disease. Non-indigenous species may arrive as a result of both natural processes (e.g. ocean currents) and anthropogenic activities (e.g. ballast water or the transport of fish and shellfish). The most significant ecological effects of non-indigenous species are pathogenic effects and competition with indigenous and/or commercially important species for food, space or light. By 1996, around a hundred non-indigenous species of great taxonomic diversity (phytoplankton, macroalgae and benthos) had been recorded in the OSPAR Maritime area.

There are at least twelve non-indigenous macroalgae in Region IV, several of which may have deleterious environmental effects. For example Japanese seaweed, which

Figure 5.11 **Distribution of *Zenopsis conchifer* and *Cynopsis roseus* catches along the Atlantic coast. Source: after Quéro *et al*. (1998).**

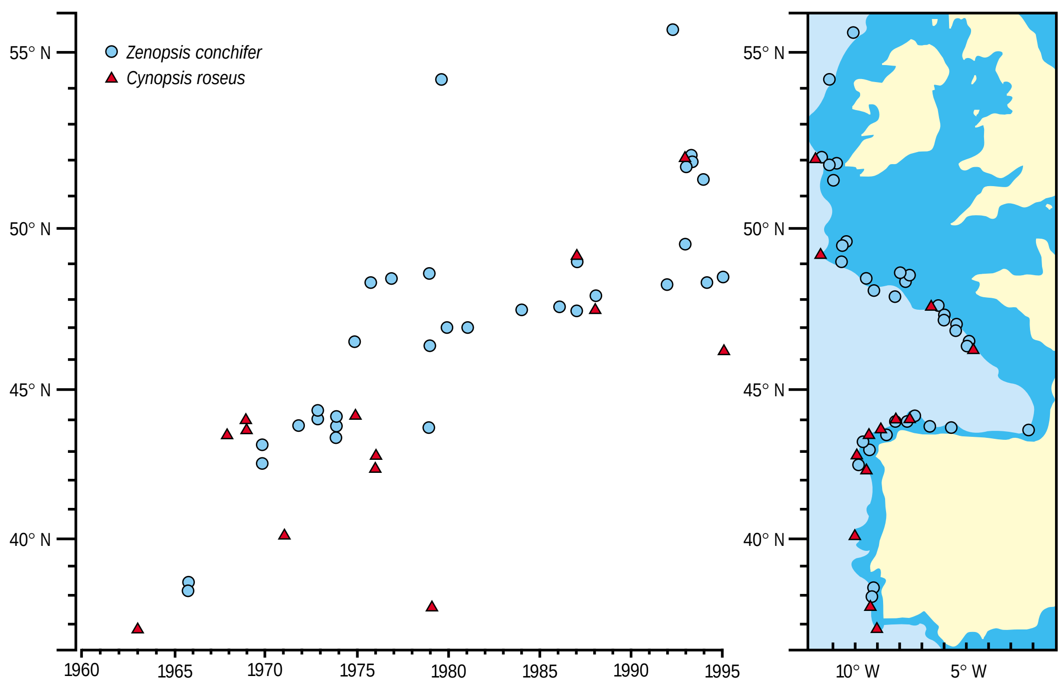
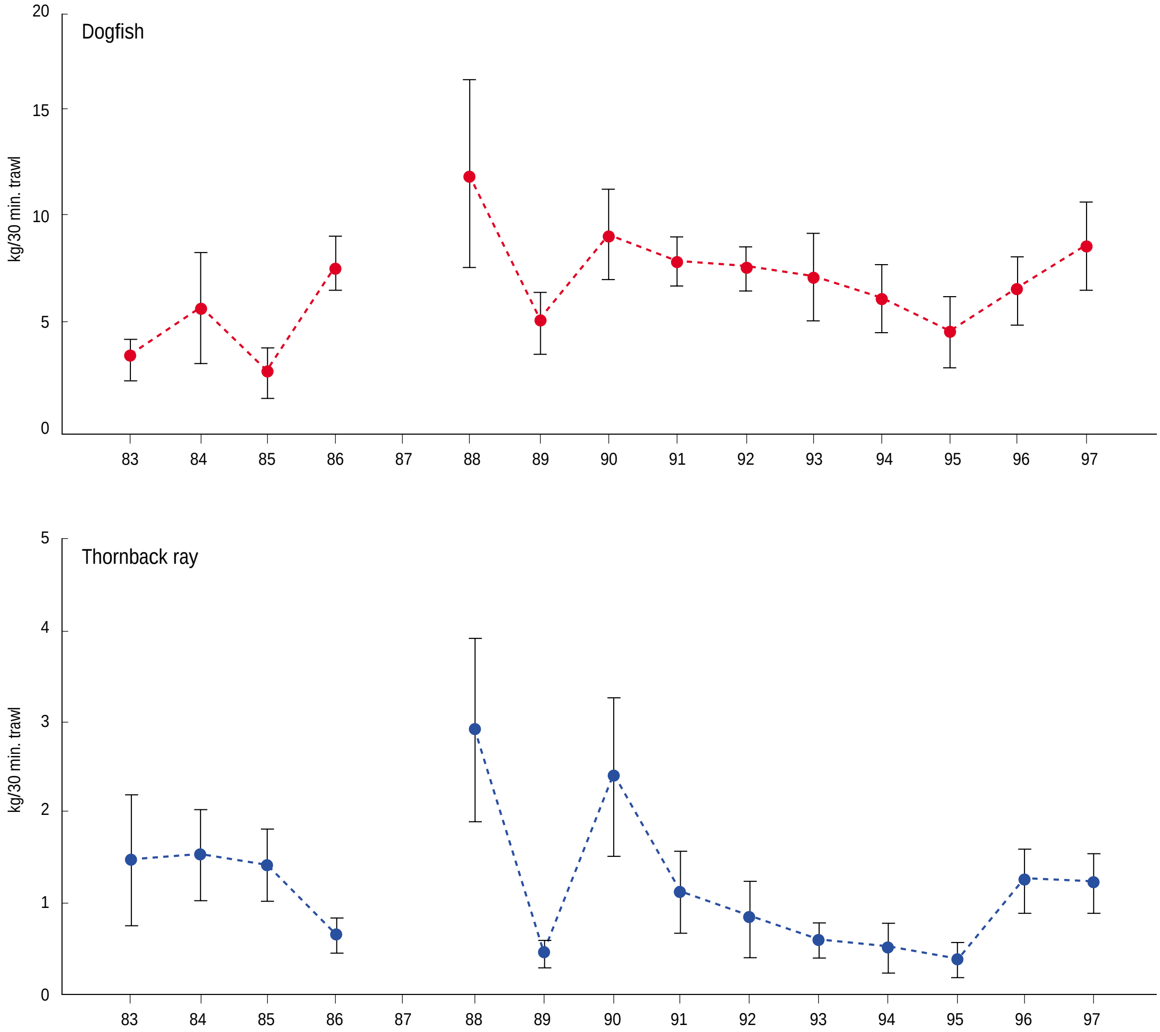


Figure 5.12 **Variations in the biomass of dogfish and thornback ray in the Cantabrian Sea, 1983–97. Source: after Sánchez (1993).**



was imported via shipments of the Japanese oyster to France in 1969 ***(Figure 5.13)***, often clogs bays and harbours and competes with other seaweeds for space. Another example is *Undaria pinnatifida* which was introduced to Europe in 1983, subsequently escaping from farms and spreading throughout the environment.

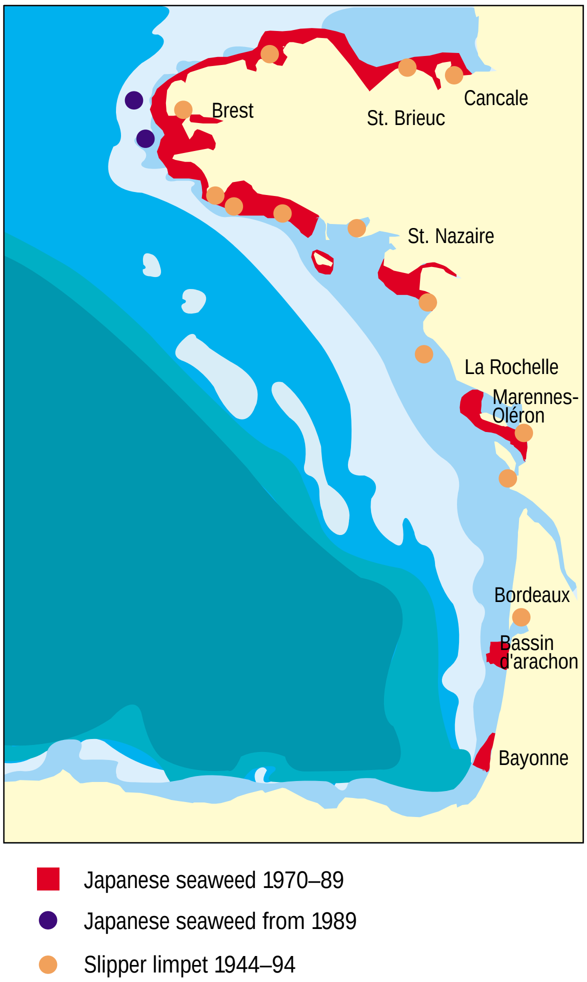
In terms of the macrofauna, the crab *Hemigrapsus penicillatus* found at La Rochelle in 1995 is a recent example of an accidental introduction. It arrived from the Far East due to fouling and has now spread over 700 km of coastline from the Vendée to the Basque Country. The slipper limpet (*Crepidula fornicata*) is thought to have negative impacts on scallop and other shellfish culture ***(Figure 5.13)***, while the barnacle *Elminius modestus*, which was introduced from Australia, may compete for space with the indigenous barnacles *Balanus* and *Cthamalus*. Large populations of Japanese oyster compete with other filter-feeding molluscs.

5.3.2 Harmful algal blooms

Some phytoplankton species produce toxins that can be harmful to both human and marine life. Their presence in high concentrations in sea water is therefore a cause for concern. Some toxic algae affect fish directly, while others produce potent neurotoxins that accumulate in filter-feeding shellfish. The consumption of such shellfish may result in fatal poisoning.

Region IV is subject to recurrent shellfish toxicity outbreaks. These are due to Amnesic Shellfish Poisoning (ASP), caused by domoic acid, Diarrhetic Shellfish Poisoning (DSP), caused by okadaic acid and its derivatives, and Paralytic Shellfish Poisoning (PSP), caused by saxitoxin-related toxins. Although there appears to have been an increase in harmful algal blooms over recent decades this is not supported by scientific studies and may just reflect the increased use of coastal waters, together with a greater public awareness of the problem and more comprehensive monitoring activities. Also,

Figure 5.13 **Distribution of the Japanese seaweed and the slipper limpet on the French Atlantic coast.**



greater economic use of coastal resources has focused interest on ecological matters, which had previously received little attention except during particularly acute toxic/noxious events.

Some toxic phytoplankton species have been introduced to Region IV via cysts in ships' ballast water, these include *Gymnodinium catenatum*, *G. chrorophorum* and *Alexandrium minutum*, which often cause PSP, and *Pseudo-nitzschia australis* which is associated with ASP.

5.4 Impact of microbiological contaminants

Sewage discharges are responsible for pathogenic bacterial and viral inputs to the sea. They pose significant human health threats via the ingestion of contaminated shellfish or exposure to contaminated water. Community Directives for bathing water quality (76/161/EEC) and for the production and marketing of live shellfish (91/492/EEC) state permissible levels of bacteria in water and shellfish.

Table 5.12 Classification of shellfish production areas in 1997 with respect to Community Directive 91/492/EEC.

	Category (%)		
	A	B	C+D
France	43.7	44.4	11.9
Spain	19.3	63.9	16.8
Portugal	25		75*

A can be sold immediately; B requires purification in an approved plant for at least 48 hours; C requires treatment in clean water for an extended period of time; D the area is forbidden for shellfish farming. * categories B+C+D.

5.4.1 Bathing water quality

The microbiological quality of bathing water has been monitored for many years in France, Spain and Portugal. In 1997 the vast majority of bathing water in Region IV was of good or fair quality; 95% in France and Spain and 87% in Portugal.

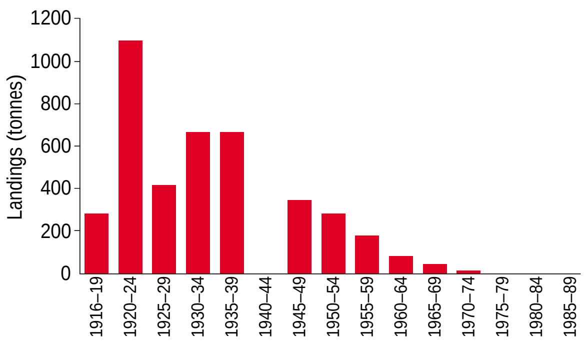
5.4.2 Shellfish quality

There are three categories of shellfish marketed for human consumption. These are based on the *Escherichia coli* and faecal coliform content; those that can be sold immediately (Category A), those that must first undergo purification in an approved plant for at least 48 hours (Category B) and those requiring treatment in clean water for an extended period of time (Category C). *Table 5.12* shows the percentage distribution for the three categories in 1997.

5.5 Impact of fisheries

Region IV includes ICES Fishing Areas VIII and IX and has traditionally been an area of intensive fishing activity, particularly with the expansion of engine-powered vessels

Figure 5.14 **Average landings of skates and rays for five-year periods at Arcachon, 1916–89. Source: after Quéro and Cendrero (1996).**



and trawling over recent decades. The region has a wider variety of fish and shellfish species of commercial interest than more northern areas and given the wider range in size and behaviour of these species, a large array of towed or fixed fishing gear must be used (see Section 3.5). Few of the fisheries target single species. Most are mixed fisheries catching several species simultaneously during each fishing operation. This creates difficulties for the management of the fisheries.

Data required for fisheries assessments on a regional scale are often sparse or deficient. Although acceptable data are available for some stocks of commercial importance internationally, they are often lacking for small-scale inshore fisheries. The effects of fishing are usually classified as direct (or short-term) and indirect (or long-term). The direct effects include the mortality of target and by-catch species of fish, shellfish, birds and marine mammals, the dumping of discards or offal, physical changes to the seabed by fishing gear, ghost fishing by lost gear and litter dumped from fishing vessels. The indirect effects include trophic changes in predator-prey relationships and energy flows, habitat alterations and genetic changes (e.g. decreased diversity).

Region IV is also an important nursery ground for hake, sardine, horse mackerel and blue whiting and therefore catches by fleets operating with gear of low selectivity often contain significant quantities of juveniles. Discards are thus a big problem as undersized fish must be returned. Quantification of discards is very difficult.

Large pelagic species such as tuna or swordfish (*Xiphias gladius*) have a very wide distribution, which includes Region IV. In the case of bluefin tuna and albacore, Region IV is a feeding area for juveniles in summer, and a traditional fishery using bait-boat and troll has developed. In 1987 pelagic trawl and drift nets began to fish this component of the stock. The swordfish fishery occurs partly in the Iberian region and is conducted with long lines.

5.5.1 Mortality in fish populations

Fisheries cause mortality. Their main effect is therefore to reduce the abundance and alter the productivity of the resources targetted. Fishing also reduces average age and length in stocks, since higher mortality means a lower probability of any individual reaching old age. This shift can be monitored by surveys at sea or by sampling catches and is a good reflection of fishing pressure. Depending on gear and fishing location, some fisheries tend to target the juvenile component of the stocks, as in the hake fishery where 75% of the catch are juveniles. When excessive, catches of immature fish may deplete the spawning stock to a point at which the sustainability of the resource is threatened. This is particularly the case for species with late maturity or low fecundity. For example, several low fecundity elasmobranches which were previously common are now virtually extinct in the southern Bay of Biscay ***(Figure 5.14)***.

Several stocks in Region IV are considered to be outside safe biological limits, meaning they have a dangerously low spawning stock biomass and are probably being exploited at an unsustainable fishing mortality rate. This is the case for hake, megrims, anglerfish, sardine and swordfish in the Iberian area, and hake in the northern part of Region IV has begun to show the same trend. Other species, such as anglerfish and megrim in the northern part, and anchovy, horse mackerel, mackerel, Norway lobster and albacore are considered to be within safe biological limits.

As shown in Section 3.5, the number of trawlers in Portugal and Spain has decreased since the early 1980s, resulting in a fall in overall fishing effort. The number of fleets operating gillnets and long lines has also declined in recent years. However, this decrease in overall fishing effort has not been reflected in fishing mortality, since this fluctuates with no apparent trend in most demersal stocks in the Iberian region ***(Table 5.13)***.

Table 5.13 Fishing mortality in 1985–7 and 1995–7.

Stock	Mean (1985–7)	Mean (1995–7)
Hake*	0.22	0.27
Anglerfish*	0.20	0.22
Megrim*	0.21	0.32
Hake†	0.45	0.37
Megrim†	0.32	0.33
Anglerfish†	ni	ni
Horse mackerel†	0.21	0.18
Sardine	0.37	0.51
Anchovy	0.57	0.81

* northern; † southern; ni no information.

5.5.2 Discards

There are other aspects of fishing mortality which are much more difficult to assess, such as death or injury due to contact with the gear or escape through the mesh, ghost fishing by lost gear (such as gillnets) and discards.

Effects of discarding on fish stocks can be assessed using models, but are much less clear for the other components of the ecosystem. Discards may enhance the provision of food for birds, demersal fish or benthic scavengers such as crustaceans and starfish. This may alter the structure of benthic communities in favour of the benthic scavengers or, in localised areas, may result in anoxia. Discards are estimated through specially designed sampling programmes.

Within ICES Divisions VIIIc and IXa, bottom trawls generate the highest levels of discards, due to the mixed species fishery and the low selectivity of the gear. Most

Table 5.14 Spanish discard data according to gear type. Source: based on Pérez *et al*. (1996).

	Year	ICES Divisions	Quarters 1	2	3	4	Mean (%)
Trawl	1994	VIIIab	36.6	40.2	55.5	56.5	48.9
		VIIIc	40.5	32.7	30.1	34.9	34.7
		IXa	28.7	67.3	73.8	54.9	59.2
		TOTAL	35.3	46.7	53.1	48.8	47.6
Long line	1994	VIIIab	2.4	21.1	0.1	12.7	12.5
		VIIIc	36.7	10.3	4.5	16.3	18.7
		TOTAL	19.6	15.7	2.3	14.5	15.6
Gillnet	1994	VIIIc	11.0	9.3	47.9	39.3	25.3
Purse seine	1994	VIIIbc east	2.8	24.0	32.5	ni	26.7
	1995		10.6	6.2	ni	ni	7.6
	1994	VIIIc west	2.0	1.4	6.3	10.1	6.4
		IXa north	0.0	0.2	0.8	2.1	0.9
		TOTAL	3.9	8.0	13.2	6.1	10.4

ni no information.

species caught in this fishery are discarded to some extent, in some cases due to their low or zero commercial value, in others because the fish are undersized or damaged (*Tables 5.14* and *5.15*). Pelagic trawl fisheries are mainly conducted by the French fleet. Although the target species (anchovy, sardine and tuna) usually comprise a high proportion of the catch, discard rates are consistently high (up to 100%) for horse mackerel.

Gillnets result in the highest proportion of damaged specimens or fish partly eaten by small crustaceans. This is because the fish may remain entangled in the nets for long periods, particularly in bad weather when the nets are left in the water. Bottom long line fisheries directed at demersal species and purse seine fisheries directed at small pelagic species have low discard rates *(Table 5.14)*.

The main fish species discarded in Region IV are the small fish silvery pout, with the medium-sized blue whiting second in importance, representing 33% of the total weight caught and 22% of the total discarded. Both species are dead when discarded. Lesser-spotted dogfish (which comprises 3.6% of total catch) is not a commercial species and so is almost totally discarded when caught. This species has a high survival rate.

Table 5.15 Portuguese discard data according to gear type. Source: Borges *et al*. (1998).

	Mean (%)	Range (%)
Crustacean trawl	83	36 – 91
Fish trawl	79	59 – 91
Pelagic purse seine	60	1 – 94
Demersal purse seine	35	1 – 86
Bottom trammel	9	2 – 92

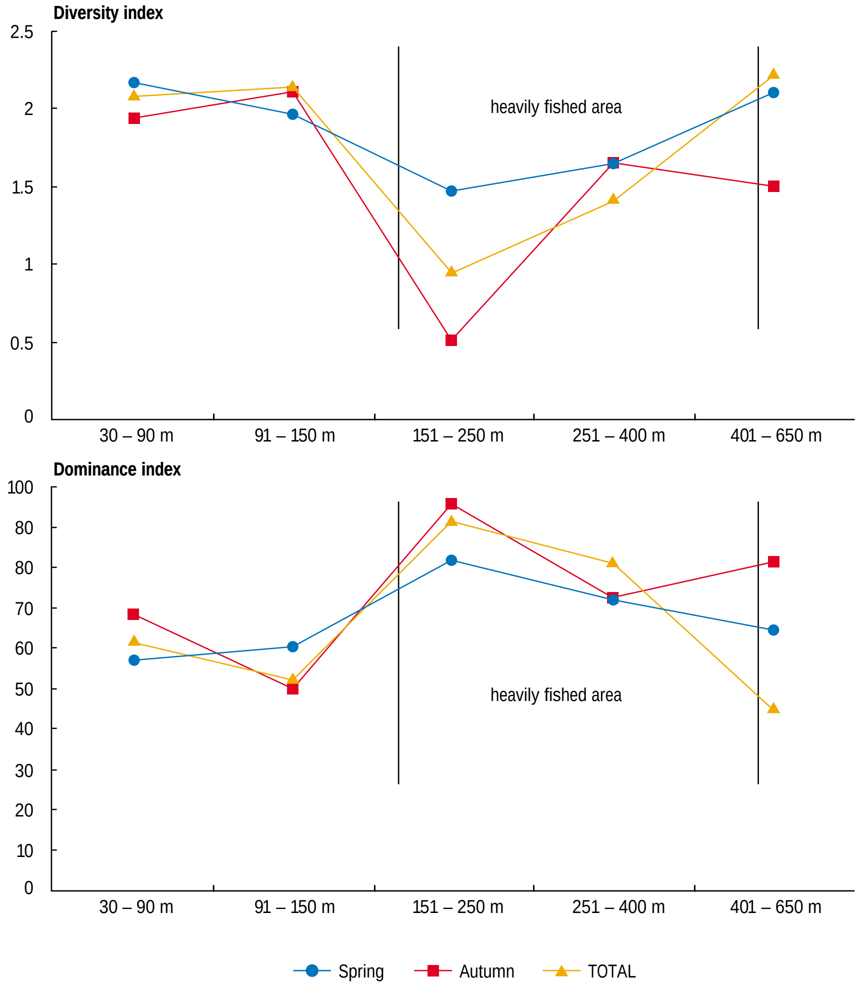
5.5.3 Effects on ecosystem diversity

The diversity of fish communities decreases in heavily fished areas *(Figure 5.15)*. In communities with a high dominance index, the dominant species are small gregarious species with high growth rates (such as blue whiting and silvery pout). Such species are the main food source for predatory demersal fish (such as hake and monkfish) which constitute the target species of the fishery. This could be interpreted as fishing intensity causing a reduction in diversity through the elimination of specialist species with low birth rates, thus altering the balance between predators and prey.

5.5.4 Effects on benthic communities

The impact on the benthic community is essentially due to the physical disturbance by fishing gear. All gear types are likely to damage the epifauna. Towed gear types can displace sediment and boulders and, depending on their weight and on the nature of the seabed, the extent to which they affect the infauna varies. Other types of trawl are also used extensively, the doors of which trench into soft bottoms. Their cumulative effects can be important. However, there have been few field studies on quantifying these effects due to their cost and difficulty.

Figure 5.15 **Diversity and dominance indices for fish communities in the Cantabrian Sea. Source: after Sánchez (1993).**



5.5.5 Effects on birds

Seabirds may benefit from fishing activities, particularly scavenging species which feed on discards. However, diving species may drown after becoming entangled in nets, although this is not a particularly significant problem in Region IV.

5.5.6 Effects on marine mammals

By-catches of cetaceans are a controversial issue concerning the gillnet fishery for albacore tuna in summer. In 1992 and 1993 (when most vessels were still allowed to fish with 5 km nets), an average by-catch of eight dolphins was estimated per 100 km of net and per day of fishing. By-catches in gillnets have been reported for several decades in the Bay of Biscay and off the Iberian coast. Cetaceans were observed as by-catches in the French tuna and sea bass pelagic trawl fisheries. Small numbers of cetaceans are known to be caught by trawlers, longlines and fish traps. The tuna fishery by-catch comprises bottle-nose and common dolphins, while the other fisheries report common dolphins only. A comparatively small by-catch of common dolphin has been reported for trawls (probably pelagic trawls) deployed in Region IV. Minke whales (*Balaenoptera acutorostrata*) occasionally become entangled in fishing trap leader-lines.

5.5.7 Feeding interactions

The most abundant species discarded in Region IV (silvery pout and blue whiting) play a significant role in the diet of fish and cetacean communities. The stomach contents of the 28 main demersal fish species showed that nineteen prey on blue whiting (eight being active predators and eleven opportunists), probably on dying, dead or decomposed individuals.

5.6 Impact of aquaculture

Aquaculture in Region IV is mainly restricted to the cultivation of oysters and mussels on moored rafts and long lines (see Section 3.6). These are usually located in semi-enclosed bays such as Arcachon, Marennes-Oléron, Bourgneuf, Vilaine and Morbihan, and rías such as Arosa and Pontevedra. At such sites the deposit of organic detritus beneath suspended mussels has increased the organic content of the sediment and changed the sediment structure. In some areas the rate of sedimentation is up to several centimetres per year. These changes may cause alterations at the ecosystem level.

Importing non-indigenous species for cultivation (see Section 5.3.1) has introduced parasites and disease. Such parasites include: *Bonamia ostrea* and *Marteilia refrigens* in oysters, and *Perkinsus marinus, Minchinia (Haplosporidium) tapetis* and *Vitorio tapetis* in clams.

5.7 Impact of eutrophication

Eutrophication results from anthropogenically-induced increases in nutrient concentration. The effects of eutrophication include increased phytoplankton production and biomass, changes in species composition (including the occurrence of harmful algae), and increased oxygen consumption in the water and sediments. According to available nutrient data (see Section 4.8.1) there is no eutrophication in the open waters of the Bay of Biscay and the Iberian Peninsula. However, high concentrations of nutrients in some estuaries (e.g. the Ría of Huelva) and the growth and accumulation of macroalgae in very shallow waters along the southern coast of Brittany may be associated with eutrophication. Although oxygen concentrations have decreased in some areas, it is only in the Bay of Vilaine that deoxygenation of the bottom water occurs each summer following the phytoplankton blooms. In some estuaries of the Cantabrian Sea and in some Galician Rías low oxygen levels near the sediment are caused by organic matter inputs from land or mussel rafts (see Section 5.6).

5.8 Impact of tourism and recreation

Tourism and recreation in coastal areas during summer are important social and economic activities along the Atlantic coast of France and Portugal. The additional services and infrastructure required can lead to a rapid degradation of coastal habitats and resources, however it is difficult to determine these impacts in detail due to poor data availability.

5.9 Impact of sand and gravel extraction

Sand and gravel extraction is an important activity along the French Atlantic coast, and the associated environmental impacts fall into three main categories: physical, chemical and biological. Physical impacts include alterations to the seabed by sediment removal, increased turbidity and the deposition of the sediment load carried by currents. The type and extent of the impact varies according to the dredging method and its intensity, and the characteristics of the extraction site. The chemical impact is minor, reflecting the low organic matter and clay content of the material extracted. The biological impact varies according to the extent of the physical impact, and concerns the disturbance and removal of the benthic fauna and its recolonization potential. Species endangered by the extraction of marine sediments are those which use the seabed for spawning or feeding. Sand and gravel extraction may also limit access to traditional fisheries. However, these impacts are minimal along the French Atlantic seafront, since they only concern a few square kilometres directly or, indirectly, a few dozen square kilometres.

5.10 Impact of dredging

Dredging occurs to enable new construction or is for the maintenance of existing channels. The material dredged is normally sand, silt or gravel. Dredged material associated with new construction only usually generates adverse effects as a result of physical and sedimentological changes. However, maintenance dredging often involves the removal of sediment that has been dumped in the relevant river, harbour, estuary or coastal region. To minimise the adverse effects of any associated contaminants, national authorities require a full description of the dredged material relative to the potential environmental impacts, and the disposal site selected must be appropriate to the composition of the material dredged. The dumping of dredged material may also affect the concentrations of suspended particulate matter and the nutrient dynamics at or near the dumpsites, particularly those in estuarine systems. The risks of contamination due to dredging are more limited in open areas than in navigation channels within estuaries. Within estuaries the tides result in the periodic resuspension/deposition of sediments, which in turn results in the metals and organic matter within the sediments being redissolved.

5.11 Impact of coastal protection and land reclamation

Coastal areas are prone to erosion. They are also the areas most likely to be affected by the consequences of climate change, particularly by rises in sea level. To protect the coast from erosion, various types of sea defences have been constructed, however to date these have been deployed regardless of any associated prediction of environmental impact (see Section 3.7). The construction of dams in rivers has also altered the hydrological pattern, resulting in a reduction in freshwater flow and sediment load, and an increase in coastal erosion. Such was the case in the Vilaine Estuary and Guadiana River in the Gulf of Cádiz (see Section 2.6.1). The potential effects of sea level rise must be addressed in future so as to ensure coastal protection for sustainable development.

5.12 Impact of offshore activities

There is no evidence that offshore activities in Region IV (see Section 3.11) have any deleterious impact on the marine environment.

5.13 Impact of shipping

Two major accidents to the north of Spain have generated public concern; the supertanker 'Monte Urkiola' was wrecked in 1976 spilling 30 000 t of oil in shallow waters (< 50 m) and the oil tanker 'Aegean Sea' was wrecked in 1992 covering the rías of A Coruña, Betanzos, Pontedeume and Ferrol with 80 000 t of oil. The effects of the Monte Urkiola oil spill were considerable, and the meiofauna on the beaches affected were totally eliminated. The abundance and diversity of the meiofauna took a year to recover *(Figure 5.16)*. The main consequences of the Aegean Sea oil spill on the benthic macrofauna were a temporary reduction in amphipods and echinoderms, and a dramatic increase in opportunist polychaetes (mainly *Pseudopolydora paucibranchiata* and *Capitella capitata*) which coincided with the period of higher hydrocarbon concentrations *(Figure 5.17)*. Cultivated mussels from 125 rafts were also affected and had to be removed. Field experiments showed that mussel growth was reduced by three to forty times, depending on the hydrocarbon concentration (i.e. high or medium) and the period of exposure (i.e. days, weeks or months). Decreases in ingestion, absorption and assimilation rates were observed, and these appear to have been a consequence of malfunctions at the cytological level in the digestive gland. Mussel cultivation resumed sixteen months after the oil spill.

Figure 5.16 **Nematode abundance on the Galician coast before (1976) and after (1977) the Monte Urkiola oil spill.**

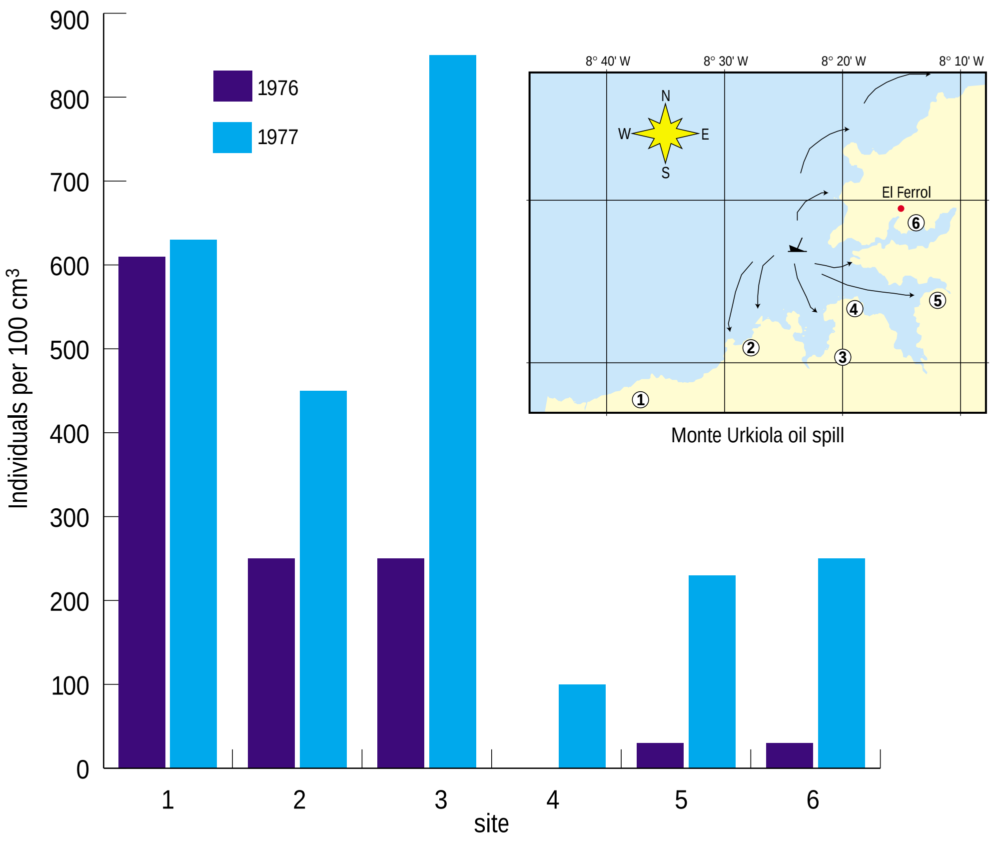
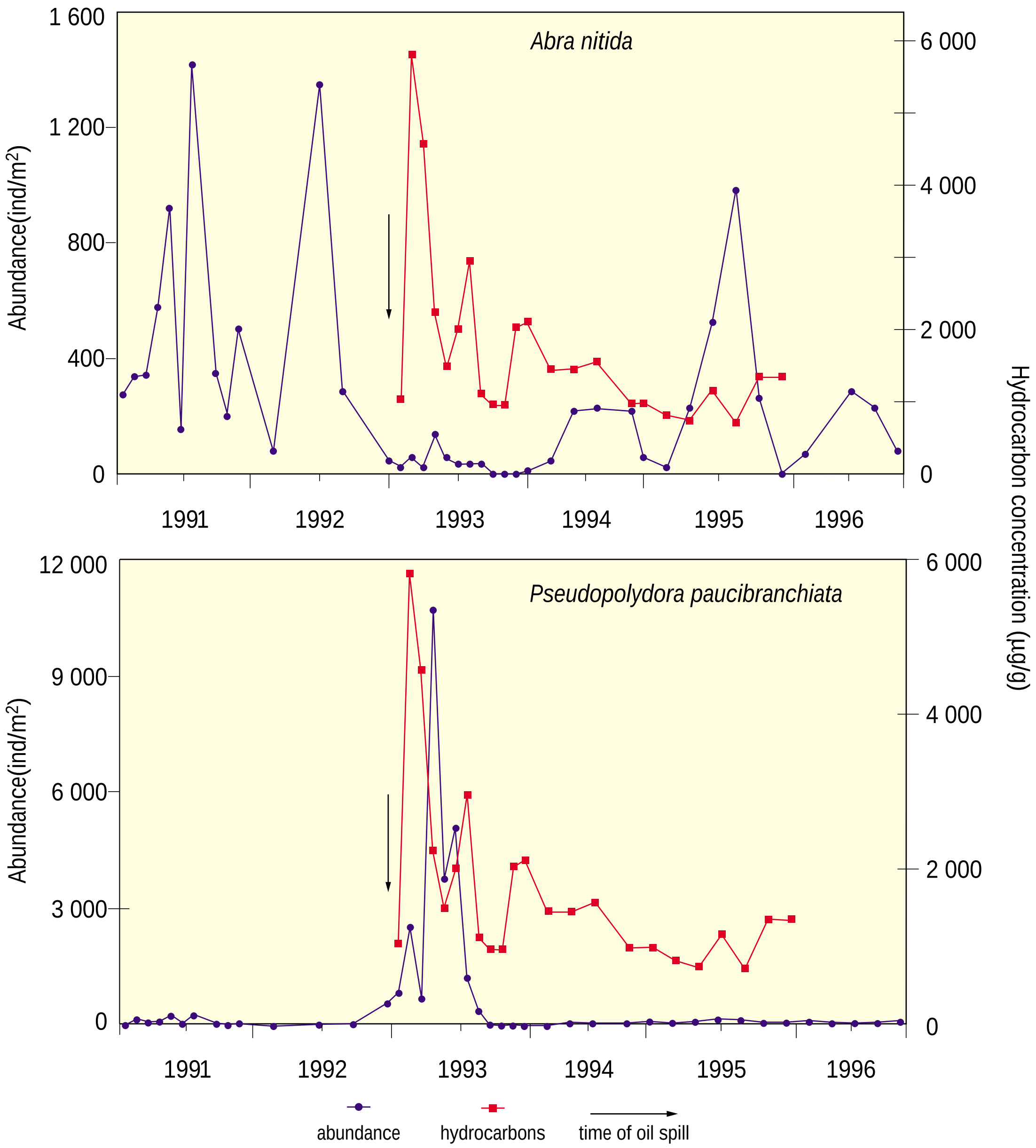


Figure 5.17 **Changes in the abundance of *Abra nitida* and colonisation of the substrate by the opportunistic polychaete *Pseudopolydora paucibranchiata* after the Aegean Sea oil spill. Source: after Parra and López-Jamar (1997).**



5.14 Impact of contaminants

The effects of contaminants at the ecosystem level are difficult to assess. Except for a few organic compounds there are no data on the direct cause/effect of individual compounds or elements in the Bay of Biscay or along the Iberian coast. Thus, BRCs and EACs (see Section 4.2) are used for assessment. Owing to the need for a standardisation of methodology, co-ordination and data interpretation, OSPAR established a Joint Assessment and Monitoring Programme for its entire maritime area.

However, data reported for the Bay of Biscay and the Iberian coast in association with the JAMP are too sparse to enable any meaningful assessment of Region IV. Thus, care should be taken when comparing levels from different areas directly, since the data provided for this report are from various national monitoring programmes or research studies carried out independently by France, Spain and Portugal and, with the exception of the JAMP data, have been used without reference to their quality assurance. With the exception of the baseline data on contaminants in sediments carried out by Spain in 1996, no other monitoring activities have been undertaken specifically for the present assessment.

5.14.1 Heavy metals

This report focuses on the small group of heavy metals included in the JAMP: mercury, cadmium, copper and lead. Data on their distribution and temporal trends are summarised in Section 4.3 and indicate that the concentrations in water, surface sediments and biota from the coastal areas are generally below those likely to be harmful to marine life. Nevertheless, for a number of metals the EACs are exceeded at sites close to densely populated and industrialised areas situated mainly in bays and estuaries.

5.14.2 Organic contaminants

The information available on organic contaminants is reviewed in Section 4.4. This includes information on PCBs, organochlorine pesticides and PAHs. Although limited the information shows low concentrations of organic contaminants in molluscs and sediments, with a few localised exceptions at sites close to highly populated and industrialised areas, mainly in bays and estuaries, where EACs are exceeded.

Various organic contaminants may induce production of the enzyme ethoxyresorufin-*O*-deethylase (EROD) in fish liver and the extent of activity can be used to measure the degree of exposure to a range of compounds, including PCBs and PAHs. EROD activity measured in dragonet (*Callionymus lyra*) and sole from coastal areas within the Bay of Biscay shows no indication of deleterious effects. However, studies in the Loire, Gironde and Vilaine estuaries indicate significant variations in EROD activity that could be caused by diffuse contamination.

The *Crassostrea gigas* embryo-larval bioassay, which was used to assess water quality in tributaries draining into an oyster farming area in Arcachon Bay, showed the percentage of normally developed larvae to vary considerably depending on the location of the sampling station. The tributaries on the southern shore of the bay (particularly the inner sites) showed enhanced toxicity, whereas only one polluted site occurred on the north-eastern shore.

Exposure to TBT (derived predominantly from antifouling paints) produces distinctive responses in various organisms, notably oysters and dogwhelks; female oysters develop male sexual characteristics, which in severe cases can lead to sterility and detrimental effects at the population level. Imposex was first observed in the Bay of Arcachon in 1975 when oyster production was significantly affected by a progressive decline in reproduction and juvenile recruitment, together with a general outbreak of shell calcification anomalies in adult oysters. Between 1975 and 1982, spatfall in the Bay of Arcachon was very low or even non-existent in certain sectors, while remaining normal outside the bay. Although TBT concentrations in the marine environment have decreased since their ban in antifouling paints in 1982, a survey in 1994 showed that concentrations in the water and sediments of sailing harbours are still high compared to concentrations in the rest of the bay.

A 1996 survey of TBT effects in dogwhelk from coastal areas off north-western Spain showed that the industrial bays and estuaries investigated had significant levels of imposex in dogwhelks. Female sterility was found in almost all the samples, although the population was not at risk of extinction. Significant levels of imposex in dogwhelk have also been reported in northern Portugal, but without female sterility.

5.15 Impact of marine litter

Marine litter has been observed at sea for many years. However, owing to the increased use of plastic packaging it is now considered a significant form of pollution. Nevertheless, its impact on vertebrate fauna has only been highlighted fairly recently. Marine litter is a worldwide problem.

Most data concern floating debris or litter washed up along the coast, particularly on beaches, where it is abundant. Marine litter comprises a range of material, including glass, plastics, metal, paper, bottles, clothing, foodstuffs, wood, rubber, packaging materials, remnants of trawl nets and other fishing gear. Plastics tend to represent around 85% of the debris owing to their poor degradability.

Plastics enter the marine environment via the recreational use of beaches, from ships, sewers, coastal run-off and from the atmosphere. Although freshly introduced plastics are buoyant, they can associate with other materials and sink to the bottom. They affect living organisms through ingestion or entanglement, and by their accumulation on the seabed where they provide a habitat for opportunistic species, thus altering the natural composition of benthic communities.

Regional information is scarce and restricted to a few areas of the Bay of Biscay. A large-scale survey of debris on the seabed of the northern section of the continental shelf *(Figure 3.8)* shows that densities vary throughout the year and are particularly high during late autumn and winter in an area offshore of the Gironde Estuary. Regional-scale studies indicate the presence of debris along the coasts of Spain and France. A particular problem exists for the French Basque Country which, owing to the general pattern of circulation, receives debris from Spain in winter and the Portugal current from late autumn to late winter. During summer the debris is from the northern part of the Bay of Biscay and from local rivers *(Figure 3.8)*.

In September 1996, around 70 000 t of debris from an urban rubbish dump fell into the sea near A Coruña. Most of the debris dissolved or sank to the bottom. Around 25 – 30% of that entering the sea was recovered. It was estimated that 5 – 10% of the debris remained at the sea surface; of which around 80% was plastics. There was no evidence of any effects on the marine fauna as a result of this accident.

The effects of litter on marine organisms, including entanglement, have been documented for the Bay of Biscay. Leatherback turtles arrive every year between June and October and autopsies on 53 from the French section between 1988 and 1998 showed that 58.4% had ingested plastic waste. Loggerhead turtles are also affected, although to a lesser extent; 27 autopsies indicated that plastic had been ingested by three individuals only.

The ingestion of large quantities of floating plastic by the mysticeti can also result in death, as demonstrated by the autopsy of a fin whale stranded on a Cantabrian beach in November 1997.

In odontoceti cetaceans the presence of plastic debris in the digestive tract is exceptional. No plastic debris was found in several hundred autopsies of Delphinidae, only once in a long-finned pilot whale (*Globicephala malaena*), and once in a pygmy sperm whale (*Kogia breviceps*). In both cases, the species feed on cephalopods and could have mistaken plastic bags for their prey.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chapter 6

Overall assessment

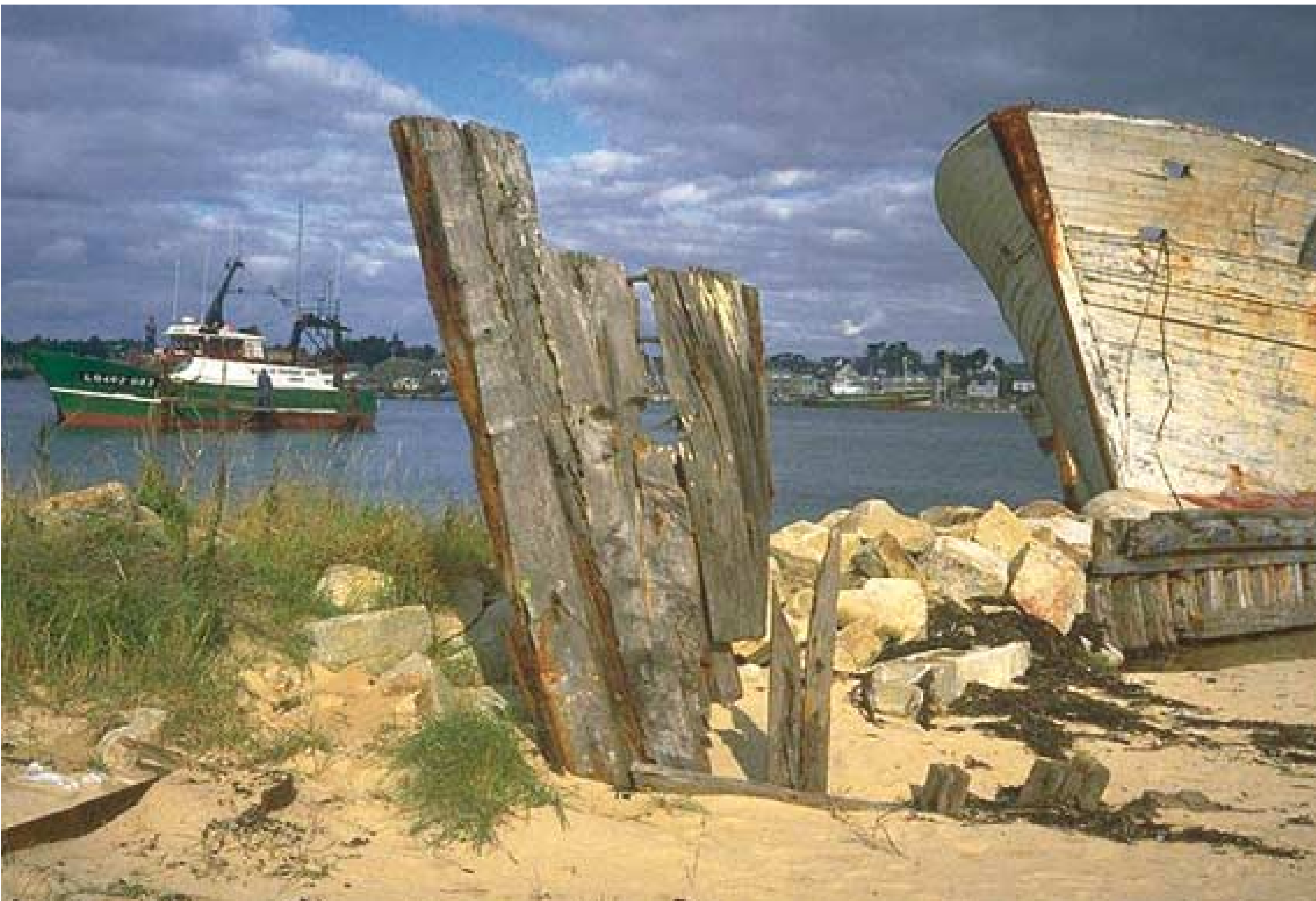
6.1 Introduction

The quality status of the open ocean and coastal zone resources of the Bay of Biscay and Iberian Coast was described in detail in the previous chapters on geography, hydrography and climate (Chapter 2), human activities (Chapter 3), chemistry (Chapter 4) and biology (Chapter 5). This final chapter presents an overall assessment of the quality status of the region.

Two general features of the region must be stressed as they influence all aspects of its character and assessment: on the one hand the lack of data and statistical information for some important human activities and their impacts, and on the other hand the naturally favourable oceanographic conditions of this part of the North-east Atlantic, with its well-oxygenated coastal waters and strong hydrodynamic processes, which have a positive influence on the ecology of the region.

The most significant features of the Region IV ecosystem are the richness and diversity of the flora and fauna. These are a consequence of:

- the biogeography, which allows a mixture of communities of boreal and subtropical origin; including at least 1000 species of phytoplankton, more than 200 species of copepod, around 700 species of fish and 28 species of cetacean;
- the diversity of the substrates and the variability of the topography which together result in a wide range of coastal habitats; and
- the high productivity of the coastal areas, enhanced by processes such as seasonal upwelling, jets and filaments and coastal runoff.



6.2 Assessment of human impacts

With regard to the impact of human activities on water quality and on the marine and coastal environment, thirteen issues were identified and assessed to varying degrees in the previous chapters. Expert judgement was used to prioritise these issues into those of high, medium or lesser importance, taking into account:

- evidence of the direct impact of human activity;
- the degree of degradation, from the large scale to the impact in local areas; and
- the level of public concern and its potential for boosting remediation policies.

6.2.1 Issues of high importance

Fishing

Region IV includes ICES Fishing Areas VIIIa, VIIIb, VIIIc and IXa and has traditionally been an area of intensive fishing activity, particularly with the expansion of engine-powered vessels and trawling over recent decades. The region has a wider variety of fish, shellfish and molluscs of commercial interest than more northern areas. Region IV is also an important nursery ground for hake, sardine, horse mackerel and blue whiting.

The extent to which natural and anthropogenic variability affects future generations of a particular species varies according to aspects of its life cycle, such as whether it has a short or long life span, for example although population fluctuations are more common in short-lived species, they are more persistent in those species for which different cohorts occur within the environment simultaneously.

Synchronous oscillations, such as the NAO, have been related to fluctuations in the recruitment index and abundance of albacore and bluefin tuna, and the intensity of upwelling within the French coastal areas of the Bay of Biscay and along the Iberian coast has a significant relationship with anchovy and sardine recruitment respectively. Sardine recruitment is also influenced by the Gulf Stream and the NAO.

Increasing sea water temperatures appear to be responsible for the appearance of tropical fish along the Iberian coast and the south-eastern shelf of the Bay of Biscay. Several tropical species (*Cyttopsis roseus, Zenopsis conchifer* and *Sphoeroides pachygaster*) have been caught throughout Region IV. During the last few years there seems to have been a change in the distribution of pelagic fish species; this occurred at the same time as the decline in the biomass of sardine stocks.

Measures

Fisheries management tools for the sustainable use of marine living resources include a progressive and significant reduction in fishing fleets, the establishment of TACs for certain species/stocks, and the adoption of technical measures to protect spawning grounds and juveniles and to avoid discards and catches of undersized fish. Taking into account the current depletion risks for several stocks, application of the precautionary approach is recommended, together with further research on ecosystem dynamics and the use of the ecosystem approach for fisheries management, in order to get a better integration of environmental policies and fisheries management.

Concerns

Several fish stocks in Region IV – sardine, hake, anglerfish, some megrims, and migratory species such as bluefin tuna and swordfish – are outside safe biological limits for sustainable fisheries (ICES, 1998). This is due to the combined effects of overfishing and the adverse effects of some natural processes on the recruitment and abundance of these resources.

Fleets operating gear with a low selectivity catch significant quantities of juveniles. As in other areas, these undersized fish are discarded. The extent to which this occurs is difficult to quantify.

Fisheries cause significant mortality. Their main effect is therefore to reduce the abundance and alter the composition and productivity of the resources targeted. This can be quantified to some extent by sampling the landings. Fishing also reduces the average age and size of the fish in the stocks, as increased mortality lowers the probability of any individual fish reaching old age.

Catches of hake, the main demersal fish species targeted in Region IV, comprise about 75% juveniles, which correlates with the poor state of the adult stock. Owing to the intensification of fishing activities since the mid-Nineteenth Century, several low fecundity elasmobranchs which were previously common are now virtually absent from the southern Bay of Biscay.

For the main fish stocks the effects of discarding can be assessed using models, but are much less clear for the other components of the ecosystem. Discards may enhance the provision of food for birds, demersal fish or benthic scavengers such as crustaceans and starfish. Discards may also alter the structure of benthic communities in favour of the scavengers.

Bottom trawls generate the most discards due to their use in mixed species fisheries and the low selectivity of the gear. The average discard rate for this fishery is about 50%, ranging from 35% in ICES Division VIIIc to 59% in ICES Division IXa. Gillnets have an average discard rate of 25% and long lines only 9%. Pelagic trawl fisheries are mainly conducted by French vessels and the target species (anchovy, sardine, hake) usually represent a large proportion of the catch, although discard rates are consistently high (up to 100%) for Atlantic horse mackerel which has a low value in France, in contrast to the situation in Spain and Portugal.

The species discarded in the greatest numbers in ICES Fishing Area VIIIc is the small fish silvery pout with the medium-sized blue whiting second in importance, representing 33% of the total weight caught and 22% of the total discarded. Both species are dead when discarded.

Climate change

The International Panel on Climate Change predicts a global rise in sea level of 25 – 95 cm (the most likely rise being around 50 cm) by 2100.

Coastal erosion and salt water intrusion into estuaries, coastal lagoons, wetlands and groundwater, represent a true degradation of the coastal environment, which is often irreversible. These effects could increase if sea levels continue to rise and especially if this rise accelerates. Impacts associated with the predicted sea level rise include enhanced coastal erosion, with the consequent flooding of extensive areas of lowlands and wetlands. Salinity in major estuaries and bays, as well as some aquifers, will increase and together with coastal erosion will cause major changes in important habitats for birds and fish.

Concerns

Over future decades it is likely that coastlines will retreat significantly in many areas and that there will also be a perceptible, permanent increase in submerged land and an increase in salt water intrusion.

Other global changes, such as air-sea gas exchanges and sea surface warming, may cause fluctuations in the NAO or changes to the coastal upwelling regime that may in turn affect the distribution, recruitment and abundance of marine species.

Sea surface warming seems to be related to the appearance of tropical fish species along the Iberian coast and the southern shelf of the Bay of Biscay.

6.2.2 Issues of medium importance

Microbiological pollution

Discharges of sewage (treated and untreated) in coastal areas, particularly estuaries, rias and coastal lagoons, affect coastal water quality. Bacteria and viruses, mainly attached to fine particulate matter, influence bathing water quality and can also accumulate in filter-feeding shellfish leading to microbiological contamination.

Measures

Data from monitoring programmes undertaken in France, Portugal and Spain in 1997, in compliance with the EC Directive on Bathing Water Quality, reveal that 87 to 95% of bathing waters were of good or fair quality. Bad water quality is currently associated with beaches near major urban sites. Where standards are not being met, action is being taken by the responsible authority within each country to improve the bacterial quality of the bathing water.

Data from monitoring programmes in shellfish farming areas, in compliance with the EC Directive on Shellfish, reveal that a small proportion of these are of good microbiological quality (Class A), a large proportion are of fair quality (Class B) and a very small proportion are of bad quality (Class C or Forbidden).

As bad quality shellfish production waters occur near outfalls discharging domestic wastewater, urban wastewater treatment plants must be improved in order to achieve the objectives of the Urban Waste Water Treatment Directive.

Marine biotoxins/harmful algal blooms

Some phytoplankton species produce potent neurotoxins that accumulate in filter-feeding shellfish and cause the toxic syndromes PSP, DSP and ASP in human consumers. There are also species which produce toxins that affect caged fish and wildlife, and non toxic species that are noxious at a high biomass. The presence of harmful phytoplankton species in sea water is clearly a cause for concern. There is no good scientific evidence linking anthropogenic activities to their occurrence, but anthropogenic inputs may influence species composition or levels of biomass. Public health authorities are aware that phytotoxins can accumulate in the edible tissues of bivalve molluscs (e.g. mussels) to levels that are dangerous to the human consumer.

Measures

In compliance with the EC Directive on the quality control of water dedicated to shellfish cultivation, France, Portugal and Spain have each established a biotoxin monitoring programme as a basis for closure orders when levels of toxins in shellfish exceed the legal standards.

Concerns

There has been an apparent increase in the frequency and intensity of toxic algal episodes in Region IV with acute shellfish toxicity resulting from the following groups of biotoxins: domoic acid (an amnesic toxin resulting in ASP), okadaic acid and derivatives (diarrhetic toxins resulting in DSP) and saxitoxin-related toxins (paralytic toxins resulting in PSP).

Those phytoplankton species resulting in shellfish toxicity are in some cases components of the natural phytoplankton communities of the region, such as *Dinophysis acuta* and *D. acuminata* (DSP), and *Alexandrium minutum* (PSP), while others, such as *Gymnodinium catenatum* (PSP) and *Pseudo-nitzschia* *australis* (ASP), have only been recorded recently and have probably been introduced to the region through ballast water from ships.

Intensive monitoring of phytoplankton and shellfish in shellfish production areas is essential in order to guarantee seafood safety and to protect public health and aquaculture resources.

There is a need for further research on toxicity and detoxification processes, phytoplankton bloom dynamics and their relation to oceanographic events, and on inputs of nutrients and organic matter of anthropogenic origin.

Tributyltin

Tributyltin pollution in Arcachon Bay, the first case of which was reported worldwide, is an example of dispersion-induced chemical contamination that has had a major impact on oyster production. In Arcachon Bay, the consequences of the TBT pollution are comparable to those resulting from previous incidents of parasitic epizootic diseases. In 1981, the cessation of all oyster farming activities was officially considered.

Exposure to TBT, derived primarily from antifouling paints, produces distinctive responses in various organisms, notably oysters and dogwhelks; female dogwhelks develop male sexual characteristics, which in severe cases can lead to sterilisation and detrimental effects at the population level. This phenomenon is known as imposex.

In 1996, a survey of TBT effects in dogwhelk from coastal areas off north-western Spain found significant levels of imposex in the industrial bays and estuaries investigated. Female sterility was found in almost all the samples, although the population was not at risk of extinction. Significant levels of imposex in dogwhelk have also been reported in Portugal, but without female sterility.

Measures

The understanding of TBT toxicity has improved considerably since the 1970s when TBT was first used in antifouling paints. The contamination of coastal waters by organotin compounds continues to be problematic; certain areas within harbours are still significant sources of contamination, with concentrations in water occasionally 200 times greater than the EAC. This contamination extends beyond the harbour areas and can affect natural mollusc populations as well as cultivated species.

Regulations concerning TBT have contributed to obvious improvements in regions where they have been properly applied. In particular, they have enabled a resumption of oyster farming. However, these regulations are to an extent limited, firstly because of their geographically sporadic application and secondly because other maritime activities (commercial, fishing or military) continue to contribute to excessive residual contamination. Numerous coasters, fishing vessels and ferries still use organotin-containing antifouling paints.

Early EC limitations on the use of tributyltin oxides in the framework of Directive 76/769 have recently been extended under Directive 99/51/EC to include total bans on use on boats in inland waterways and lakes in any free association with antifouling paints. The Community position is that the remaining use of some TBT in ocean going vessels is addressed more appropriately at IMO. Within the IMO, a general ban on organotin compounds in antifouling paints is being prepared in order to prohibit the application from 2003 and the presence of TBT on ship hulls by the 2008.

Concerns

The extent of the biological impacts observed indicate that the EC Directive regulating the use of TBT-based paints has not been effective in reducing TBT contamination, thus suggesting that the local sources are mainly larger merchant and fishing vessels, to which the current legislation does not apply.

Close attention should be paid to gathering and treating careening waste. Cleaning ship hulls by sand-blasting or by high-pressure water systems will remove toxic wastes. Harbour dredging should be monitored with great care. High concentrations of dissolved organotin compounds measured within harbours are on a par with their presence in highly contaminated sediments stirred up during dredging operations.

Coastal development

As is the case for the other OSPAR Regions, the human population in Region IV is concentrated in coastal areas, creating increasing conflict between the exploitation of natural resources and the consequent development and the need for nature conservation. The main pressures are as follows:

- a high population density and intense economic activity – approximately 36.6 million people live in the coastal areas adjacent to Region IV, and this is also where most of the economic activities and industries are located;
- high inputs of urban wastewater;
- significant changes to the morphology of the coastline – sand and gravel extraction, a reduction in sedimentary flows in rivers, as well as dredging in the main estuaries and in shallow coastal waters, have accelerated erosion in many sensitive sectors of the coastline. In some cases the regeneration of sandy beaches and the construction of artificial structures such as spurs and rock walls have been used as temporary measures to protect the shore. Over occupation of the coastline, mainly related o the expansion of urban areas, has led to the destruction of large areas of dunes and cliffs and to the consequent retreat of the shoreline, with the sea subsequently invading important agricultural areas;

- changes to the major drainage basins – dams and dredging have decreased the natural flow of sediments into the coastal zones and even to the continental shelf. The storage capacities of many rivers have been significantly regulated. Dams have interrupted the supply of sand particles to the ocean, contributing to erosion phenomena in coastal areas. Conversely, reduced river run-off due to agricultural irrigation practices can affect coastal mariculture (e.g. as has been the case for the Charente river); and
- the silting of estuaries and coastal lagoons – continuous changes to the coastline cause the silting of coastal wetlands. These areas are among the most productive in biological terms and increasing sedimentation causes these ecosystems to collapse (lagoons gradually become smaller, water quality decreases and the wetland eventually disappears).

Measures

Many of these conflicts could eventually be reduced by adopting and implementing a Code of Good Practice for Coastal Zone Management. Such a code would enable the identification of sensitive coastal areas and the adoption and implementation of measures to minimise human impact, including the enforcement of the EC Urban Waste Water Treatment Directive.

Concerns

The global rise in sea level is already affecting some coastal areas in Region IV.

Litter

The impact of marine litter on cetaceans and sea turtles, mainly plastic bags and other debris, has already been reported. Plastics represent 60 to 95% of marine litter.

Recent regional studies have shown the presence of marine litter along the coasts of Spain and France, with a particularly heavy occurrence along the coast of the French Basque Country during winter. A pilot project to establish assessment methodologies is under way in Portugal.

In terms of the larger sized items of marine litter, operations to collect floating items near the shore should be promoted in order to avoid them drifting further offshore. Approximately 80% of marine litter washing up on beaches comprises driftwood and other natural materials, for the remaining 20% (household waste) land-based collection schemes remain a priority.

Measures

Annex V to the MARPOL Convention, which entered into force December 31 1988, defines rules for the prevention of pollution from marine litter and, in particular, prohibits the ocean disposal of all plastic material. An amendment in effect since 1995 requires all ships of a tonnage equal to or exceeding 400 tonnes, and for those transporting more than 15 people, to file a waste management plan. The application of MARPOL Convention rules should be improved and better prevention of litter disposal in the catchment areas is recommended.

6.2.3 Other important issues

Heavy metals

The highest contaminant concentrations and their geographical distribution in sea water, sediments and biota, reflects the presence of urban and industrial sites in the coastal areas. These high concentrations are mainly found in estuaries, rias and semi-enclosed regions, due to their low flushing rates and to the high levels of urban and industrial activity in such areas.

The accumulation of contaminants in organisms depends on the quantities ingested and on the existence and effectiveness of specific detoxifying mechanisms. In the case of trace metals these mechanisms include metallothioneins.

The highest mercury concentrations in wild mussel were found in the Ria of Pontevedra and in the most contaminated areas of the Ria of Aveiro and the Tagus Estuary, where different industrial sources of mercury can be identified.

High lead concentrations in mussel and in peppery furrow shell were found in sea areas close to industrial or highly populated regions such as Vigo, Gijón and Bilbao, or the mouth of the Guadalquivir River.

High levels of cadmium were observed in mussel from industrialised sites of Bilbao, in Portuguese oysters from the upper Sado Estuary and in wild mussel at sites remote from urban and industrial areas on the west coast of Galicia.

Portuguese oysters from the upper Sado Estuary and the Guadalquivir Estuary are highly contaminated by copper. These very high concentrations are due to residues from mining activities enhanced by the peculiar physiology of this species. For these reasons, Portuguese oysters from these areas should not be consumed.

Metal concentrations in surface sediments are generally low to moderate. Concentrations above the EACs have been found in sediments from confined sites of the urban and industrial areas of Bilbao, (mercury, cadmium, lead and copper), Gijón (mercury, lead, cadmium and copper), Pontevedra (mercury), Vigo (lead), the Aveiro and Tagus estuaries (mercury, lead and cadmium), Huelva (mercury, cadmium, lead and copper) and the mouths of the Guadalquivir and Guadiana rivers (lead).

Concerns
High concentrations of metals in some molluscs from areas close to known sources is worrying even if there is no evidence of widespread toxic effects.

Dredging

Sediments are currently dredged in harbour areas, estuaries and navigation channels. Dredged material is usually mud, sand, silt or gravel.

In terms of the French coastal and estuarine areas of the Bay of Biscay, the annual quantity of dredged material dumped was approximately 10 x 10^6 m^3 in 1993, with about 1% representing contaminated sediments. Large harbours such as Nantes and Bordeaux account for 94% of the annual input. This material is usually dumped at licensed sites off the main harbours.

Dredging operations in Portugal have increased over the last five years. Sediment quality was assessed prior to dredging in the Tagus, Sado, Mondego and Lima estuaries and in the lagoons of Aveiro and Formosa. Most of the dredged material was dumped in the marine environment, the Portuguese authorities requiring that contaminated material be dumped in deep water. Sandy sediments contained low concentrations of contaminants, while muddy sediments had a broader range of contaminants and were highly contaminated in the vicinity of harbours and industrial sites by metals (mercury, zinc, chromium, lead) and organic compounds.

Measures
Monitoring and research on metal availability and accumulation has suggested that for most metals there is no evidence of uptake by organisms; mussel growth experiments close to dumpsites showed no influence on growth within their first year.

Changes in the nature of the substrate may affect benthic community structure and succession, and thus the type of food available for fish and shellfish.

Rational selection of disposal sites, where sand is placed on a sand bottom or mud on a mud bottom, is essential to minimise the immediate and long-term physical impacts at the site.

Biodiversity

The structure of fish communities showed low levels of diversity in some heavily fished areas (150 – 250 m and 250 – 400 m). Small gregarious species with high growth rates (such as blue whiting and silvery pout) are the dominant species and the main food resources for the demersal predatory fish (such as hake and monkfish) which constitute the target species of the fishery. This could be interpreted as the intensive fishing activities causing a reduction in diversity through the elimination of specialist species with low birth rates, thus altering the balance between predators and prey.

Impacts on the benthic community are essentially due to the physical disturbance by fishing gear. Although it is easy to list the effects qualitatively, it is difficult to quantify the overall impact at the regional scale. Even at a local scale, field studies are few owing to the cost and difficulty of data collection in deep sea areas, and no area is effectively closed to fishing to provide a control.

By-catches of cetaceans are a central issue in the controversies surrounding the summer gillnet fishery for albacore tuna in Region IV. In 1992 and 1993 (when most vessels were still allowed to fish with 5 km nets) observers were placed on board eighteen French netters for 130 trips. A total of 1420 hauls were monitored resulting in the by-catch of 204 common dolphin and 573 striped dolphin. An average by-catch of eight dolphins (both species) was estimated per 100 km of net and per day of fishing. According to recent data, between 1987 and 1997, at least 85 cetaceans died during interactions with different types of fishing gear along the Portuguese coast. Gillnets were responsible for 76% of cases, followed by beach purse-seines with a by-catch of seventeen common dolphin.

Measures
In June 1998, EU fisheries ministers voted to introduce a ban on drift net fishing for tuna to come into effect January 2002. Concern for the consequences on biodiversity (both at the species and ecosystem level) led to the establishment of several protection measures aimed at:

- preserving the biodiversity of native species of flora and fauna and their habitats, especially those considered threatened;
- promoting the investigation and spread of information on issues related to the conservation of nature in order to facilitate sustainable development; and
- creating special zones for conservation that, together with the Special Protected Areas (SPA), will be an important component of the ‘Natura 2000’ net.

These measures constitute the basis of the Habitats Directive, which has already been ratified by France, Portugal and Spain. Several coastal and marine species and ecosystems have been classified according to this Directive and now receive special protection status. Habitats such as coastal lagoons, estuaries and shallow waters deserve particular attention, and several protected areas have already been established in Region IV (maps with coastal protected areas).

The establishment of marine protected areas also represents an important tool for the preservation of biodiversity. In such areas special attention must be given to the sustainable use of natural resources and to the correct management of the ecosystem, in accordance with the Ministerial Statement produced at the 1999 OSPAR meeting in Sintra, Portugal.

Non-indigenous species

By 1996, around a hundred non-indigenous species of great taxonomic diversity (phytoplankton, macroalgae and benthos) had been recorded in the OSPAR Maritime area. Unintentional introductions via shipping (as ballast water and associated sediments, and fouling on hulls) and aquaculture are the major sources of non-indigenous species. Introductions and transfers of marine organisms for fisheries and aquaculture also include the risk of transporting competitors, predators, parasites, pests and diseases. The potential effect of an introduction is hard to predict and control methods have generally been ineffective. The most significant ecological effects of non-indigenous species are pathogenic effects and competition with indigenous species for food, space or light.

Only one non-indigenous species was deliberately introduced to Region IV – the Pacific oyster – introduced by France to cultivate for human consumption. Unfortunately, a by-product of this commercial venture was the introduction of another non-indigenous species – Japweed – that has led to some bays and harbours becoming clogged. To date, most of the non-indigenous species in Region IV have not had significant impacts on either man or the marine ecosystem.

In addition, the algae *Asparagopsis armata* has been reported in French, Portuguese and Spanish waters and *Undaria pinnatifidia* in French and Spanish waters only.

The limpet *Crepidula fornicata* is now a pest on commercial oyster beds in France. One of the best documented cases of damage to native species through international transfers is that caused by the protistan *Bonamia ostrea*. Bonamiasis is a disease of flat oysters, which was first described in 1979 in Brittany where it caused a high level of mortality in flat oyster stocks. It is now widespread in flat oyster populations, where losses due to the disease may reach 80% or more.

Measures

To minimise the problems resulting mainly from shellfish introductions, ICES established a Code of Practice for the Introductions and Transfers of Marine Organisms, which was issued in 1995.

France, Portugal and Spain have not yet put in place practices to minimise the risk of unintentional introductions via ballast water, either through national regulations or by the application of IMO guidelines.

Non-indigenous species are also a threat to biodiversity, human health and to the sustainable use of resources.

Organic contaminants

Owing to their lipophilicity organic compounds tend to leave the aqueous phase and adsorb onto suspended particles, which are then ingested by living organisms or sediment out of the water column. The accumulation of contaminants in marine organisms depends on the quantities ingested and on the existence and effectiveness of specific detoxifying mechanisms. In the case of organic compounds, these include metabolic mechanisms which reduce lipophilicity and favour excretion.

PCB concentrations in biota from the Atlantic Portuguese and Spanish coasts are relatively low, but since industrial activities are the major source of these compounds moderate to high concentrations of $\sum PCB_7$ occur at sites closest to industrial areas of Bilbao, Santander, A Coruña, the Tagus and Sado estuaries and the Gulf of Cadiz. Along the French coast the higher concentrations occur in large estuaries (e.g. the Loire and Gironde). The highest concentrations found near the Bidassoa River require further investigation.

The PCB concentrations in the sediments of estuaries, coastal lagoons and rias of Portugal and Spain are relatively low or moderate in comparison with the EACs. The highest concentrations occur at sites closest to Bilbao, Santander, A Coruña, and the Tagus and Sado estuaries.

Organochlorine pesticide concentrations in mussels from the Galician coast and the Cantabrian Sea are very low. Concentrations are moderately high in Portuguese oysters and peppery furrow shells from the mouth of the Guadalquivir River. DDE concentrations in Portuguese oysters from the Sado Estuary and in clam from the Tagus Estuary are low relative to the EAC.

The concentrations of PAHs in sediments are not high, and only in the case of phenanthrene, pyrene and anthracene are the maximum EACs exceeded. The highest levels occur in the Ria of Bilbao, and show a clear gradient within the estuary and coastal sites, with concentrations decreasing offshore.

Eutrophication/deoxygenation

The direct effect of extra nutrients in sea water is an increase in the growth of phytoplankton. If the nitrogen to phosphorus ratio also deviates from 16 : 1, this can affect the phytoplankton species composition which can in turn lead to changes in the zooplankton community structure. If the zooplankton are unable to take advantage of the additional food, the bacterial decomposition of the excess phytoplankton cells may significantly reduce the oxygen levels in the water. In some cases, the oxygen consumption is so great that anoxic conditions develop. Since this deoxygenation usually occurs near the seabed, following the sedimentation of the dead plant cells, this can result in the death of bottom living fish and benthic organisms.

The few data available on nutrients, dissolved oxygen, phytoplankton species composition and the concentration of benthic fauna indicate no evidence of eutrophication in the coastal zones of Region IV.

In restricted areas of some estuaries and coastal lagoons (the Bay of Vilaine, Arcachon, Ria Formosa and Huelva) oxygen depletion events have been recorded as the combined result of a high organic load, weak local circulation, high primary productivity and temperature. Only in the Bay of Vilaine, does deoxygenation of bottom waters occur each summer following the phytoplankton blooms.

6.3 Gaps in knowledge

Previous chapters have revealed a remarkable amount of data and information, much of which has not been compiled or assessed for management purposes. There are a number of important topics for which knowledge and understanding are relatively poor, for example:

- the lack of input data for the major contaminants, including atmospheric inputs;
- the lack of quality assurance information for a large number of contaminant datasets;
- the lack of understanding concerning the relationships between contaminant inputs, concentrations and effects data;
- the impact of fishing on benthic species and marine mammals;
- the lack of data on fishing discards for the target and non-target species;
- the lack of understanding concerning the development of toxin-forming species of microalgae and why their presence and abundance is only sometimes associated with the occurrence of toxins in shellfish;
- the risks of introducing non-indigenous species in ballast waters;
- the lack of knowledge concerning the relationship between trends in climate change and changes in the physical environment and how this might influence water movements and biological production;
- the lack of understanding concerning the role of fronts in the variability of the abundance and distribution of fish eggs, fish larvae and adult fish;
- the lack of suitable data sets for identifying temporal trends (e.g. in nutrient concentrations and plankton);
- the lack of understanding concerning interactions between fish stocks and the functioning of marine ecosystems; and
- the lack of data on contaminants in biota and on standards for impact evaluation.

6.4 Overall assessment

The naturally favourable oceanographic conditions in this part of the North-east Atlantic, with its well-oxygenated coastal waters and strong hydrodynamic processes, positively influence the ecology of the region.

Generally, the waters off the Atlantic coast of the Iberian Peninsula and in the Bay of Biscay are relatively unaffected by contamination arising from within Region IV.

Several fish stocks within Region IV – sardine, hake, anglerfish, megrims and swordfish – are outside safe biological limits for sustainable fisheries, as a result of the combined effects of overfishing and the adverse effects of some natural processes on the recruitment and abundance of these resources.

A large proportion of shellfish farming areas are affected by some microbiological pollution, which implies that most of the shellfish must undergo depuration in an approved plant before they can be marketed.

Toxic algal blooms are widespread throughout Region IV, with incidences of acute shellfish toxicity caused by amnesic toxins (ASP), diarrhetic toxins (DSP) and paralytic toxins (PSP).

Mariculture in Region IV is mainly restricted to the cultivation of bivalve molluscs (usually mussels) on moored rafts or long lines. The impact of this type of mariculture is often minimal, but in some areas the deposition of organic detritus beneath suspended mussels has resulted in benthic enrichment; with a substantial increase in the organic content of the sediments, a dramatic decrease in faunal diversity and the predominance of opportunistic organisms.

6.5 Conclusions and recommendations

Taking into account the human activities highlighted in this quality status report, their impact on the marine environment and the evaluation of existing measures, it is recommended that the appropriate authorities consider:

- establishing a Code of Good Practice for Coastal Zone Management;
- implementing the FAO Code of Conduct for Responsible Fisheries;
- increasing the use of Marine Protected Areas as tools for the integrated management of coastal zones, their living resources and the protection and conservation of biological diversity;
- promoting more studies on ecosystem functioning and the sources of variability (natural and anthropogenic), as well as on investigations into the impact of human activities on coastal and marine habitats;
- increasing research on non-indigenous species, ballast water transfers and the control of particular nuisance species;
- increasing research on toxicity and detoxification processes, phytoplankton bloom dynamics and their relation to oceanographic events, and inputs of nutrients and organic matter of anthropogenic origin;

- implementing the 1994 ICES Code of Practice on the Introductions and Transfers of Marine Organisms;
- improving the monitoring and forecasting of human impact on the marine ecosystem, identifying trends in marine ecosystems based on key species and by monitoring the state of conservation in selected areas (mainly estuaries and coastal lagoons);
- developing research and management policy programmes for all activities affecting the marine environment, including the obligatory establishment of environmental assessments for specific areas of concern related to significant effects of human activities;
- applying the precautionary approach to fisheries management;
- promoting experimental work on indigenous biota in different coastal ecosystems to establish reference levels for marine contaminants; and
- establishing national programmes aimed at the recovery of degraded coastal habitats.

SPECIES

Reference list of species mentioned in this report (sorted by common (English) name within categories and including a number of common French, Spanish and Portuguese names)

Common (English) name	Scientific name	French name	Portuguese name	Spanish name
Mammals				
Atlantic spotted dolphin	*Stenella frontalis*			
Bearded seal	*Erignathus barbatus*	Phoque barbu	Foca barbuda	Foca barbuda
Blainville's beaked whale	*Mesoplodon densirostris*			
Blue whale	*Balaenoptera musculus*	Baleine bleue	Baleia azul	Ballena azul
Bottle-nose dolphin	*Tursiops truncatus*	Souffleur	Roaz corvineiro	Mular
Bottlenosed whale	*Hyperoodon ampullatus*	Hyperoodon boréal	Bico-de-garrafa	Ballena hocico de botella
Bryde's whale	*Balaenoptera edeni*	Baleine de Bryde	Baleia de Bryde	Rorcual de Bryde
Common dolphin	*Delphinus delphis*	Dauphin Commun	Golfinho	Delfín Común
Cuvier's beaked whale	*Ziphius cavirostris*	Baleine à bec d'oie	Bico-de-pato	Cifio viviparo
Dwarf sperm whale	*Kogia simus*			
False killer whale	*Pseudorca crassidens*	Faux orque	Falsa orca	Orca negra
Fin whale	*Balaenoptera physalus*	Rorqual commun	Baleia Comum	Rorqual Común
Gervais' beaked whale	*Mesoplodon europaeus*			
Greenland right whale	*Balaena mysticetus*	Baleine franche boréale	Baleia franca boreal	Ballena franca
Grey seal	*Halichoerus grypus*	Phoque gris	Foca cinzenta	Foca gris
Harp seal	*Phoca groenlandica*			
Harbour porpoise	*Phocoena phocoena*	Marsouin	Boto	Marsopa
Harbour seal	*Phoca vitulina*	Phoque Commun	Foca Vulgar	Foca Común
Harp seal	*Pagophilus groenlandicus*	Phoque du Groenland	Foca da Gronelândia	Foca de Groenlandia
Hooded seal	*Cystophora cristata*	Phoque à capuchon	Foca de mitra	Foca capuchina
Humpback whale	*Megaptera novaeangliae*	Mégaptère	Baleia de bossas	Ballena jorobada
Killer whale	*Orcinus orca*	Orque	Orca	Orca
Long-fin pilot whale	*Globicephala melaena*	Globicéphale noir	Boca-de-panela	Calderón
Minke whale	*Balaenoptera acutorostrata*	Petit Rorqual	Baleia anã	Ballena enana
Northern right whale	*Eubalaena glacialis*			
Pygmy Sperm whale	*Kogia breviceps*			
Ringed seal	*Phoca hispida*	Phoque marbré	Foca Marmoreada	Foca anillada
Risso's dolphin	*Grampus griseus*	Dauphin de risso	Boto raiado	Calderón gris
Rough-toothed dolphin	*Steno bredanensis*			
Sei whale	*Balaenoptera borealis*	Rorqual Boréal	Baleia boreal	Rorqual negro
Short-fin pilot whale	*Globicephala macrorhyncha*	Globicéphale tropical	Caldeirão	Calderón tropical
Sowerby's beaked whale	*Mesoplodon bidens*			
Sperm whale	*Physeter macrocephalus*	Cachalot	Cachalote	Cachalote
Striped dolphin	*Stenella coeruleoalba*	Dauphin bleu et blanc	Golfinho riscado	Delfín azul
True's beaked whale	*Mesoplodon mirus*			
Walrus	*Odobenus rosmarus*	Morse	Morsa	Morsa
White whale (beluga)	*Delphinapterus leucas*	Dauphin blanc	Golfinho branco	Beluga
White-beaked dolphin	*Lagenorhynchus albirostris*	Lagénorhynque à bec blanc	Golfinho-focinho branco	Delfin de hocico blanco
White-sided dolphin	*Lagenorhynchus acutus*	Lagénorhynque à flancs blancs	Golfinho branco do Atlantico	Delfín de lomo blanco
Birds				
Atlantic puffin	*Fratercula arctica*			
Balearic shearwater	*Puffinus mauretanicus*			
Black-headed gull	*Larus ridibundus*			
Common gull	*Larus canus*			
Cory's shearwater	*Calonectris diomedea*			
European storm-petrel	*Hydrobates pelagicus*			
Great black-backed gull	*Larus marinus*			
Great cormorant	*Phalacrocorax carbo*			
Great skua	*Catharacta skua*			
Guillemot	*Uria aalge*			
Herring gull	*Larus argentatus*			
Kittiwake	*Rissa tridactyla*			
Leach's petrel	*Oceanodroma leucorhoa*			
Lesser black backed gull	*Larus fuscus*			
Little tern	*Sterna albifrons*			
Mediterranean gull	*Larus melanocephalus*			
Northern gannet	*Morus bassanus*			
Razorbill	*Alca torda*			
Common scoter	*Melanitta nigra*			
Shag	*Phalacrocorax aristotelis*			
Skua	*Stercorarius* sp.			
Sooty shearwater	*Puffinus griseus*			
Tern	*Sterna* sp.			
Yelkouan shearwater	*Puffinus yelkouan*			
Yellow-legged gull	*Larus cachinnans*			
Fish				
American John Dory	*Zenopsis conchifer*	Zéé bouclée d'Amérique	Galo branco	Pez de San Pedro americano
Anchovy	*Engraulis encrasicolus*	Anchois européen	Biqueirao	Anchoa europea
Atlantic bluefin tuna	*Thunnus thynnus*	Thon rouge	Atun rabillo	Atún rojo
Atlantic John Dory (John Dory)	*Zeus faber*	Saint-Pierre	Galo negro	Pez de San Pedro
Atlantic mackerel	*Scomber scombrus*			
Atlantic pomfret	*Brama brama*	brème de mer	Xaputa	Japuta
Axillary seabream	*Pagellus acarne*	Pageot acarné	Besugo	Aligote
Bigeye rockling	*Antonogadus macrophthalmus*			
Birdbeak dogfish (deep sea catshark)	*Deania calceus*			
Black sea bream	*Spondyliosoma cantharus*	Dorade grise	Choupa	Chopa
Black scabbardfish	*Aphanopus carbo*			
Black-bellied angler	*Lophius budegassa*	Baudroie rousse	Tamboril sovaco-preto	Rape negro
Black-mouthed dogfish	*Galeus melastomus*	Chien espagnol	Leitao	Pintarroja bocanegra
Black-spot grenadier	*Coelorhynchus coelorhynchus*	Rat	Legartixa do mar	Pez rata
Blotched picarel	*Spicara flexuosa*			
Blue whiting	*Micromesistius poutassou*	Merlan bleu	Verdinho	Bacaladilla
Blue-mouth	*Helicolenus dactylopterus*	Sébaste-chèvre	Cantarilho legitimo	Gallineta
Boarfish	*Capros aper*	Sanglier	Pimpim	Ochavo

Common (English) name	Scientific name	French name	Portuguese name	Spanish name
Bogue	*Boops boops*	Bogue	Boga do mar	Boga
Bogue	*Sarpa salpa*	Saupe	Salema	Salpa
Brown comber	*Serranus hepatus*	Serran hépate	Serrano-ferreiro	Merillo
Butterfish	*Pholis gunnellus*	Gonelle	Peixe-gonela	Pez mantequilla
Canary drum	*Umbrina canariensis*			
Chub mackerel	*Scomber japonicus*	Maquereau espagnol	Cavala	Estornino
Cod	*Gadus morhua*	Cabillaud	Bacalhau do Atlántico	Bacalao
Common dragonet	*Caliblepharis ciliata*			
Common european skate	*Raja batis*			
Common ling	*Molva molva*			
Common two-banded seabream	*Diplodus vulgaris*	Sar à tête noire	Sargo-safia	Sargo-mojarra
Conger eel	*Conger conger*	Congre commun	Congro	Congrio
Couch's seabream	*Pagrus pagrus*	Pagre commun	Pargo Legitimo	Pargo
Cuckoo ray	*Raja naevus*	Raie fleurie	Raia de dois olhos	Raya santiguesa
Dab	*Limanda limanda*	Limande commune	Solha escura do mar do Norte	Limanda
Deep-water sole	*Bathysolea profundicola*			
Dentex	*Dentex* sp.	Denté	Dentão	Dentón
Dragonet	*Callionymus lyra*	Dragonet	Peixe-pau-lira	Lagarto
Eel	*Anguilla anguilla*	Anguille d'Europe	Enguia europeia	Anguila europea
Flounder	*Platichthys flesus*	Flet	Solha das pedras	Platija europea
Four-spot megrim	*Lepidorhombus boscii*	Cardine à quatre taches	Areeiro de quatro manchas	Gallo
Goby	*Lesueurigobius friesii*			
Goby	*Lesueurigobius sanzoi*			
Great silver smelt	*Argentina silus*	Grande argentine	Argentina dourada	Peferrey
Greater forkbeard	*Phycis blennoides*	Phycis de fond	Abrótea-do-alto	Brótola de fango
Greater sandeel	*Hyperoplus lanceolatus*	Grand Lançon	Galeota major	Lanzón
Greater weever	*Trachinus draco*	Grande vie	Peixe-aranha major	Araña blanca
Greenland halibut	*Reinhardtius hippoglossoides*			
Gulper shark	*Centrophorus granulosus*	Squale-chagrin commun	Barroso	Quelvacho
Haddock	*Melanogrammus aeglefinus*	Eglefin	Arinca	Eglefino
Hake	*Merluccius merluccius*	Merlu européen	Pescada-branca	Merluza europea
Herring	*Clupea harengus*	Hareng de l'Atlantique	Arenque	Arenque
Horse mackerel	*Trachurus trachurus*	Saurel	Carapau	Jurel
Lancet fish	*Notoscopelus kroeyerii*			
Large eyed lepidion	*Lepidion eques*			
Large-scaled gurnard	*Lepidotrigla cavillone*			
Lemon sole	*Microstomus kitt*	Limande sole	Solha limao	Falsa limanda
Lesser silver smelt	*Argentina sphyraena*			
Lesser spotted dogfish (dogfish)	*Scyliorhinus canicula*			
Little scorpionfish	*Scorpaena notata*	Rascasse pustuleuse	rascasso-escorpiao	Escórpora
Long-finned gurnard	*AspitriglIa obscura*	Grondin sombre	Cabra de bandeira	Arete oscuro
Long-finned tuna (albacore)	*Thunnus alalunga*	Germon	Atum voadar	Bonito del norte
Meagre	*Argyrosomus regius*	Courbine	Corvina legitima	Corvina
Mediterranean bigeye rockling	*Antonogadus megalokynodon*			
Mediterranean scad	*Trachurus mediterraneus*	Saurel	Carapau do Mediterraneo	Jurel mediterráneo
Megrim	*Lepidorhombus whiffiagonis*	Cardine franche	Areeiro	Gallo
Monkfish	*Lophius piscatorius*			
Mullet	*Mullus* sp.			
Nilsson's pipefish	*Syngnathus rostellatus*	Petite aiguille de mer	Marinha-cabeça chata	Aguja de mar armada
Norwegian topknot	*Phrynorhombus norvegicus*	Phrynorhombe de Norvège	Bruxa norueguesa	Limanda noruega
Offshore jack mackerel	*Trachurus picturatus*	Chinchard du large	Carapau negrão	Chicharro
Pagro breams	*Pagrus* sp.			
Pearlfish	*Echiodon drummondi*			
Pearlsides	*Maurolicus muelleri*			
Pilchard	*Sardina pilchardus*			
Plaice	*Pleuronectes platessa*	Plie d'Europe	Solha	Solla
Poor cod	*Trisopterus minutus*	Capelan	Fanecao	Capellán
Pout (bib)	*Trisopterus luscus*	Tacaud	Faneca	Faneca
Ratfish	*Chimaera monstrosa*	Rat de mer	Ratazana	Borrico
Red bandfish	*Cepola rubescens*	Jarretière	Suspensório	Cinta
Red dory	*Cyttopsis rosea*			
Red gurnard	*Aspitrigla cuculus*	Rouget-grondin	Cabra vermelha	Arete
Red mullet	*Mullus surmuletus*	Rouget de roche	Salmonete legitimo	Salmonete de roca
Roughnose grenadier	*Trachyrhynchus trachyrhynchus*			
Roughtip grenadier	*Nezumia sclerorhynchus*			
Saithe	*Pollachius virens*	Lieu noir	Escamudo	Carbonero
Sand goby	*Pomatoschistus minutus*	Gobie buhotte	Caboz da areia	Cabuchino
Sandeel	*Ammodytes tobianus*	Petit lançon	Galeota menor	Pequeño lanzón
Scabbardfish	*Benthodesmus elongatus*			
Scaldfish	*Arnoglossus laterna*	Arnoglosse	Carta do Meditarrâneo	Peluda
Scorpionfish	*Scorpaena loppei*			
Sea spotted bass	*Dicentrarchus punctatus*	Bar tacheté	Robalo-baila	Baila
Seabass	*Dicentrarchus labrax*	Bar	Robalo legítimo	Lubina
Seabream	*Pagellus* sp.			
Seabream	*Sparus aurata*	Dorade royale	Dourada	Pargo dorado
Seabream	*Diplodus* sp.			
Seahorse	*Hippocampus hippocampus*	Cheval de mer	Cavalo-marinho	Caballito de mar
Shortfin spiny eel	*Notacanthus bonapartei*			
Silver scabbardfish	*Lepidopus caudatus*	Sabre argenté	Peixe-espada	Pez cinto
Silvery pout	*Gadiculus argenteus*	Merlan argenté	Badejinho	Faneca plateada
Smooth pufferfish	*Sphoeroides pachygaster*			
Snipefish	*Macroramphosus scolopax*	Bécasse de mer	Trombeteiro	Trompetero
Sole	*Solea solea (Solea vulgaris)*	Sole commune	Linguado legitimo	Lenguado común
Solenette	*Buglossidium luteum*	Petite sole jaune	Lingua-de-gato	Tambor
Spanish mackerel	*Scomberomorus maculatus*	Thazard atlantique	Serra espanhola	Carite atlantico
Spanish seabream	*Pagellus erythrinus*	Pageot rouge	Bica	Breca
Splendid alfonsino	*Beryx splendens*	Beryx	Imperador-costa estreita	Besugo americano
Spotted dragonet	*Callionymus maculatus*			
Spotted flounder	*Citharus linguatula*	Cithare feuille	Carta de bico	Solleta
Sprat	*Sprattus sprattus*	Sprat	Espadilha	Espadin
Spurdog	*Squalus acanthias*	Aiguillat commun	Galhudo malhado	Mielga
Striped mullet	*Mullus barbatus*	Rouget de vase surmulet	Salmonete da vasa	Salmonete de fango

Common (English) name	Scientific name	French name	Portuguese name	Spanish name
Swordfish	*Xiphias gladius*	Espadon	Espadarte	Pez espada
Thickback sole	*Dicologlossa cuneata*	Céteau	Língua	Acedia
Thin-lipped grey mullet	*Liza ramada*	Mulet ramada	Tainha-pataça	Morragute
Thornback ray	*Raja clavata*	Raie bouclée	Raia lenga	Raya común
Three-bearded rockling	*Enchelyopus cimbrius*			
Toadfish	*Halobatrachus didactylus*			
Transparent goby	*Aphia minuta*	Nounat	Caboz transparente	Chanquete
Tub gurnard	*Trigla lucerna*	Grondin rouge	Cabra-cabaço	Begel
Turbot	*Psetta maxima*	Turbot commun	Pregado	Rodaballo
Velvet belly	*Etmopterus spinax*	Sagre commun	Lixhina da fundura	Negrito
Wedge sole	*Microchirus variegatus*	Sole panachée	Azevia raiada	Acedia
Whiting	*Merlangius merlangus*	Merlan	Badejo	Merlán
Reptiles				
Green turtle	*Chelonia mydas*	Tortue verte	Tartaruga verde	Tortuga verde
Hawksbill sea turtle	*Eretmochelys imbricata*			
Kemp's ridley	*Lepidochlys kempii*			
Leatherback turtle	*Dermochelys coriacea*	Tortue-luth	Tartaruga gigante	Tortuga Laùd
Loggerhead turtle	*Caretta caretta*	Caouanne	Tartaruga	Tortuga boba
Lower animals				
Amphipod	*Bathyporeia guilliamsoniana*			
Amphipod	*Haustorius arenarius*			
Amphipod	*Maera othonis*			
Amphipod	*Pontocrates arenarius*			
Angular crab	*Goneplax rhomboides*			
Arrow worm	*Sagitta friderici*			
Arrow worm	*Sagitta lyra*			
Arrow-worm	*Sagitta decipiens*			
Barnacle	*Balanus perforatus*			
Barnacle	*Balanus* sp.	Balanes	Cracas	Balanos
Barnacle	*Cthamalus stellatus*			
Barnacle	*Elminius modestus*			
Basket shell	*Corbula gibba*			
Bivalve mollusc	*Chloeia venusta*			
Bivalve mollusc	*Thyasira flexuosa*			
Blue and Red Shrimp	*Aristeus antennatus*	Crevette rouge	Camarão vermelho	Gamba rosada
Blue mussel	*Mytilus edulis*	Moule commune	Mexilhao vulgar	Mejillón
Bristle worm	*Capitella capitata*			
Bristle worm	*Glycera rouxi*			
Bristle worm	*Glyceridae*			
Bristle worm	*Jasmineira caudata*			
Bristle worm	*Lumbrineris flabellicola*			
Bristle worm	*Lumbrineris impatiens*			
Bristle worm	*Nephtys cirrosa*			
Bristle worm	*Pista cristata*			
Bristle worm	*Spio filicornis*			
Bristleworm	*Phyllodoce madeirensis*			
Broad-tail shortfin squid	*Illex coindetii*	Encornet rouge	Pota voadora	Pota voladora
Brown shrimp	*Crangon crangon*	Crevette grise	Camarao negro	Quisquilla de arena
Brown shrimp	*Penaeus aztecus*			
Caramote prawn	*Penaeus kerathurus*	Crevette royale	Gamba manchada	Camarón
Carpet shell	*Tapes* sp.	Clovisse	Amêijoa	Almejas
Carpet shell	*Venerupis* sp.	Clovisse	Amêijoa	Almeja
Catworm	*Aglaephamus malmgrenis*			
Cladoceran	*Evadne nordmanni*			
Cladoceran	*Evadne spinifera*			
Cladoceran	*Penila avirostris*			
Cladoceran	*Podon intermedius*			
Cladoceran	*Podon leuckartiI*			
Cladoceran	*Podon polyphemoide*s			
Cladoceran	*Pseudevadne tergestin*a			
Clam	*Spisula solida*			
Cnidarian	*Antomastus agaricus*			
Cockle	*Cerastoderma edule*	Coque	Berbigáo vulgar	Berberecho
Common cuttlefish	*Sepia officinalis*	Seiche	Choco vulgar	Jibia
Copepod	*Acartia discaudata*			
Copepod	*Rhincalanus nasutus*			
Copepod	*Temora stylifera*			
Crab	*Bathynectes superbus*			
Crab	*Calappa granulata*			
Crab	*Dorhynchus thomsoni*			
Crab	*Hemigrapsus penicillatus*			
Crab	*Liocarcinus pusillus*			
Crevette	*Crangon septemspinos*a	Quisquilla		Camarao
Cupped oyster	*Crassostrea angulata*			
Cuttlefish	*Alloteuthis* sp.			
Cuttlefish	*Sepia* sp.			
Cuttlefish	*Sepia elegans*			
Deep sea coral	*Desmophyllum cristagalli*			
Deep sea coral	*Lophelia pertusa*			
Deep-water rose shrimp	*Parapenaeus longirostris*	Crevette rose du large	Gamba branca	Camarón de altura
Dogwhelk	*Nucella lapillus*			
Echinoderm	*Amphilepis norvegica*			
Echinoderm	*Ophiactis abyssicola*			
Echinoderm	*Phormosoma placenta*			
Edible crab	*Cancer pagurus*	Tourteau	Sapateira	Buey
Euphausiid	*Nyctiphanes couchi*			
Fan mussel	*Atrina pectinata*			
Giant red shrimp	*Aristaeomorpha foliacea*			
Grooved carpet shell	*Tapes decussatus*			
Harbour crab	*Liocarcinus depurator*			

Common (English) name	Scientific name	French name	Portuguese name	Spanish name
Isopod	*Eurydice pulchra*			
Isopod	*Idotea balthica*			
Isopod	*Idotea pelagica*			
Krill	*Meganyctiphanes norvegica*	Krill norvégien	Krill da Noruega	Krill de Noruega
Lamellibranch larva	*Tellina* sp.			
Lamellibranch larva	*Tellina fabula*			
Lamellibranch larva	*Tellina tenuis*			
Lancelet	*Amphioxus lanceolatus*			
Lancelet	*Amphioxus* sp.			
Madreporian	*Flabellum alabastru*			
Madreporian	*Flabellum chunii*			
Mantis shrimp	*Squilla mantis*	Squille	Zagaia-castanheta	Galera
Mediterranean mussel	*Mytilus galloprovincialis*			
Mollusc	*Cymbium olla*			
Mollusc	*Siphonodentalium quinquangulata*			
Mud shrimp	*Solenocera membranacea*	Crevette de vase	Camarao da vasa	Gamba de fango del Atlántico
Native/flat oyster	*Ostrea edulis*	Huître plate	Ostra plana europeia	Ostra plana
Nematode	*Metacomesoma punctatum*			
Nematode	*Sabatieria ornata*			
Nematode	*Sabatieria pulchra*			
Norway lobster	*Nephrops norvegicus*	Langoustine	Lagostim	Cigala
Octopus	*Octopus vulgaris*	Poulpe	Polvo vulgar	Pulpo común
Pacific oyster	*Crassostrea gigas*	Huître creuse japonaise	Ostra portuguesa	Ostion del Pacifico
Paddle worm	*Mysta picta*			
Pandalid shrimp	*Plesionika heterocarpus*	Crevette pandalide	Camarõe marreco	Camarone nórdico
Pandalid shrimp	*Plesionika martia*	Crevette pandalide	Camarõe marreco	Camarone nórdico
Polychaete worm	*Paradoneis armata*			
Polychaete worm	*Pseudopolydora paucibranchiata*			
Prawn	*Alpheus glaber*			
Prawn	*Palaemon serratus*	Crevette rose	Camarao branco legitimo	Camaron comun
Prawn	*Pasiphaea* sp.			
Prawn	*Processa* sp.			
Purple sea urchin	*Paracentrotus lividus*	Oursin violet	Ouriço-do-mar púrpura	Erizo común
Rayed artemis	*Dosinia exoleta*			
Sand hopper	*Talitrus saltator*			
Sandhopper	*Urothoe brevicornis*			
Scale worm	*Eunice harassii*			
Scale worm	*Eunice pennata*			
Scale worm	*Eunice vittata*			
Scallop	*Chlamys bruei*			
Sea cucumber	*Labidoplax digitata*			
Sea fan anemone	*Amphianthus dohrnii*			
Sea jelly	*Bentharca pteroessa*			
Sea louse	*Lepeophtheirus salmonis*			
Sea slater	*Tylos europeus*			
Sea urchin	*Cidaris cidaris*			
Sea urchin	*Echinus esculentus*	Oursin comestible	Ouriço-do-mar	Erizo
Shrimp	*Plesionika* sp.			
Slipper limpet	*Crepidula fornicata*			
Soft-shelled clam	*Mya arenaria*	Mye	Clame de areia	Almeja de rio
Spider crab	*Inachus* sp.			
Spider crab	*Macropodia* sp.			
Spider crab	*Maja squinado*	Araignée de mer	Santola europeia	Centolla
Sponge	*Petrosia filiformis*			
Squat lobster	*Munida intermedia*			
Squid	*Loligo vulgaris*	Calmar	Lula vulgar	Calamar
Stalked barnacle	*Pollicipes cornucopia*	Pouce-pied	Perceve	Percebe
Striped venus	*Chamelea gallina*	Petite praire	Pré-de-burrinho	Chirla
Swimming crab	*Macropipus tuberculatus*			
Tellin	*Abra longicallis*			
Tellin	*Abra nitida*			
Tellin	*Macoma* sp.			
Tunicate	*Fritillaria pellucida*			
Tunicate	*Oikopleura dioica*			
Tusk shell	*Dentalium agile*			
Unsegmented worm	*Aspidosiphon muelleri*			
Velvet swimming crab	*Necora puber*	Etrille	Navalheira-felpuda	Nécora
Venus shell	*Chamelea striatula*			
Venus shell	*Circomphalus casina*			
Wedge shell	*Donax* sp.			
Wedge shell	*Donax trunculus*			
White octopus	*Eledone moschata*	Elédone musquée	Polvo mosqueado	Pulpo amizclado
Plants				
Bladder wrack	*Fucus vesiculosus*			
Brown ribweed	*Alaria esculenta*			
Brown seaweed	*Cystoceira barbata*			
Brown seaweed	*Dictyota* sp.			
Brown seaweed	*Saccorhiza polyschides*			
Brown seaweed	*Zonaria tournefortii*			
Carragheen	Chondrus crispus	Chondrus	Musgo gordo	Condrus
Channelled wrack	*Pelvetia canaliculata*			
Dulse	*Palmaria palmata*			
Green seaweed	*Valonia utricularis*			
Green seaweed	*Ulva linearis*			
Japanese seaweed	*Sargassum muticum*			
Kelp	*Laminaria hyperborea*			
Kelp	*Laminaria ochroleuca*			
Kelp	*Laminaria saccharina*			
Kelp	*Sargassum flavifolium*			
Kelp	*Sargassum polyschides*			

Common (English) name	Scientific name	French name	Portuguese name	Spanish name
Kelp	*Undaria pinnatifida*			
Knotted wrack	*Ascophyllum nodosum*			
Micro alga	*Alexandrium minutum*			
Micro alga	*Chaetoceros affinis*			
Micro alga	*Chaetoceros didymus*			
Micro alga	*Chaetoceros socialis*			
Micro alga	*Coscinodiscus* sp.			
Micro alga	*Dinophysis acuminata*			
Micro alga	*Dinophysis acuta*			
Micro alga	*Dinophysis caudata*			
Micro alga	*Dinophysis sacculus*			
Micro alga	*Dinophysis tripos*			
Micro alga	*Distephanus speculum*			
Micro alga	*Fragilaria* sp.			
Micro alga	*Gymnodinium catenatum*			
Micro alga	*Gymnodinium chrorophorum*			
Micro alga	*Gyrodinium glaucum*			
Micro alga	*Gyrodinium spirale*			
Micro alga	*Halidrys siliquosa*			
Micro alga	*Lauderia borealis*			
Micro alga	*Leptocylindrus danicus*			
Micro alga	*Melosira* sp.			
Micro alga	*Navicula* sp.			
Micro alga	*Noctiluca* sp.			
Micro alga	*Nitzschia longissima*			
Micro alga	*Paralia sulcata*			
Micro alga	*Protoperidinium bipes*			
Micro alga	*Pseudo-nitzschia* sp.			
Micro alga	*Pseudo-nitzschia australis*			
Micro alga	*Rhizosolenia delicatula*			
Micro alga	*Rhizosolenia fragilissima*			
Micro alga	*Rhizosolenia setigera*			
Micro alga	*Schroederella delicatula*			
Micro alga	*Skeletonema costatum*			
Micro alga	*Thalassiosira fallax*			
Oarweed	*Laminaria digitata*			
Red seaweed	*Amphiroa beauvoisii*			
Red seaweed	*Asparagopsis armata*			
Red seaweed	*Caliblepharis aliata*			
Red seaweed	*Caulacanthus ustulatus*			
Red seaweed	*Ceramium ciliatum*			
Red seaweed	*Ceramium shuttleworthianum*			
Red seaweed	*Chondracanthus acicularis*			
Red seaweed	*Corallina elongat*a			
Red seaweed	*Corallina mediterranea*			
Red seaweed	*Gelidium latifolium*			
Red seaweed	*Gelidium microdon*			
Red seaweed	*Gelidium sesquipedale*			
Red seaweed	*Gelidium spathulatum*			
Red seaweed	*Griffithsia opuntiodes*			
Red seaweed	*Halopitys incurvus*			
Red seaweed	*Phyllophora heredia*			
Seaweed oak	*Phycodrys rubens*			
Serrated wrack	*Fucus serratus*			
Thong weed	*Himanthalia elongata*			
Wrack	*Cystoseira baccata*			
Wrack	*Cystoseira tamariscifolia*			
Wrack	*Fucus spiralis*			
Other organisms				
Bacteria	*Escherichia coli*			
Parasitic protozoan	*Bonamia ostrea*			
Parasitic protozoan	*Marteilia regrigens*			
Parasitic protozoan	*Minchinia lapensis*			

ABBREVIATIONS

µ (prefix)	micro, 10^{-6}
∑PAH	Sum of concentrations for individual PAH compounds
∑PCB	Sum of concentrations for individual chlorinated biphenyl congeners
∑ (prefix)	Sum (of concentrations)
°C	Degrees Celsius
ACG	Assessment Coordination Group (OSPAR)
AMAP	Arctic Monitoring and Assessment Programme
ASMO	Environmental Assessment and Monitoring Committee (OSPAR)
ASP	Amnesic Shellfish Poisoning
atm	1 atmosphere = 1.013 x 10^5 Pascal
BAT	Best Available Techniques
BC	Before Christ
Bq	Becquerel (1 disintegration per second)
BRC	Background / Reference Concentration
CB	Chlorinated Biphenyl
CCMS	Centre for Coastal and Marine Science, Plymouth Marine Laboratory
CEDRE	Centre de documentation de recherche et de expérimentations sur les pollutions accidentelles des eaux (Brest, France)
cm	Centimetre
CNRS	Centre national de recherche scientifique (France)
CPMR	Conference of Peripheral Maritime Regions
CROSS	Regional Operational Centres for Surveillance and Rescue (France)
CTD	Continuous temperature and depth
d	Day
DBT	Dibutyltin
DDD	pp'-dichlorodiphenyldichloroethane
DDE	1,1-dichloro-2-(2-chlorophenyl)-2-(4-chlorophenyl)ethene
DDT	4,4'-dichlorodiphenyl-1,1,1-trichloroethane
DGA	Direcção Geral do Ambiente (Portugal)
DSP	Diarrhetic Shellfish Poisoning
dw	Dry weight
EAC	Ecotoxicological Assessment Criteria
EC	European Commission
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
ENACW	Eastern North Atlantic Central Water
ENAM	European North Atlantic Margin project (EU MAST 3, 1996–99)
EROD	Ethoxyresorufin-*O*-deethylase
ETC/NC	European Topic Centre on Nature Conservation (EEA)
EU	European Union
FAO	UN Food and Agriculture Organization
fw	Fat weight
G (prefix)	Giga, 10^9
ICES	International Council for the Exploration of the Sea
ICN	Instituto da Conservaçao da Natureza (Portugal)
IEO	Instituto Español De Oceanografía
IFEN	Institut français de l'environnement
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
IMO	International Maritime Organization
IMPACT	Working Group on Impacts on the Marine Environment (OSPAR)
INPUT	Working Group on Inputs to the Marine Environment (OSPAR)
INSEE	National statistical office, France
IPIMAR	Instituto de Investigação das Pescas e do Mar (Portugal)
IUCN	International Union for Conservation and Natural Resources
IUPAC	International Union for Pure Applied Chemistry
JAMP	Joint Assessment and Monitoring Programme (OSPAR)
kg	Kilogramme
km	Kilometre
km^2	Square kilometre
km^3	Cubic kilometre
LSW	Labrador Sea Water
lw	Lipid weight
M	Molar mass
M (prefix)	Mega, 10^6
MARPOL	International Convention for the Prevention of Pollution from Ships (1973/1978)
MBT	Monobutyltin
ME	Ministère de l'environnement (France)
Meddies	Mediterranean water eddies
mm	Millimetre
MMA	Ministerio de Medio Ambiente (Spain)
MNHM	Musée National d'Histoire Naturelle (France)
MON	Ad Hoc Working Group on Monitoring (OSPAR)
MW	Molecular Weight
MW	Mediterranean Water
n (prefix)	nano, 10^{-9}
NAO	North Atlantic Oscillation
nm	Nautical mile
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}
PAH	Polycylic Aromatic Hydrocarbon
PARCOM	Paris Commission (now part of the OSPAR Commission)
PCBs	Polychlorinated Biphenyls
PML	Plymouth Marine Laboratory
PNOC	Programme national d'Océanologie Cotière (France)
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
RNO	Réseau National d'Observation de la Qualité du Milieu Marin
RPSI	Relative Penis Size Index
RTT	Regional Task Team (OSPAR)
s	Second (time)
SASEMAR	State Society for Maritime Safety and Rescue (Spain)
SIME	Working Group on Concentrations, Trends and Effects of Substances in the Marine Environment (OSPAR)
SNSM	National Society for Maritime Rescue (France)
SPA	Special Protection Area
SPM	Suspended Particulate Matter
Sv	Sievert (1 J kg^{-1} x (modifying factors))
SWODDIES	Slope Water Oceanic eDDIES
t	Tonne
T (prefix)	Tera, 10^{12}
TAC	Total Allowable Catch
TBT	Tributyltin
TPT	Triphenyltin
UNESCO	UN Educational Scientific and Cultural Organization
VDSI	Vas Deferens Sequence Index
W	Watt
WCMC	World Conservation Monitoring Centre (UNEP)
ww	Wet weight
yr	Year

GLOSSARY

Abyssal plain	The more or less flat region of the deep ocean floor below 4000 m, excluding ocean trenches, formed by deposition of pelagic sediments and turbidity currents that obscure the pre-existing topography
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
ASP biotoxins	The toxin domoic acid (and isomers) produced by certain species of diatoms that, if transmitted through the food web, causes a syndrome known as Amnesic Shellfish Poisoning (ASP) because it is mainly caused after the ingestion of shellfish with amnesia being the main symptom
Background/Reference Concentrations (BRCs)	The following operational definitions have been used by OSPAR to determine Background/Reference Concentrations (BRCs): concentrations eflecting 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, or 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
Bioconcentration	The net result of the uptake, distribution and elimination of a substance by an organism due to water-borne exposure
Biomass	The total mass of organisms in a given place at a given time
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
Chelator	A compound that binds ions, especially metal ions, by its several functional groups
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
Continental rise	The gently sloping seabed from the continental slope to the abyssal plain
Continental shelf	The shallowest part of the continental margin between the shoreline and the continental slope; not usually deeper than 200 m
Continental slope	The steeply sloping seabed from the outer edge of the continental shelf to the continental rise
Contour current	An ocean current flowing approximately parallel to the bathymetric contours on the ocean bottom
Contourite	Sediments deposited on the continental rise by contour currents
Convergence	An oceanic region in which surface waters of different origins come together and where the denser water sinks beneath the lighter water
Coriolis effect	This is the apparent force generated by the rotation of the Earth that is produced by the conservation of angular momentum. In the northern hemisphere this imparts a clockwise rotation to a body of moving air or water
Cross-shelf exchanges	Exchanges of water across the shelf-break between the open ocean and shelf waters
Diagenesis	The chemical and physical processes, in particular compaction and cementation, involved in rock formation after the initial deposition of a sediment
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
Ecosystem approach	The ecosystem approach (to fisheries management) involves a consideration of all the physical, chemical and biological variables within an ecosystem, taking account of their complex interactions. In the management of living resources this means that the decisions are based upon the best available scientific knowledge of the functions of the ecosystem, including the interdependence of species and the interaction between species (food chains) and the abiotic environment of the ecosystem. It could therefore imply a widening of the multi-species approach, currently used in fisheries, to encompass not only fish but also other organisms which directly or indirectly depend on fish or on which fish depend, as well as other significant biotic and abiotic environmental factors
Ecotoxicology	The study of the effects of toxic substances on the ecological function and structure of natural communities
Emission	A release into air
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
Exclusive Economic Zone (EEZ)	An area in which a coastal state has sovereign rights over all the economic resources of the sea, seabed and subsoil (see Articles 56 – 58, Part V, UNCLOS 1982)
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
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
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
Internal waves structure	Waves occurring on density surfaces within the ocean and most commonly generated by the interaction between tidal currents and the sea bed
Intrusion	Water that is intermediate in density between two contiguous water masses and so flows between them
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
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
Meddy	A mesoscale eddy of Mediterranean Outflow Water which occurs at a depth of around a kilometre in the North-east Atlantic
Mesoscale eddy	An eddy with dimensions of 10 – 200 km
Meteorology	The study of weather and climate
Methylation	The addition of a methylgroup ($-CH^3$) to a compound
Miocene	A geological epoch within the Upper Tertiary Period (*c*. 26 to 5 million years ago)
Nepheloid layers	Layers of water containing high concentrations of suspended particulate material, which are readily identified by their light scattering properties (as measured by nephelometers)
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
Oligotrophic	Pertaining to waters having low levels of the nutrients required for plant growth, and thus low levels of primary productivity
Overflow waters	Cold high density waters that spill over the relatively shallow sills that lie between Greenland, Iceland and Scotland, or flow through the deep channels dissecting these sills
pH	Quantitative measure of the acidity or basicity of aqueous or other liquid solutions
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
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
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
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
Seamount	An elevated area of limited extent rising 1000 m or more from the surrounding ocean floor, usually conical in shape
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
Sverdrup	A unit of transport used in oceanography to quantify flow in ocean currents. It is equivalent to 10^6 m^3/s.
Tectonic processes	Pertaining to movement of the rigid plates that comprise the Earth's crust and to ocean floor spreading
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.
Thermohaline circulation	Oceanic circulation caused by differences in density between water masses, which is itself determined primarily by water temperature
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
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
Tsunami	A large ocean wave, of long wavelength but small amplitude, caused by submarine volcanic or earthquake activity. When such waves encounter land they grow to catastrophic heights and cause extensive flooding and damage; commonly referred to as 'tidal waves'
Turbidite	A marine sediment deposited at the base of a submarine slope by a turbidity current
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
Wind-mixed layer	The upper layer (usually a few tens of metres deep) of sea water that shows no vertical structure in its temperature, salinity and chemical composition, due to mixing by the action of waves caused by the wind
Zooplankton invertebrates	The animal component of the plankton; animals suspended or drifting in the water column including larvae of many fish and benthic

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