Charting Progress 2
The state of UK seas








United Kingdom Marine Monitoring & Assessment Strategy

UKMMAS

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Charting Progress 2

An assessment of the state of UK seas

Prepared by the UK Marine Monitoring and Assessment Strategy (UKMMAS) community

July 2010

This printed version does not contain links or references. Readers requiring access to the downloadable electronic versions of the report chapters and each of the four Feeder Reports should visit: http://chartingprogress.defra.gov.uk. These webpages provide navigation between the summary maps, tables and chapters of this report through to the Feeder Report chapters on which they are based. The Feeder Reports are fully referenced.

Ministerial Foreword

In 2005, the UK Government and the Devolved Administrations published *Charting Progress*, which provided the first overall assessment of the state of our seas. It also identified gaps in knowledge about the marine environment and proposed actions, which have since been implemented, to improve the way we monitor, gather information and assess the state of our seas.

The UK Marine Monitoring and Assessment Strategy (UKMMAS) community, which has prepared *Charting Progress 2*, was established in response to *Charting Progress* to provide a more structured and co-ordinated approach to the assessment and monitoring of our seas. *Charting Progress 2* illustrates the changes since 2005 and the advances we have made towards our shared vision of 'clean, healthy, safe, productive and biologically diverse oceans and seas'. It reports data for the eight regional seas.

As the lead Ministers for the Marine Science Co-ordination Committee, we welcome *Charting Progress 2* and are confident that it has a broader evidence base and provides a more robust and reliable assessment of the state of our seas than the 2005 report. The data for *Charting Progress 2* have been gathered by scientists from marine agencies, research institutes, universities, environmental organisations and industries across the UK. All the data have been peer-reviewed by independent national or international scientists and UKMMAS has reported confidence in the findings, as well as identifying any gaps in knowledge.

Charting Progress 2 gives us the evidence for our seas, which we need to inform policy decisions on their future management. It also provides the foundation for the initial assessment required by the EU Marine Strategy Framework Directive in 2012. This Directive requires us to ensure that we are taking measures to achieve 'Good Environmental Status' for our seas by 2020. It focuses our efforts towards a common goal and enables the international collaboration that is vital to achieving the vision we share for the sustainable use of our seas.

With *Charting Progress 2*, the UKMMAS community has also published a summary leaflet giving a map-based overview of the findings. The web version of *Charting Progress 2* at http://chartingprogress.defra.gov.uk has links to the technical Feeder Reports which open up the data for the assessment to everyone. There are also links from Google Earth to the findings.

We have published a Government Commentary on *Charting Progress 2*, available at www.defra.gov.uk/environment/marine. This highlights the important messages coming from UKMMAS's work and our approach to them and also identifies where we need to improve knowledge or reduce uncertainty before we can make policy and management decisions.

We would like to thank the many organisations and individual scientists who have contributed to make *Charting Progress 2* the authoritative report on the state of our seas and a model for others worldwide.

Richard Benyon

Parliamentary Under-Secretary for Natural Environment and Fisheries

Edwin Poots

Minister of the Environment, Northern Ireland

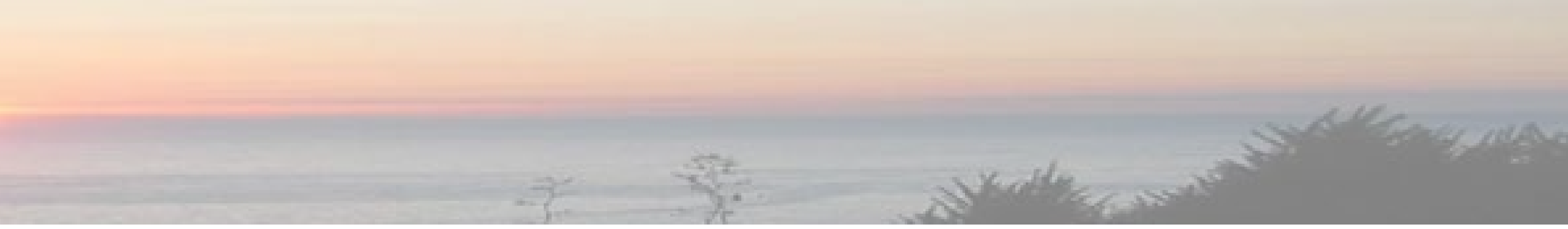
Richard Lochhead

Cabinet Secretary for Rural Affairs and the Environment, Scotland

Jane Davidson

Minister for the Environment, Sustainability and Housing, Wales

Contents



Executive Summary

Chapter 1: Aim of the Assessment

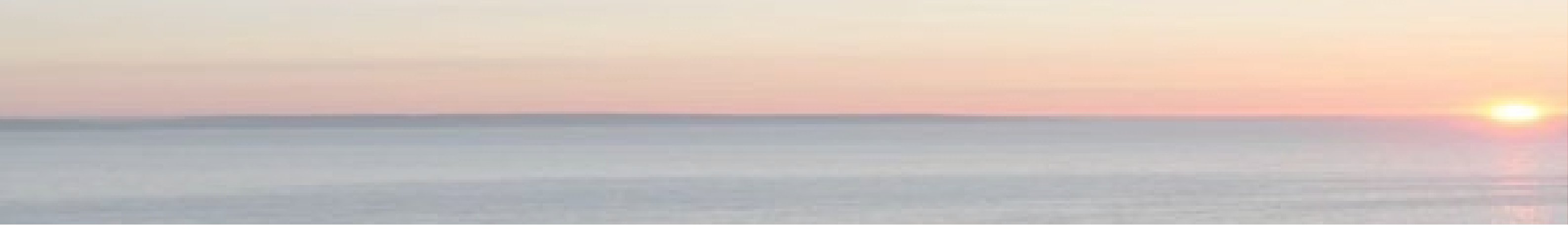
The UK seas are rich in marine life and natural resources, which are the basis for a considerable level of economic activity. In 2002, the UK Government and the Devolved Administrations set out a vision of clean, healthy, safe, productive and biologically diverse oceans and seas. The first UK-wide assessment of progress towards that vision, *Charting Progress*, showed in 2005 that the UK seas were productive and supported a wide range of ecosystems, but it also revealed that human activities were adversely affecting marine life.

This second report on the state of the UK seas, *Charting Progress 2*, provides a considerably improved assessment of the productivity of our seas, and the extent to which human uses and natural pressures are affecting their quality – addressing the specific species, habitats and economic issues of the eight UK marine regions. It helps show whether current environmental protection measures are working, and aims to provide policy makers, planners and the public with a clear evaluation of our progress towards the vision.

The findings are based on a wide-ranging and robust evidence base compiled by UK government agencies, the research community (including marine institutes and universities), non-governmental organisations and industry. The assessment highlights where we are making improvements; where environmental problems remain or deterioration has occurred; issues for which the evidence is lacking; the robustness of the assessment tools; and important gaps in our knowledge together with how these might be addressed.

Changes in the state of the seas take place over relatively long timescales, so we have found few such changes in the five years since *Charting Progress*. However, there have been some significant improvements. We have sought to set these changes in the context of long-term trends where possible. We have also considerably improved our methodology for the assessment. Unlike *Charting Progress*, this report also provides a specific assessment of the productive use of our seas, as well as a chapter focused specifically on the impacts of climate change.

Although some uncertainties remain, *Charting Progress 2* provides a much broader, more authoritative and more transparent assessment of the state of the UK seas, which will help efforts to safeguard marine ecosystems for generations to come and in doing so ensure their long-term sustainable use.



Chapter 2: Ocean Processes

The main changes in ocean processes over the past few decades are largely due to the effects of rising sea surface temperature, rising sea levels and ocean acidity. The changes are already affecting some sensitive ecosystems and could have significant long-term impacts.

Key findings

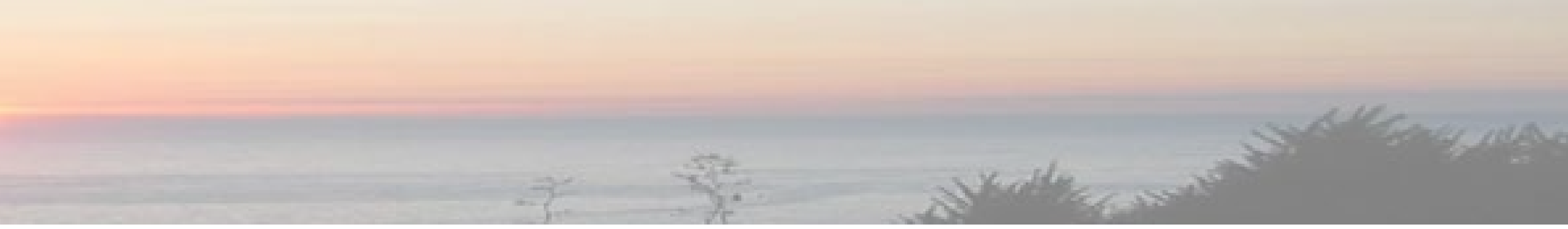
- Sea-surface temperatures around the UK have risen by between 0.5 and 1 °C from 1870 to 2007, with much of this change having occurred since the mid-1980s. This reduces the ability of the ocean to hold oxygen and to soak up carbon dioxide (CO_2); forces certain species to adapt, move or suffer detrimental consequences; and contributes to rising sea level. There is extensive coastal erosion around parts of the UK and a decrease in the intertidal area (known as 'coastal squeeze'), caused at least in part by the presence of hard coastal defences. This in turn is causing loss of land, property and coastal habitat, particularly saltmarshes and mud flats, which are also bird feeding grounds.
- Over the 20th century, mean and extreme sea levels rose in tandem by about 14 cm. Sea level rise increases the risk of flooding, and infusion of land with salt. It also allows larger waves to approach the shore leading to more erosion, damage and risk to coastal structures.
- UK seawater is probably becoming more acidic, mirroring the global pattern. This could affect many marine species. Acidification also decreases the ability of the oceans to take up human emissions of CO_2, which may affect the rate of global warming.
- The Atlantic Meridional Overturning Circulation, which is partly responsible for the temperate UK climate, is extremely variable, and it is not clear whether it has yet shown the longer term decline suggested by most climate models. It continues to contribute to the UK's temperate climate.

Improvements in assessment methodology and future requirements

Since *Charting Progress*, we have made considerable progress in our ability to assess the state of ocean processes through more comprehensive datasets, and improved models and their more widespread application. Many new monitoring projects have greatly helped our assessments, notably RAPID, which monitors the Atlantic Meridional Overturning Circulation (AMOC); the deployment of FerryBox equipment; more extended observatory time-series and the recently introduced measurements of pH and dissolved CO_2 concentrations. To get a more robust picture, it will be necessary to maintain existing time-series, and to improve the resolution, scope and representation of ocean processes by the models. Beyond that, we will need to reassess the location and extent of our observations, using models to determine the best coverage from the point of view of costs and benefits.

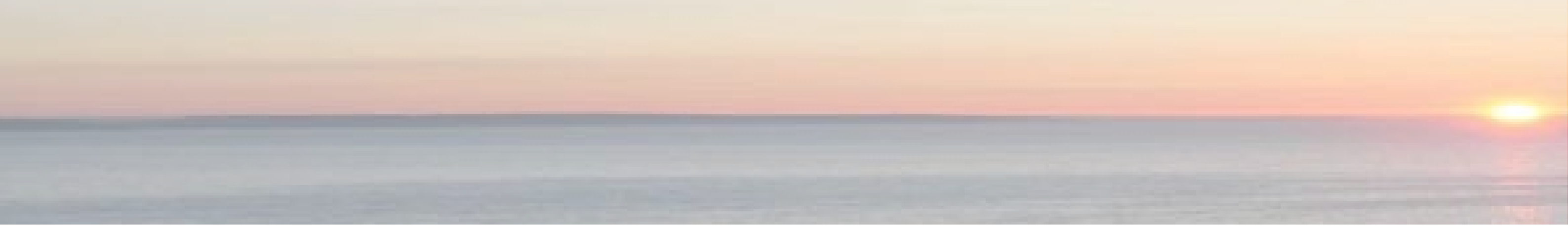
Gaps in knowledge

Gaps in knowledge associated with ocean processes are addressed under *Climate Change*.



Ocean Processes - Summary assessment

Trend in variable assessed	*Status in UK atmosphere and seas*	*Influencing factors and significance for UK seas*
Air temperature Upward trend	**Rising in all regions** UK annual mean temperature has risen by about 1 °C since the beginning of the 20th century. 2006 was the warmest year in central England since records began in the 17th century	**Influencing factors** Global climate change mostly resulting from anthropogenic greenhouse gas emissions **Significance** Raises sea temperature
Sea temperature Upward trend	**Rising in all regions** Sea-surface temperature has risen by between 0.5 and 1 °C from 1870 to 2007. Warming since the mid-1980s has been more pronounced in Regions 2, 5 and 6 (Southern North Sea, Irish Sea, Minches and Western Scotland)	**Influencing factors** Air temperature **Significance** Reduces the ability of the oceans to take up CO_2, affects certain species, e.g. forcing them to move or adapt, and contributes to rising sea level. Shifts in plankton populations on which most marine animals feed are associated with temperature rise
Sea level Upward trend	**Rising in all regions** Mean sea level around the UK coast rose by about 1.4 mm per year during the 20th century	**Influencing factors** Temperature (the greater effect to date) and melting land-based ice (potentially more important in future) **Significance** Intertidal habitats and groundwater regimes are affected, and the flooding risk for vulnerable coastal populations will increase, notably in Region 2 (Southern North Sea), if upward trends continue
Carbon dioxide and ocean acidification Upward trend	**Acidification in all regions** Oceans are acidifying (pH decreasing) as CO_2 is absorbed. In UK waters we have no baseline measurements of pH against which changes can be judged, and it will be some time before we can make accurate judgements about the rate of acidification relative to natural annual and interannual cycles of pH	**Influencing factors** CO_2 which is present naturally and released from anthropogenic sources (e.g. combustion of fossil fuel). Various climatic factors influence its concentration in the sea **Significance** There are potential threats to marine species and ecosystems if acidification continues
Circulation, suspended particulate matter, turbidity, salinity and waves No significant trend	**Variable** These processes vary on daily to interannual timescales but show no significant trend over the past decade, except for a slight salinity decrease in Region 2 (Southern North Sea) and a slight increase in salinity in the northern Regions 1, 7 and 8	**Influencing factors** *Circulation:* tides and weather, especially winds *Salinity:* rainfall near the surface and near river outflows; adjacent Atlantic salinity **Significance** *Suspended particles:* can reduce light availability and inhibit plant growth *Waves:* the main cause of damage to offshore and coastal structures

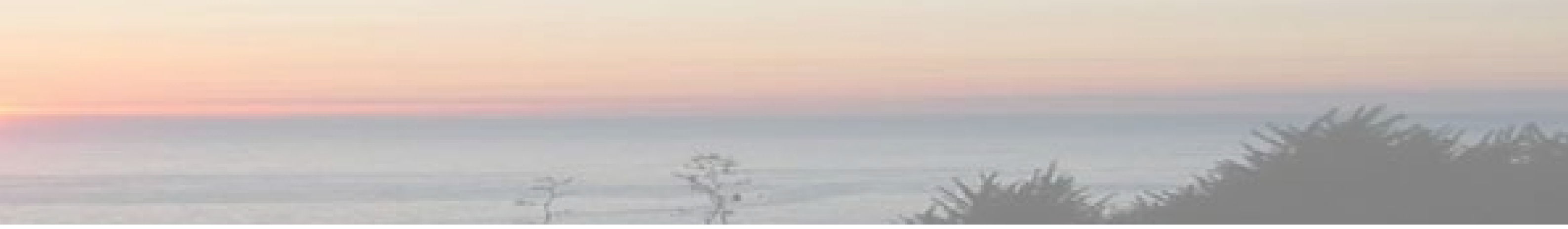


Chapter 3: Healthy and Biologically Diverse Seas

We are making some progress towards our vision of healthy and biologically diverse seas. There have been recent improvements in some fish communities in most regions: probably linked to a reduced amount of fishing. There have also been long-term improvements in waterbird populations since the 1970s, but climate change is now causing waders to over-winter on the coasts of mainland Europe rather than in the UK. Marine industries are generally well regulated and the pressures they impose on habitats and species tend to be small and localised, but the impacts of climate change and fishing have a much larger footprint. For example, although fishing has a significant economic value and is of benefit as a food source, mobile fishing gear has adversely affected large areas of the seabed. There have been declines in seabird and harbour seal populations in some regions but the reasons for this are not fully understood.

Key findings

- The habitats assessment suggests that intertidal rocky and nearshore subtidal rocky habitats (see Habitats map on Page xii), which cover a small area of the UK seas and coasts, are in reasonable condition. However, rising seawater temperatures are already affecting species composition in the English Channel and Celtic Seas. Many seabed sedimentary habitats in large areas of the North Sea, the Western Channel and Celtic Sea, and the Irish Sea have been adversely affected, particularly by mobile fishing gears.
- Although there is some way to go before the exploitation of the majority of commercial fish stocks is at safe levels, there have been some improvements, probably because of a reduction in fishing effort. There are also signs of improvement since *Charting Progress* in the marine fish community. However, a number of species are suffering sharp declines, particularly sharks and rays, which are especially vulnerable to fishing pressure. Overall, the situation is still considerably worse than historical conditions. For estuaries, there have been improvements in certain species, probably as a result of better management and pollution control in recent years, but eel recruitment has declined in some regions, reflecting an Atlantic-wide downturn in the numbers of elvers returning to rivers.
- Harbour seal numbers in some areas have declined dramatically since 2001. The causes are not clear, but contributory factors could be either natural or anthropogenic or both and include competition with grey seals, predation by killer whales around the northern islands of Scotland, declines in important prey species (such as sandeels) and unregulated shooting in some local areas.
- There have been improvements in waterbird communities, but the numbers of some seabird species have been falling since the mid-1990s. Certain seabird species (e.g. kittiwakes) have suffered poor breeding success in recent years because of shortages in the availability of their prey species – sandeel. This is probably due to the combined effects of climate change and fishing. There is strong evidence of a rapid change in the wintering distribution of estuarine birds in response to global warming during recent years, which may explain recent declines in the numbers of some wader species in some regions.



Improvements in assessment methodology and future requirements

The wider scope of this assessment compared to *Charting Progress* and the link to pressures that are causing problems, are major contributions that should help determine exactly what we mean by healthy and biologically diverse seas and where actions need to be taken. This has also enabled us to identify the areas requiring more detailed assessments in the future.

Most of the assessments are based on expert judgement or a combination of expert judgement and a range of state and pressure indicators. Some of the assessments carry low confidence because of a lack of knowledge, data and assessment tools and this will need to be addressed.

Gaps in knowledge

We need to develop a better understanding of the causes of the decline of harbour seal populations in the north and east of Scotland in order to develop effective management measures to protect them.

We have gaps in our basic understanding of certain fish species, such as lampreys, sturgeon and shad, and need to know more about the causes of decline in salmon and eel recruitment in some catchments.

We need to know more about the links between human activities and the marine environment, particularly the cumulative impact of several activities in one area and the ability of a species or habitat to recover once a pressure has been removed. This will enable us to develop better measurement tools and to influence what the state of the marine environment should be in the future. We also need better models that integrate more fully the biological and physical components with the pressures at different scales.

In addition, we need better data on those habitats where there is a lack of knowledge. To get a better assessment of the status of microbes, turtles and cetaceans, we would need new, targeted and long-term monitoring programmes.

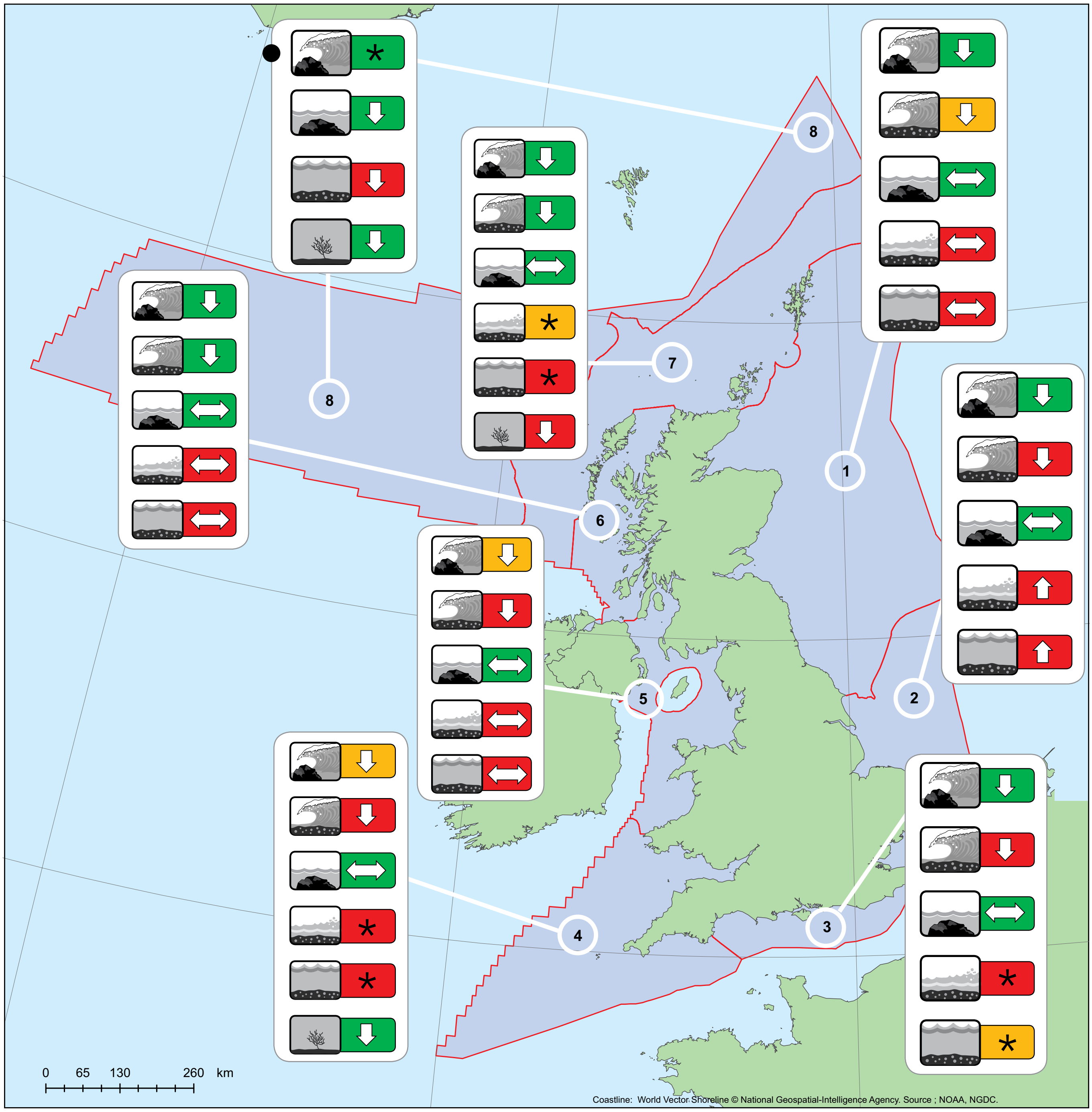
Current habitat maps cover only 10% of the UK continental shelf and we are forced to rely on modelling for the rest. For future assessments we will need to improve the accuracy, resolution and scope of these habitat maps by undertaking more surveys and making the existing data more widely available.

Summary maps

The maps on Pages xii and xiii display the status and trends of the healthy and biologically diverse components of the eight regions. For further details see the Chapter 3 summary table on Pages 56 and 57 and for further information on how 'traffic light status' and trend arrows have been assigned see Page 9 (*Communicating the findings*).

Note: In some cases an assessment has not been possible. This is also the case in the clean and safe seas assessment. Further details are found in the Chapter 3 and Chapter 4 summary tables on Pages 56/57 and 86/87, respectively.

Healthy and Biologically Diverse Seas – Habitats



Regional sea boundaries

1. Northern North Sea
2. Southern North Sea
3. Eastern Channel
4. Western Channel and Celtic Sea
5. Irish Sea
6. Minches and Western Scotland
7. Scottish Continental Shelf
8. Atlantic North-West Approaches

Intertidal rock

Intertidal sediments

Subtidal rock

Shallow subtidal sediments

Shelf subtidal sediments

Deep-sea habitats

Few or no problems

Some problems

Many problems

Stable

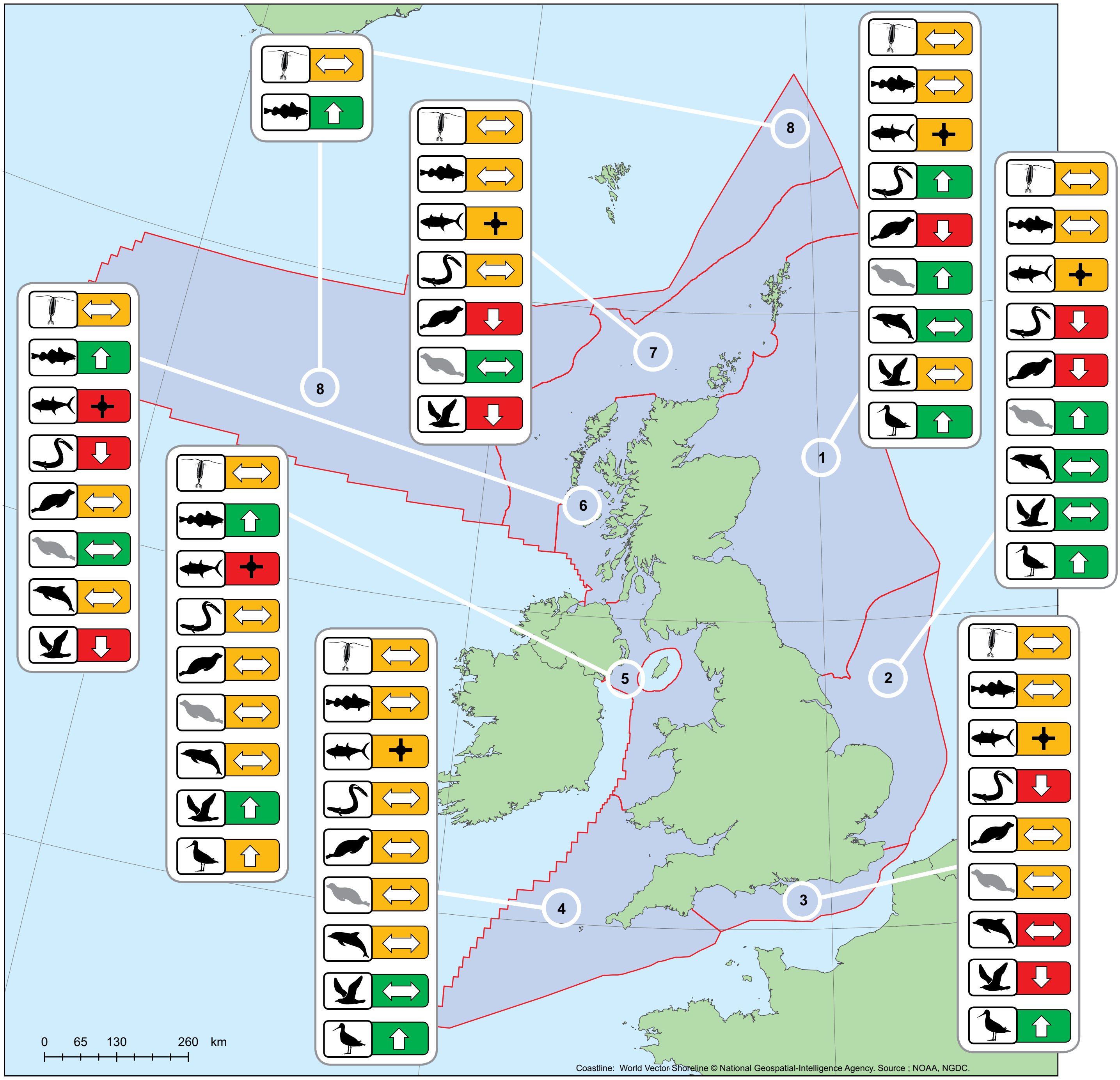
Improvement

Deterioration

No trend information available

Rockall Island

Healthy and Biologically Diverse Seas – Species



Regional sea boundaries

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8. Atlantic North-West Approaches

Plankton

Bottom-living marine fish

Commercial fish stocks

Estuarine fish

Harbour seals

Grey seals

Cetaceans

Seabirds

Waterbirds

Few or no problems

Some problems

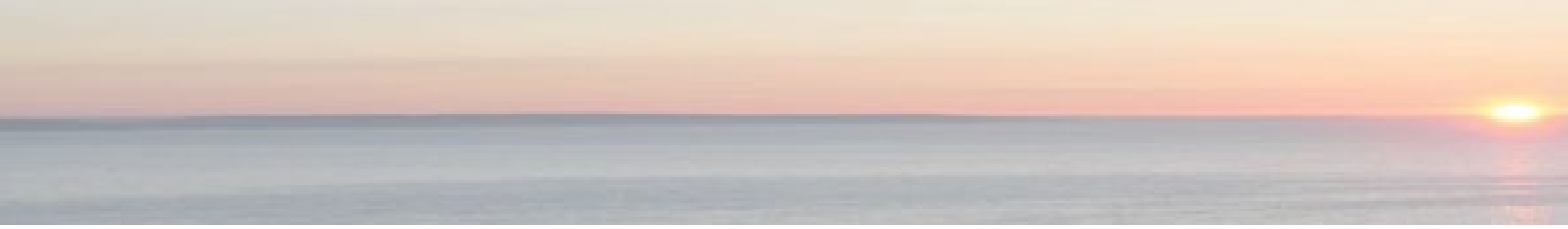
Many problems

Stable

Improvement

Deterioration

Trend for each region not assessed

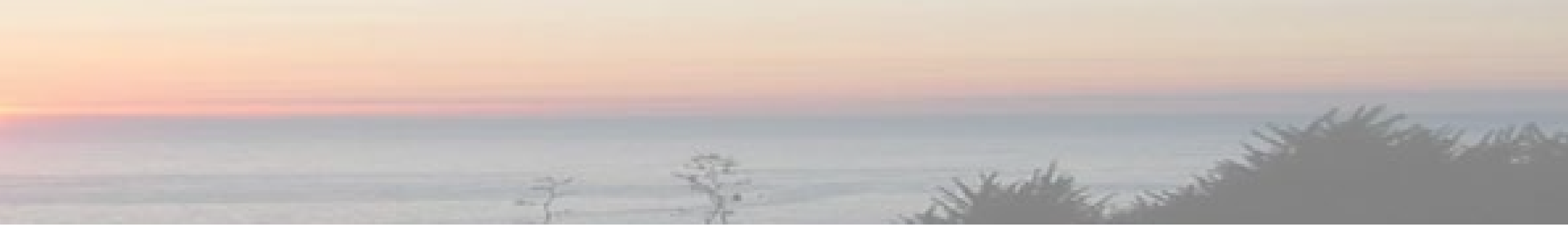


Chapter 4: Clean and Safe Seas

We are making good progress towards our vision of clean and safe seas. The open seas are still little affected by pollution, and improved regulation and practices have reduced the inputs of a range of contaminants. Most problems are local in nature, particularly in industrialised estuaries and coasts, and generally associated with historic discharges and emissions from industry and agriculture. However, we are still finding man-made chemicals in environmental samples, and need to keep gathering data to assess their potential impacts and the need for further controls. Litter is still found on all beaches that we have monitored, and we do not yet have the capacity to assess the levels and impacts of underwater noise and litter in the sea and on the sea floor.

Key findings

- The open seas are still little affected by pollution and levels of monitored contaminants continue to fall, albeit slowly in many cases. This reflects reductions in riverine inputs of a range of contaminants and in atmospheric deposition of some heavy metals and polycyclic aromatic hydrocarbons (PAHs) to UK seas. However, a range of persistent chemicals appear in deep-sea fish and marine mammals off UK coasts, and we have also found litter at a depth of 1000 metres.
- New data show that the five areas assessed in the previous UK-wide assessment (*Charting Progress*) as being of concern from nutrient inputs (East England, East Anglia, Liverpool Bay, Solent, Firth of Clyde) do not suffer from eutrophication. However, we have identified 17 small harbours and estuaries that are problem areas for eutrophication. Measures are in place to control these but recovery is likely to be slow.
- Further regulation preventing the use of tributyltin-based antifouling paints on large seagoing vessels has led to a fall in the development of male characteristics in female dogwhelks in some areas.
- Levels of several flame retardant compounds are declining in porpoise blubber, following EU regulatory action and as a result of improvements in industry practice. However, polychlorinated biphenyls (PCBs) are present at levels that affect harbour porpoises around the UK, probably by suppressing their immune systems and making them more prone to death from infectious diseases. Levels are declining only slowly, despite a ban on these chemicals in the 1980s.
- Where there are problems, these usually occur in localised areas near the source rather than across whole regions. However, some substances travel long distances through the atmosphere and have been detected in fish offshore and some become concentrated as they pass through the food chain to accumulate in cetaceans.
- Some 'legacy' contaminants are present at high concentrations in estuaries historically contaminated by industrial processes. For example, in the northeast of England, PAHs are present in sediments at concentrations which may be toxic to organisms living in or on the seabed, and may take many tens to hundreds of years to degrade.
- There have been no major marine oil or chemical spills in UK waters since the publication of *Charting Progress*. Levels of oil in produced water discharged by the offshore



oil and gas industry are falling in response to regulatory controls. Doses of radioactivity received by people and wildlife continue to be well within regulatory limits. Work is underway at Sellafield and Dounreay to retrieve radioactive particles from the beaches; the levels are not high enough for the beaches to be closed, but harvesting of seafood around Dounreay is currently banned.

- For algal toxins, only 0.3% to 1% of the roughly 1000 samples analysed annually give positive results, and even these are often not above regulatory limits. Controls are in place to prevent harvesting of shellfish contaminated to a level that would pose a risk to human consumers.
- We found microbiological contamination of coastal waters in some localised areas in both bathing waters and shellfish growing waters, although inputs from sewage treatment plants have fallen significantly because of investments in infrastructure. Shellfish harvested from contaminated areas are treated prior to sale to reduce microbiological contamination to safe levels.

Improvements in assessment methodology

We have increased monitoring coverage since *Charting Progress* through more efficient use of ships, and the use of novel technologies such as remote sensing, smart buoys and ferry boxes.

Gaps in knowledge

Although we have good information on the number of small oil spills around the UK, assessing the cumulative impact of a large number of small spills is problematic and poorly understood.

We do not have an accurate picture of the extent of litter in the sea or of its impacts. Microplastics are thought to be widespread in sediments around UK coasts. These may have physical impacts on the environment and may also adsorb contaminants and deliver them into food chains. As yet we do not know either the scale or potential consequences of these effects.

Certain algal blooms that occur naturally in UK waters could generate toxins such as azaspiracids and spirolides and those responsible for Neurotoxic Shellfish Poisoning. These toxins are not included in current monitoring programmes, and we need to know more about the risks they pose in order to decide whether they should be monitored in the future.

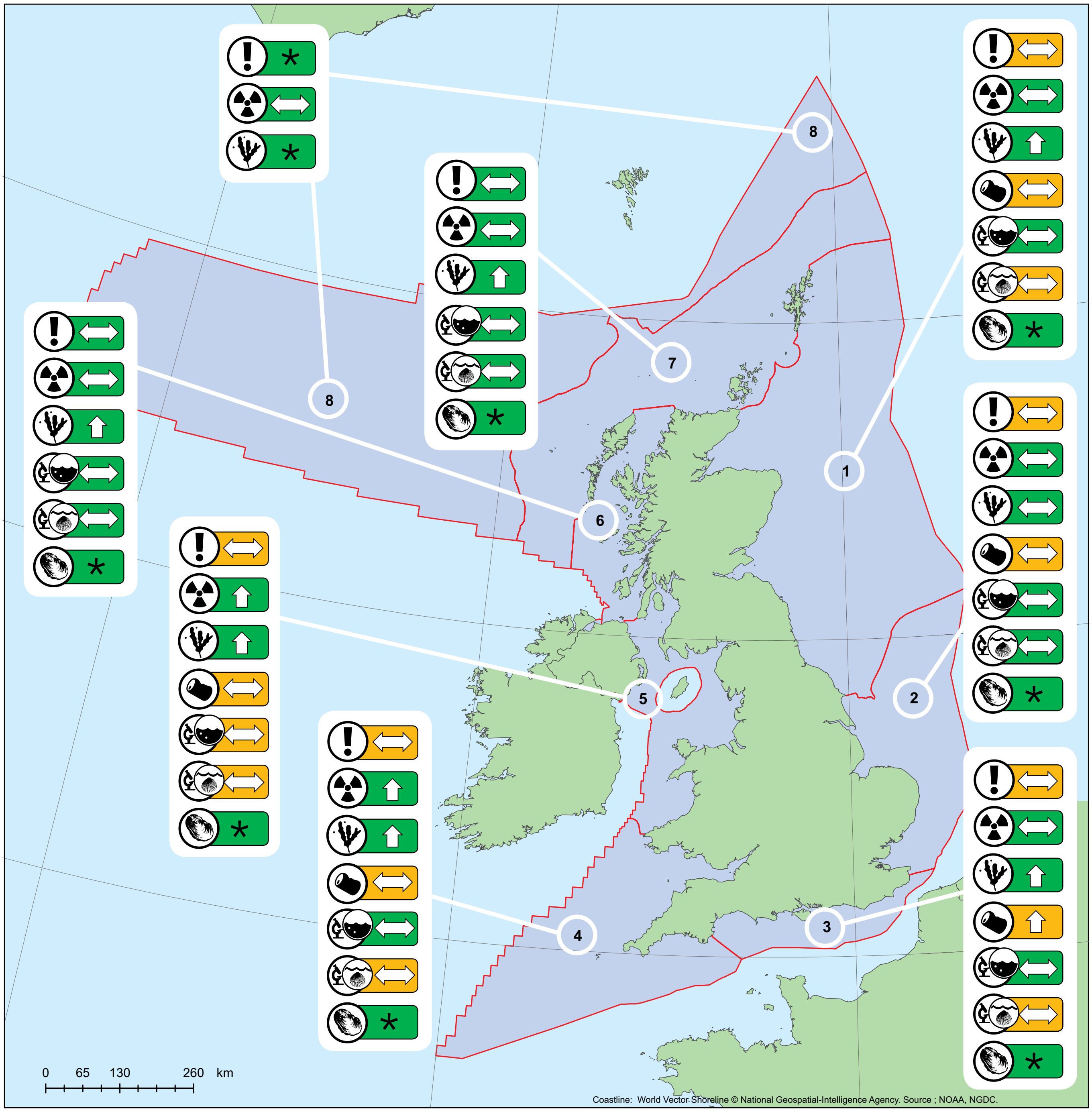
We identified potential impacts from underwater noise from a variety of sources, including seismic surveys undertaken by the oil and gas industry, the use of sonars, and the construction of offshore wind farms. However, we need more research and monitoring to understand the scale of these impacts.

Although we know a great deal about the effects of many single substances, there are some, such as pharmaceuticals, where we need more information. Also, we understand little about the cumulative effects of simultaneous exposure to a variety of chemicals.

Summary map

The map on Page xvi displays the status and trends of the clean and safe seas components of the eight regions. For further details see the Chapter 4 summary table on Pages 86/87 and for further information on how 'traffic light status' and trend arrows have been assigned see Page 9.

Clean and Safe Seas



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Hazardous substances

Radioactivity

Eutrophication

Beach litter

Microbiological quality of bathing waters

Microbiological quality of shellfish growing waters

Algal toxins

Few or no problems

Some problems

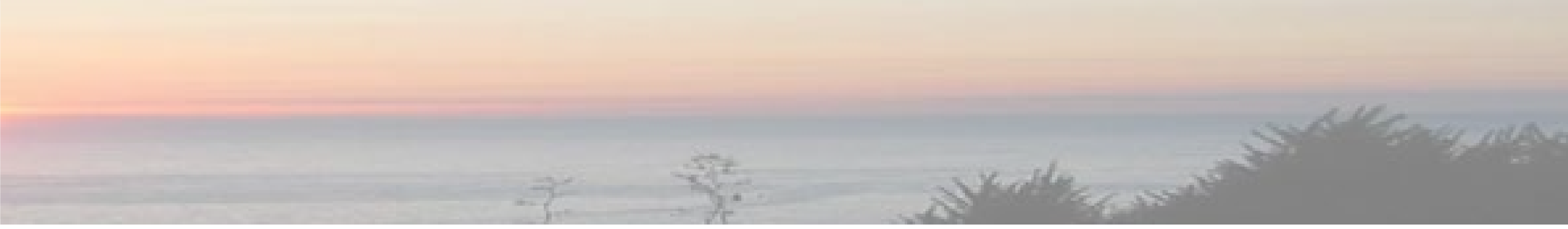
Many problems

No overall trend discernable

Improvement

Deterioration

No trend information available

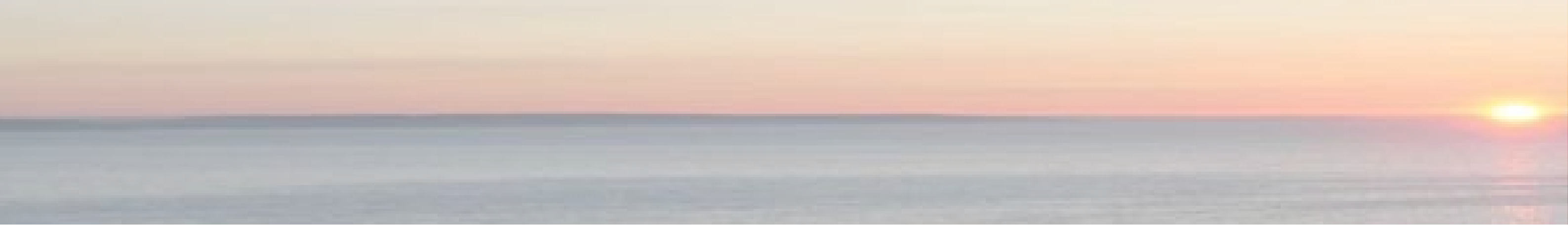


Chapter 5: Productive Seas

This is the first time that a comprehensive assessment of the productive use of the UK seas has been carried out. We found that our seas are economically productive and there are strong policy drivers to increase this productivity. Most activities are highly regulated in order to limit impacts on the marine environment and, aside from fisheries, have localised pressure footprints. Although we have begun measurements of sustainability we do not yet know how sustainable our use of the seas is overall.

Key findings

- Oil and gas make the highest annual contribution to the economy of any activity in the marine environment, with a gross value added of £37 billion in 2008. Maritime transport and telecommunications provide vital links within the UK and to the rest of the world offering significant economic benefit. Expenditure related to leisure and recreation activities is high and likely to be underestimated given current limitations in sourcing data for this sector. Expenditure on military defence activities provides additional benefits to the economies surrounding the main naval bases. Fisheries and aquaculture within the UK continue to supply food nationally and abroad and support local fishing communities.
- During the past ten years, fishing mortality (mortality caused by fisheries) has declined significantly in 67% of assessed fish stocks in UK waters. Out of 20 indicator fin-fish stocks in UK waters, the proportion being harvested sustainably and at full reproductive capacity has risen from around 10% in the early 1990s to around 25% in 2007. The proportion of these stocks being harvested sustainably has risen from 10% to around 40% over the same time period. However, the large majority of scientifically assessed stocks continue to be fished at rates well above the values expected to provide the highest long-term yield.
- Renewable energy projects and work on flood and coastal defences have more than doubled since *Charting Progress* and will continue to increase. For marine renewable energy, the target is to increase installed capacity from 0.7 GW (as at the start of 2010) to at least 33 GW by 2020. Most of this additional capacity is expected to come from new offshore wind farms.
- Many socio-economic activities put varying degrees of pressure on the marine environment, notably damage and loss of habitat on the seabed from fishing and the presence of physical structures; pollution and other chemical changes from land and marine-based sources; introduction of invasive species from shipping and mariculture; noise from construction and operational activities; and litter from a wide range of sources. Stricter controls in a number of evolving UK, European and international policies have reduced some of these pressures since *Charting Progress* and most industries now have sustainable development strategies.



Improvements in assessment methodology and future requirements

We cannot yet determine whether we are using the seas sustainably, largely because we are not in a position to assess the cumulative impacts of all activities such as fisheries and leisure and recreation. Assessing sustainable use will be an important focus for the coming years.

We need a better way to establish a market value for some activities, including leisure and recreation, waste disposal, telecommunications and power transmission, and pipelines, as well as future activities such as carbon capture and storage. We also need a way to evaluate the contribution that marine activities make to social values, such as upholding cultural traditions in local fishing communities. As yet there is little primary research on the economic value of ecosystem goods and services and the non-use value of the marine environment. We need to agree a methodology on how to spatially allocate socio-economic data to support regional assessments.

Future assessments would greatly benefit from a more coordinated and centralised collation of data on the distribution of pressures associated with aquaculture, with leisure and recreation, and with temporal and size aspects of shipping density.

Gaps in knowledge

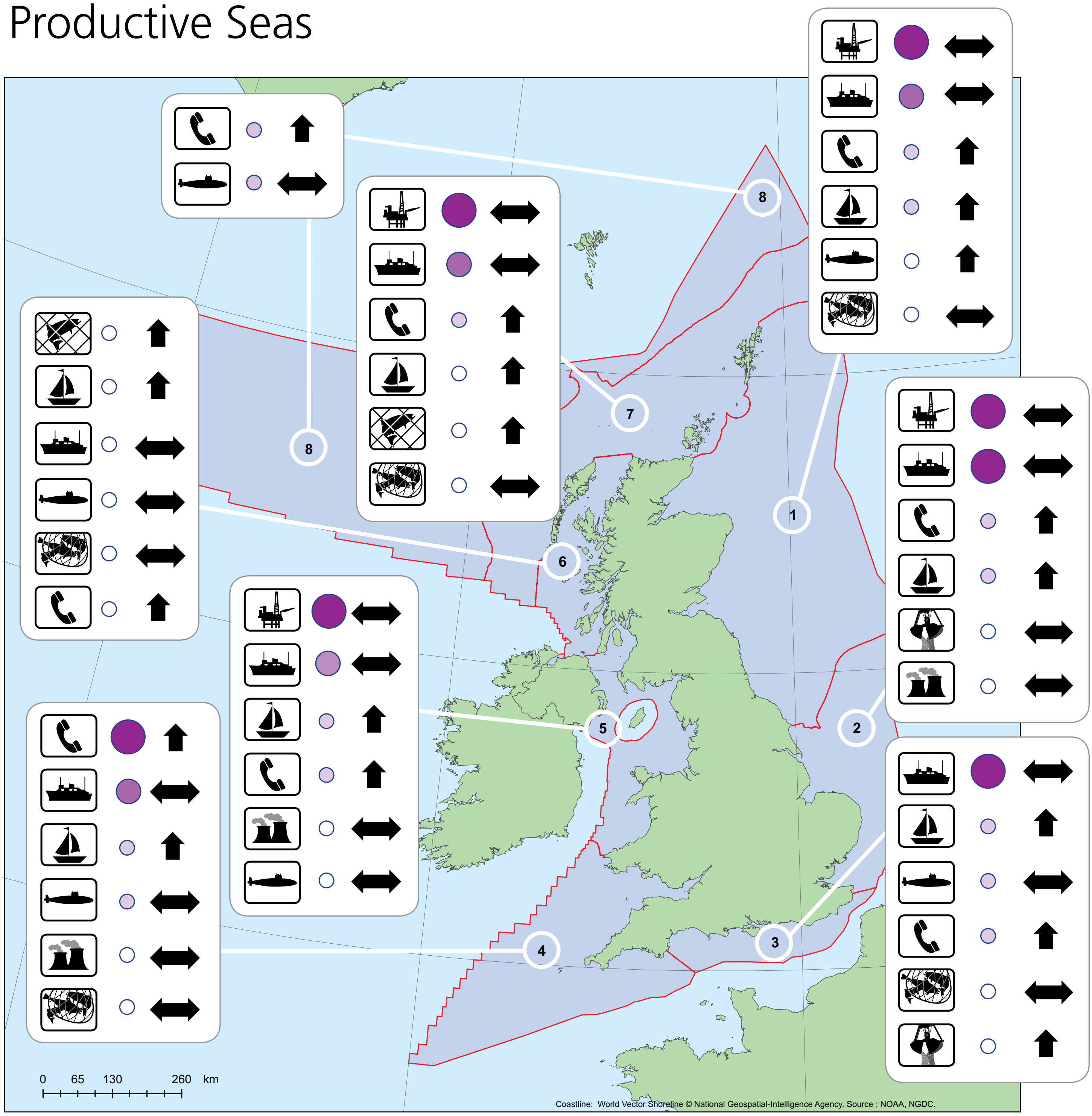
We also need to know more about the nature and extent of many pressures arising from productive use of the seas, notably the spatial and temporal distribution of noise sources, litter and invasive species and to agree on the methodology used to assess them. We do not yet know the extent of the environmental pressures that will arise from increasing activity in renewable energy, coastal defence and gas storage. We also need tools to take account of the fact that some industries, which may cause impacts while they are being constructed, can then act as areas for species to settle once they are established.

Summary map

The map on Page xix displays the top six activities in terms of market value within each region (drawn from Table 2.3 in the Feeder Report prepared by the Productive Seas Evidence Group), except Region 8 in which the only significant activities are telecommunications and military defence.

Pressures for each activity have been assessed based largely on an expert judgement of their spatial and temporal aspects ensuring that we captured issues such as intensity, size of footprint and distribution.

Productive Seas



Regional sea boundaries

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Oil and gas
Maritime transport
Telecoms
Leisure and recreation
Fisheries
Defence
Water abstraction
Aquaculture
Mineral extraction

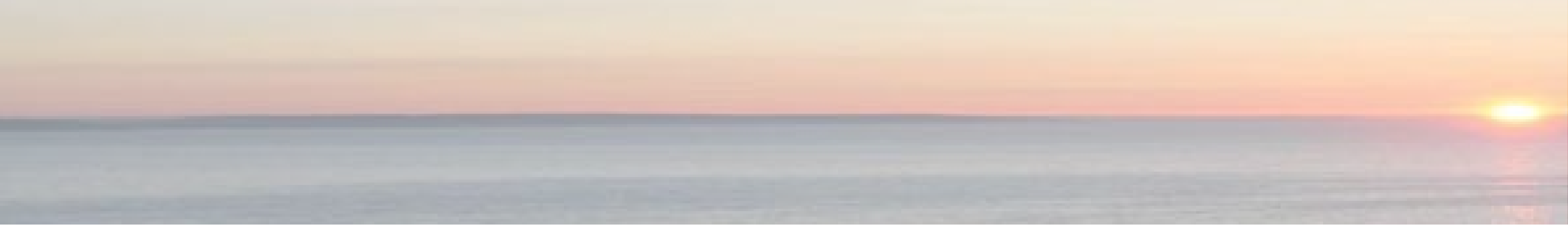
For more information on pressures see Chapter 5 and the summary table on Pages 112/113

Gross Value Added (£)

- >1bn
- 500m - 1bn
- 100 - 500m
- 10 - 100m

Change in pressure since 2003

- Increase
- Decrease
- No change



Chapter 6: Climate Change

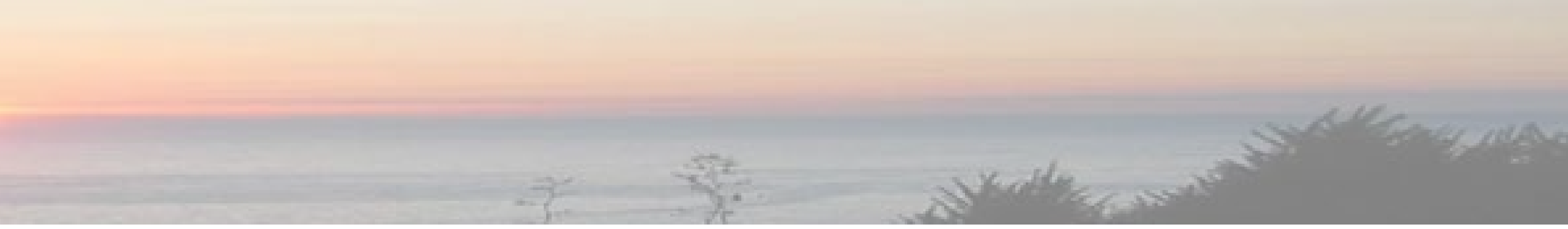
Climate change is already having significant impacts on the marine environment and the goods and services it provides. Against the backdrop of natural variation we have evidence that human activities are contributing to a long-term warming trend. Our scientific confidence in projections of future climate varies widely, due to lack of understanding of key processes such as storms and ice melt, and also because we do not know how greenhouse gas (GHG) emissions will change over time. However, climate change caused by human activity is likely to play an increasingly significant role in the changing state of our seas.

Key findings

- The world is getting warmer. Global average air and sea temperatures have risen markedly since the mid-20th century and human activities are very probably responsible for much of this.
- In the mid- to late 1980s rising sea temperatures were at least partly responsible for a sudden shift in plankton species in UK waters which affected the marine ecosystem.
- Distributions of some exploited and non-exploited North Sea fish species have responded to increases in sea temperature by moving northward and to deeper waters over the past three decades.
- Warmer sea temperatures since the 1980s have increased the length of the marine growing season.
- In some areas of the North-East Atlantic, there are more reports of harmful algal blooms, especially since the mid-1980s.
- Recent studies in the offshore North Sea show that low oxygen events in these areas are more likely to be due to climate change than to nutrient enrichment from human sources.
- Concerns over climate change impacts on the coast have already increased activity and spending on coastal defences, which will need to double again by 2080.

Main projections

- In 2007, the Intergovernmental Panel on Climate Change (IPCC) projected that global mean sea level will rise by 18 to 59 cm during the 21st century, principally through thermal expansion of seawater and melting of land-based glaciers and ice sheets.
- Rising sea levels and possible changes to wave conditions will increase 'coastal squeeze', habitat loss, coastal erosion and the steepening of intertidal profiles.
- Under a medium emissions scenario the latest UK climate information package (UKCP09) projects that UK shelf seas will be 1.5 to 4 °C warmer by the end of the 21st century. UK seas will seasonally stratify in the same locations as now, but this may be stronger, start earlier and break down later each year.
- Climate models project that the AMOC will decrease over the 21st century, but not shut down completely. This will not prevent an overall net warming of UK seas.
- Unless we reduce human GHG emissions, by the end of the 21st century the acid content of the ocean's surface water may have doubled. This could adversely affect hard-shelled marine organisms such as corals and molluscs. It could also reduce the ocean's capacity to soak up CO_2, thus rendering the problem of climate change more severe.



Improvements in assessment methodology and future requirements

We have made considerable progress in assessing the evidence and predicting the consequences of climate change following the establishment of the Marine Climate Change Impacts Partnership (MCCIP). MCCIP was formed following a recommendation from *Charting Progress* specifically to facilitate the transfer of scientific evidence to decision-makers.

We are beginning to have access to projections of changes in many aspects of the physical environment, for example sea temperature, sea level and acidity. However, these all depend on particular scenario projections for the levels of human-induced GHG emissions.

The evidence for climate change impacts in marine ecosystems is now regularly assessed and updated but an understanding that goes beyond hypotheses of future change in the observed ecosystem impact is limited; and the full impacts of climate change acting through the ecosystem as a whole are a very long way from being understood.

The potential for increasing levels of atmospheric CO_2 to cause changes in the chemistry and pH of the upper ocean is receiving significant attention.

Gaps in knowledge

We now have regular assessments of the evidence for the effects of climate change on marine ecosystems. However we are a long way from understanding the full impacts and predictions of future changes are still largely hypothetical.

Climate change may alter the natural uptake of carbon by the oceans on a scale and in a direction that is presently difficult to predict.

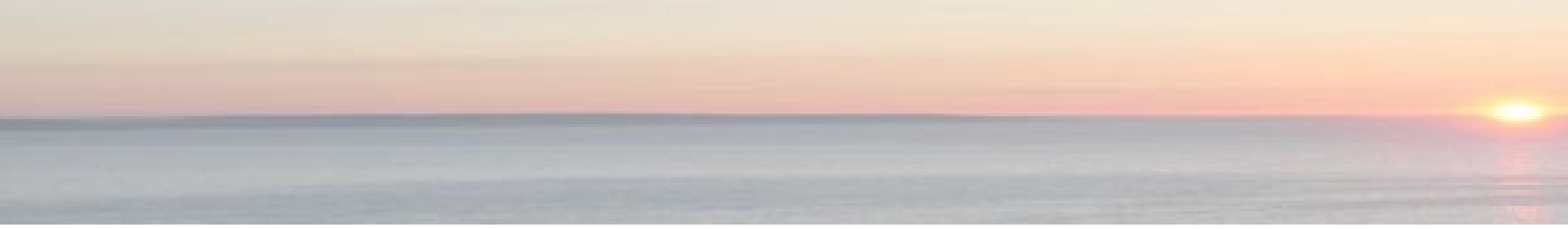
We know very little about the rates of processes leading to ice sheet melting, and hence the contribution of ice sheets to sea level rise – both globally and in UK seas.

For fish and the food webs that rely on them it is difficult to tease out the impacts of climate change from the pressures of fishing activities.

Models are not good at predicting the preferred tracks, strength or frequency of storms into the future.

Carbon dioxide emissions will have a significant effect on the pH and marine life of the UK seas. We cannot accurately predict future CO_2 emissions, and therefore our projections of their likely impacts on the marine life and pH of our seas remain correspondingly uncertain.

Beyond the 21st century, there is currently little confidence in predictions of whether the Atlantic Meridional Overturning Circulation might eventually shut down or what effect changes in this circulation would have on UK climate.



Chapter 7: Common Issues and Regional Perspectives

The regional analyses link the benefits and pressures of human activity associated with each region to the impacts they have on the marine environment. These allow scientists and managers to focus on specific regional issues and problems. They enable UK, devolved, regional and local administrations to prioritise their planning and use of resources, and to contribute to the development of the marine plans that are now being drawn up.

Key findings

- All of the regions support, or are affected by, human activities but more remote regions such as the Atlantic North-West Approaches have little activity compared to regions such as the North Sea and Irish Sea, which are closer to centres of human population.
- The varied extent of human use leads to different pressures. Each of the regions makes an important contribution to the economy and jobs and, in most cases, the environmental footprint of industry is small as a result of good regulation.
- Despite a reduction in fishing effort or change in the nature of the fishing activities in several regions, fishing continues to be a widespread pressure on both target and non-target fish stocks and on significant areas of seabed sediment habitats.
- Rising sea temperature and rising sea levels affect all regions. The threat of increasing coastal erosion and flooding is greatest in the south and east of England, where the land is sinking and where changes to the marine ecosystem associated with rising temperature are most apparent.
- The threat due to pollution by hazardous substances and nutrients is greatest around the coasts of England and Wales although inputs are declining in most areas. There is a legacy of past contamination that will be present for some time even though the required management measures are in place.
- There are significant changes in the populations of seabirds and seals across the different regions but the causes are often unclear, and could be due to both human and environmental changes.

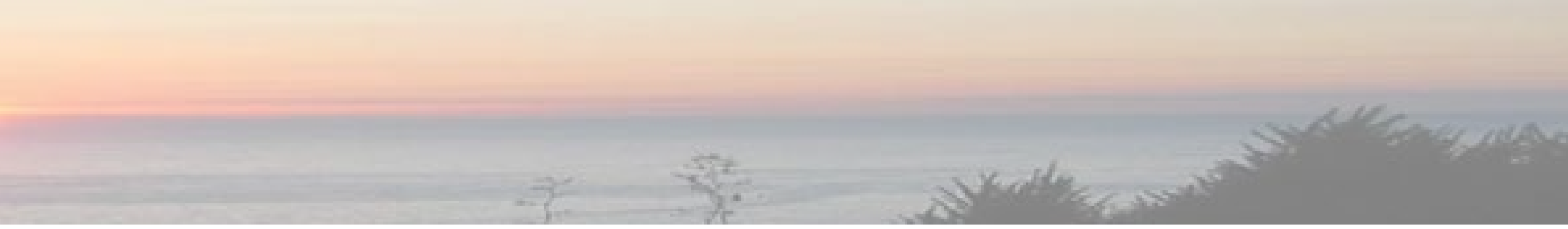
Improvements in assessment methodology and future requirements

The more holistic picture presented here of how well we are using the sea helps to identify, and place in context, barriers preventing our progress towards the vision of clean, healthy, safe, productive and biologically diverse oceans and seas. The aggregation of information, either on a geographical basis or across different pressures and impacts, is an important step towards applying an ecosystem approach but there is some way to go before we can deliver a truly 'integrated' assessment.

Gaps in knowledge

Our knowledge of the sea is patchy and needs improving. While there is often good information for coastal areas, there are generally few data for the offshore parts of most regions. Innovation in data collection is required.

To support the management and sustainable use of our seas, we need to develop new tools for integrating varied and disparate information across different scales of time and space.



Chapter 8: Achievements, Lessons Learned and Next Steps

Achievements since *Charting Progress*

With this report, we have made a broader, more integrated assessment than was possible in *Charting Progress*. We have also provided a more robust baseline against which we can measure future progress towards the vision of clean, healthy, safe, productive and biologically diverse oceans and seas. The interdisciplinary approach has proved very fruitful as have the stronger relationships that we have fostered between researchers and policy makers. We have also made significant progress in the methodologies for assessing the state of the UK seas.

Lessons learned

We now have a greater understanding of the obstacles that are preventing us from reaching our vision for the UK seas. However, we need better criteria, better baselines and better targets for assessing our progress. As well as improved tools, greater coverage and new data to fill key gaps in knowledge.

Next steps

The UK Marine Monitoring and Assessment Strategy community will work under the Marine Science Coordination Committee to help realise its recently published 15-year UK Marine Science Strategy. We will also advise on the characteristics needed to display 'Good Environmental Status' under the EU Marine Strategy Framework Directive, as well as playing a key role in monitoring and assessing changes in the quality status of the UK seas in the future. The evidence compiled for this report will provide the bulk of the initial assessment of the state of the UK seas that is one of the early requirements of the Directive.

CHAPTER 1
AIM OF THE ASSESSMENT

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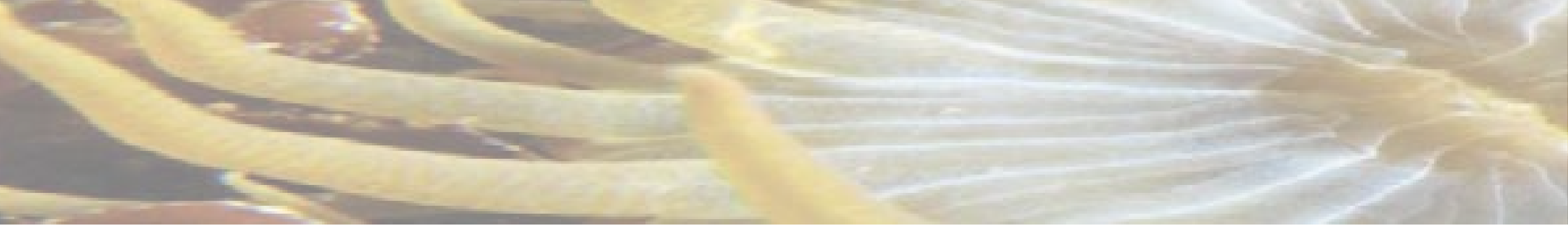
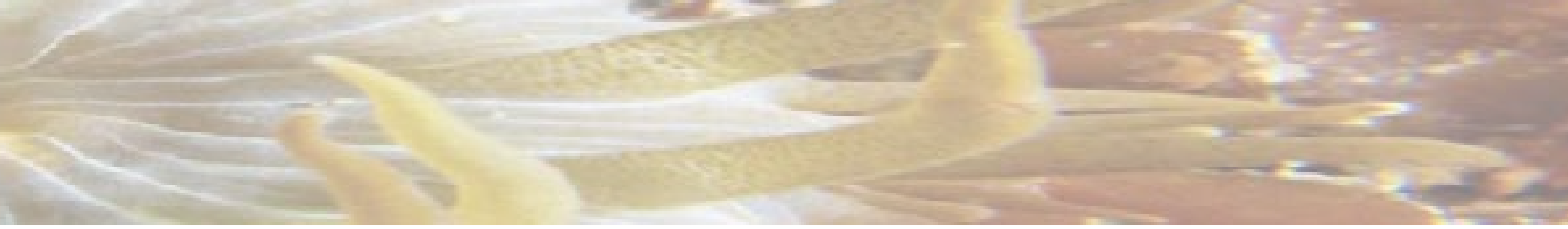


Charting Progress

The vision of achieving clean, healthy, safe, productive and biologically diverse oceans and seas was set out in the first marine stewardship report – *Safeguarding our Seas* – published in 2002. As an initial step towards this vision, the Department for Environment, Food and Rural Affairs (Defra) and the Devolved Administrations published *Charting Progress* in 2005, which was the first integrated assessment of the state of the UK seas. In overview, the report concluded:

> *The general picture that emerges from the evidence is that the UK seas are productive and support a wide range of fish, mammals, seabirds and other marine life. The open seas are generally not affected by pollution and the levels of monitored contaminants have decreased significantly. The main contamination problems which are identified are in part due to the legacy of the past and are generally observed at higher levels in industrialised estuaries or areas local to the activity.*
>
> *However, human activity has already resulted in adverse changes to marine life and continues to do so. For example, widespread commercial fishing practices threaten many fish stocks by over-exploitation and damage sea floor areas. There is also evidence that the marine ecosystem is being altered by climate change: for example sea temperatures are rising and the distribution of plankton species is changing. These changes pose a real threat to the balance and integrity of the marine ecosystem.*

Charting Progress made a number of recommendations for action to improve our understanding of the marine environment and the way we manage and collect information about it.



Charting Progress 2

Charting Progress 2 presents an updated and improved assessment of the state of the UK seas. The report is based on a robust, peer-reviewed evidence base and describes progress made since 2005. It is a source of the key findings from UK marine research and monitoring and is intended to be used in policy-making as we move towards the goal of clean, healthy, safe, productive and biologically diverse oceans and seas.

Through a combination of increased general awareness and developing national and international regulation, there has been a large drive in recent years to improve our understanding of the marine environment and also to take action to manage the seas and oceans more sustainably. *Charting Progress 2* provides a solid foundation for policy-makers to make the strategic and far reaching decisions needed to meet our legislative obligations and to protect our marine resources. For the first time, the report also provides a socio-economic analysis of our use of the seas, and summarises the detailed impacts of climate change on the marine environment.

Table 1.1 shows how each of the recommendations for action arising from *Charting Progress* has been dealt with in the period since the report was published.

One of the major policy initiatives to address the recommendation calling for a more coordinated and systematic approach to marine monitoring, assessment and data collection was the setting up in 2006 of the UK Marine Monitoring and Assessment Strategy (UKMMAS), co-chaired by Defra and the Scottish Government. *Charting Progress 2* has been produced by the UKMMAS community and represents a more joined-up way of working, one which shares resources and maximises efficiency in the collection and management of marine data. This report is the first major publication by the UKMMAS community (Annex 1 lists the organisations which make up the UKMMAS community).

Preparing this assessment report

The assessments in this report are the result of a three step process.

Step 1: Each of the evidence groups set up under UKMMAS carried out a detailed assessment of progress towards the vision for the UK seas, which they set out in a comprehensive and fully-referenced technical report known as a 'Feeder Report'. The assessments draw on monitoring data collected by marine institutes and agencies across the UK, other relevant information and research undertaken at research institutes and universities.

The *Ocean Processes* Feeder Report provides evidence covering the state of the ocean processes through components such as circulation, weather and climate, waves, temperature, salinity, carbon (including acidification), sea level, turbidity and sedimentary processes.

Evidence groups set up under UKMMAS

- Ocean Processes Evidence Group (OPEG) (established mid-2009)
- Healthy and Biologically Diverse Seas Evidence Group (HBDSEG)
- Clean and Safe Seas Evidence Group (CSSEG)
- Productive Seas Evidence Group (PSEG)

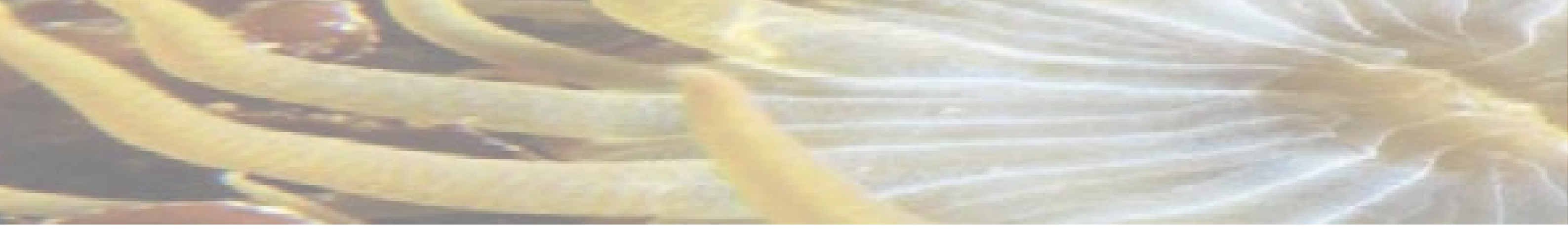
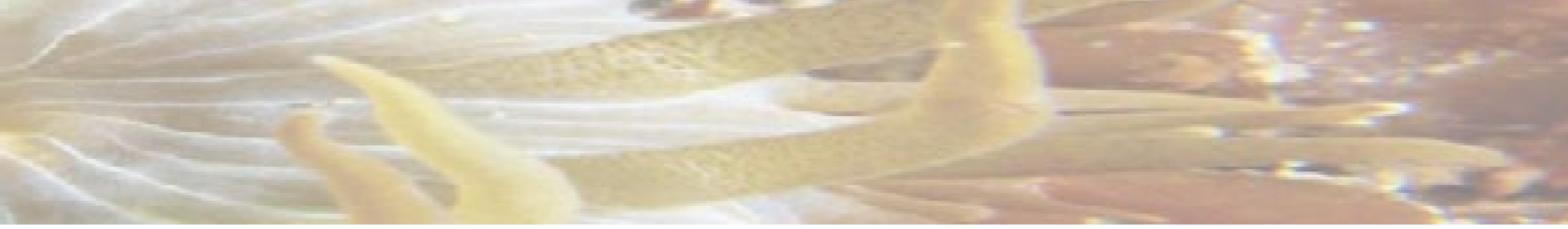


Table 1.1 Response to specific actions recommended by Charting Progress.

Recommendations for action	*What has been achieved*
Action 1: Develop marine ecosystem indicators to enable the state of the seas to be more precisely measured and progress towards the vision to be monitored	Evidence groups have reviewed and identified indicators that can be used in each of their monitoring programmes
Action 2: Evaluate and revise our current Marine Monitoring programmes	The UK Marine Monitoring and Assessment Strategy (UKMMAS) has been set up, allowing more efficient and robust collection of marine data. The UK Directory of Marine Observing Systems (UKDMOS) has been set up to help coordinate monitoring programmes (www.ukdmos.org)
Action 3: Promote marine research into the more fundamental gaps in basic knowledge that the process has revealed	Specific projects have been initiated to fill knowledge gaps and the Marine Science Co-ordination Committee (MSCC) has been set up. MSCC published a UK marine science strategy in January 2010
Action 4: Capture 'knowledge' to make better use of the expertise and information available in all of the relevant UK institutions which deal with the marine environment, so that it can be more effectively integrated into policy making	This is a cross-cutting issue facilitated by setting up the UKMMAS and its Evidence Groups, and involving Marine Institutes, Agencies and the research community in the UKMMAS framework. Other initiatives have also been put in place, such as the joint Defra-NERC Ocean Acidification programme
Action 5: Establish a national framework for managing marine data and information based on the principle of 'capture once and use many times'	The Marine Environmental Data and Information Network (MEDIN) has been set up to provide a single framework for data management and has established a number of Data Archive Centres for access of information
Action 6: Develop a better understanding of how climate change affects the marine environment	The Marine Climate Change Impacts Partnership (MCCIP) has been set up to provide a UK-wide co-ordinating framework for the transfer of high-quality marine climate change impact evidence to policy advisors and decision-makers. MCCIP has published two annual report cards and a special topic report on ecosystem connections and climate change
Action 7: Develop appropriate legislation to apply the ecosystem approach within a framework of sustainable development	Marine Acts are in place across the UK which will provide a framework for marine planning and licensing of activity plus the setting up of Marine Conservation Zones and Marine Protected Areas to protect habitats and species



The *Healthy and Biologically Diverse Seas* Feeder Report provides evidence on cetaceans, marine and estuarine fish, marine habitats, microbes, plankton, seabirds and waterbirds, seals and turtles.

The *Clean and Safe Seas* Feeder Report provides evidence on hazardous substances, radioactivity, eutrophication, oil and chemical spills, marine litter, underwater noise, microbiological contamination and algal toxins.

The *Productive Seas* Feeder Report provides evidence on the use of the marine environment and identifies both the socio-economic value and resulting pressures of these activities on the environment.

Step 2: Each of the Feeder Reports was peer-reviewed by independent UK and international experts outside Government and revised following the comments received. A stakeholder workshop was held to present and discuss the findings of the Feeder Reports with industry representatives and environmental non-governmental organisations and to consider any additional information.

Step 3: *Charting Progress 2* is a summary document which draws on the detailed evidence and conclusions from the Feeder Reports. It examines all the evidence together with a summary on the impact of climate change, and provides an assessment of the overall status of the UK seas. We have also developed a web-based tool, which enables easy navigation between the various parts of the report and provides user-friendly access to the evidence and assessments. This is available at http://chartingprogress.defra.gov.uk

A regional basis for *Charting Progress 2*

The *Charting Progress 2* assessment subdivides the entire UK sea area into eight regions (Figure 1.1). There is greater emphasis today on the ecosystem-based approach in both domestic and international legislation. Thus, rather than basing the division on administrative boundaries, we chose the regions, based on the bio-geographic regions identified as part of the Review of Marine Nature Conservation (RMNC) 2004, principally using physical and biological features such as tidal fronts and seabed flora and fauna. Since *Charting Progress* there have been some small but important changes to the boundaries of the regions. These changes reflect improved knowledge about the distribution of bio-geographical features, and ensure alignment with EU Water Framework Directive water bodies and the need in future, to align with the regions and sub-regions of the EU Marine Strategy Framework Directive. Given the broad regional assessment scale, these boundary changes have a minor impact when comparing status now with that assessed in 2005. However, it should be noted that these boundaries are not absolute and will not necessarily be used for determining jurisdiction or to inform planning in the marine area.

Full titles of the eight regions and the areas they contain (shortened names are given in brackets)

Region 1: Northern North Sea
Region 2: Southern North Sea
Region 3: Eastern English Channel (Eastern Channel)
Region 4: Western Channel, Celtic Seas and South West Approaches (Western Channel and Celtic Sea)
Region 5: Irish Sea Region and North Channel (Irish Sea)
Region 6: Minches and Western Scotland
Region 7: Scottish Continental Shelf
Region 8: Atlantic North-West Approaches, Rockall Trough and Faeroe / Shetland Channel (Atlantic North-West Approaches)

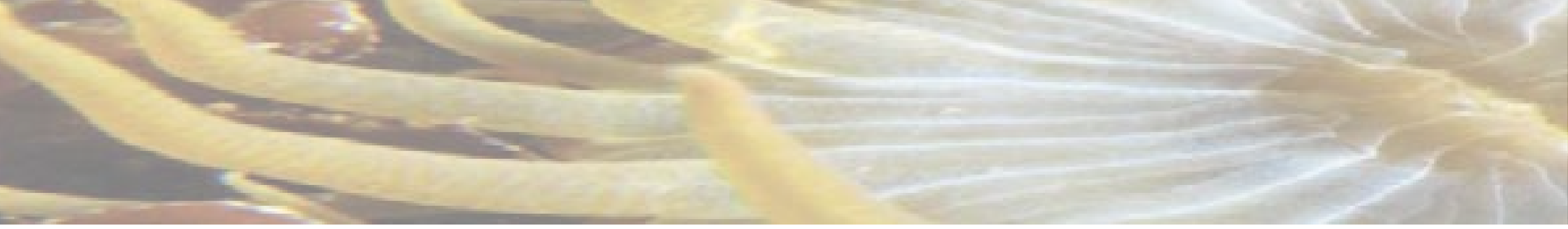
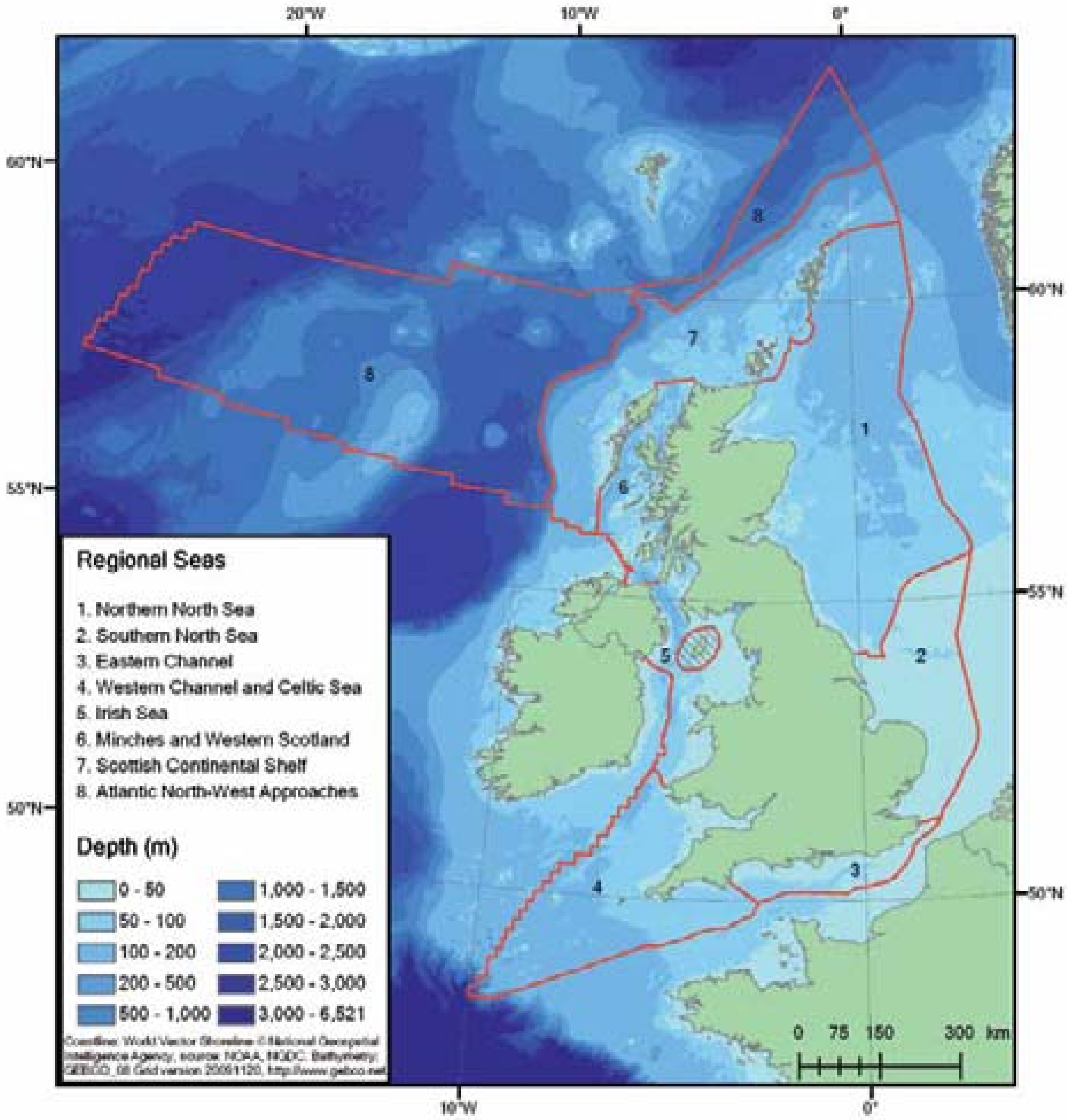


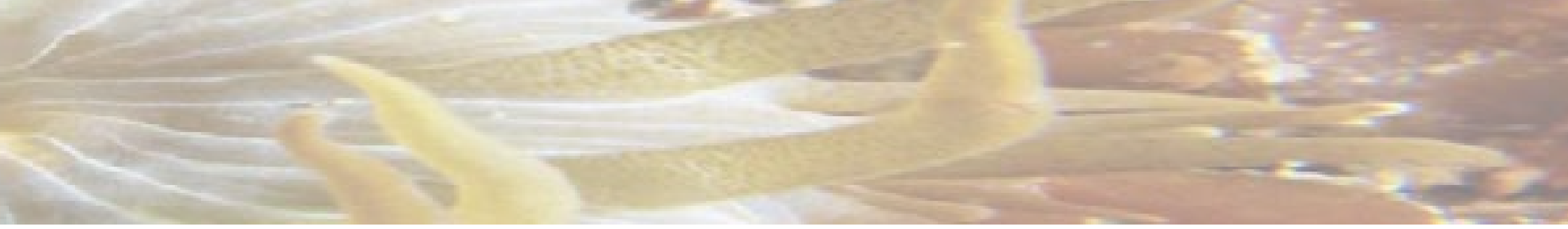
Figure 1.1 Charting Progress 2 *Regional Sea boundaries.*



Assessing the state of our seas

To make this assessment we have used standards, criteria or indicators that describe a particular desired status or quality associated with the vision for the UK seas and then checked how the evidence measures up. Where, for example, there was insufficient information to do this, we have relied on expert judgement; this is where experienced scientists have used available evidence and understanding to assign status.

We have also compared results collected in different years to assess whether status is improving over time and to try to project whether the vision is likely to be achieved.



Jewel anemone

The evidence base

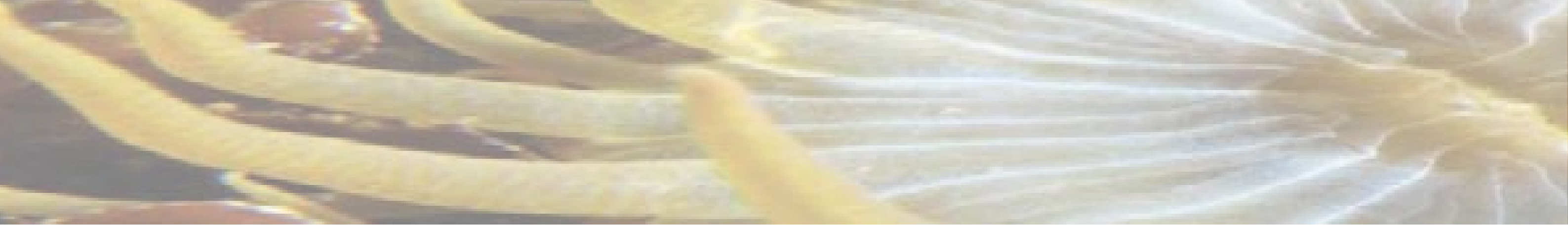
The evidence in *Charting Progress 2* comes from data collected by the UKMMAS Evidence Groups, which help fulfil our national and international obligations under the various policy initiatives and legislation. This also includes research undertaken at marine research institutes and universities across the UK and further afield. For the assessment of productive use of our seas, we also used economic information and statistics gathered from government agencies, regulatory authorities and the key industries that use the marine environment. The evidence is presented in detail in the four Feeder Reports which are available at: http://chartingprogress.defra.gov.uk

Our conclusions about the state of the UK seas depend critically on the extent and sufficiency of the available evidence. However, marine research and monitoring varies hugely in its spatial and temporal coverage. In some cases, such as for hazardous substances, we had robust data that have full quality assurance and internationally recognised standards. In other cases such as for marine litter, the data, although useful are less robust and were largely collected on a voluntary basis. Where data were simply not available, were not collected to a recognised standard or were too variable to allow us to draw any firm conclusions, we used expert judgement to estimate the likely status, if this was possible.

Key principles for the assessment

To ensure that the assessments were robust, and that the evaluation of progress towards the vision is reliable, we adopted the following principles during the assessment process:

- That the assessment criteria were suitable for the job, and were acknowledged by the international marine science community as being fit for purpose
- That the degree of confidence we have in what the assessments are telling us about status is clear.



Suitability of the assessment criteria

The development of assessment criteria is at different stages for the different components in the report. Some are well developed and have been used with confidence for years, while others are still in development. In several cases we continue to rely on expert judgement.

We still need to produce a more specific and comprehensive set of practical indicators to assess the status of the seas around the UK and this will evolve as knowledge of the ecosystem develops. This process will be guided by the need to deliver assessments of Good Environmental Status under the EU Marine Strategy Framework Directive.

Confidence in the assessments

We are not able to make an assessment of status for all of the components covered with the same degree of robustness and reliability. We have adopted a framework for assigning 'confidence' to each assessment which has been based on that used by the Marine Climate Change Impacts Partnership (MCCIP) and the Intergovernmental Panel on Climate Change (IPCC). The framework brings together an evaluation of the amount of data and information available at the right spatial and temporal scale and an assessment of the 'degree of consensus' about what the data mean. The latter aspect covers situations where limited expert judgement is available, which would score low on the scale, through to an internationally adopted assessment method complete with robust criteria and standards.

The confidence level has been allocated High, Medium or Low according to the framework described in Figure 1.2 and full information can be found in the four Feeder Reports. We have indicated assessments made with low confidence in the summary tables.

Figure 1.2 Tabulation used to establish the degree of confidence in an assessment.

Degree of consensus in interpretation	L	M	H
H	**L**	**M**	**H**
M	**L**	**M**	**M**
L	**L**	**L**	**L**

Amount of data available both spatially and temporally

Spatial and temporal aspects

It is vital that the data available are representative of the area assessed. For example, if our monitoring has historically focussed on a small area near the coast, then using these data to assess the status of the region as a whole may give a false picture. There is no one scale that fits all issues equally well and the relationship between scales needs to be understood. This report aims to provide assessments at the *regional scale* and the extent of problems are reported on this basis.

However, we also identify in the report those cases where issues that need to be addressed occur in smaller areas within a region or where the appropriate scale is larger than the region.

The main timeframe considered in *Charting Progress 2* is the five years that have passed since the first assessment; see *Charting Progress*. Because this period is probably too short to identify major changes in many environmental features, we have also set the changes reported within the context of any known long-term trends. The period over which reliable data is available varies considerably from component to component. In some cases, we are reporting information for the first time, while in others we have reliable data extending over decades. It is often apparent that we do not have sufficient observations over a long enough period to distinguish between what is simply natural environmental change and variability and changes induced by human activity. This problem is particularly the case for some parameters associated with climate change. We therefore need a strong understanding of the link between cause and effect in order to avoid taking action that is either unnecessary or that would result in the wrong outcome.

Communicating the findings

We have tried to present our findings in a clear and simple way to convey to the reader the state of various components of the marine environment and productive use of UK seas by marine industries, using summary tables and maps.

For Chapter 3 (*Healthy and Biologically Diverse Seas*) and Chapter 4 (*Clean and Safe Seas*), we have done this by using a simple traffic-light scale based on the assessments in the Feeder Reports to indicate whether there are 'many problems' (red), 'some problems' (amber) or 'few or no problems' (green) for each of the eight regions.

This approach differs from that used in *Charting Progress* where the terms 'acceptable', 'room for improvement' and 'unacceptable' were used to describe the state for all of the UK seas together. For *Charting Progress 2*, we decided that reporting on the extent of problems on a regional basis was a more realistic approach giving policy makers a better perspective from which to make decisions about sustainable use of the marine environment. (See the Government Commentary which accompanies this report, available at: www.defra.gov.uk/environment/marine.)

Scuba diver

For some components, it has been relatively straightforward to decide on the extent of the problems within a region. For example, the eutrophication assessment showed that eutrophication problems occurred in several small estuaries. However, these areas, which are already being addressed under the EU Urban Waste Water Treatment Directive and the Nitrates Directive, constitute less than 0.2% of the area of each region and less than 0.003% overall, so it was possible to assign a green status, denoting 'few or no problems', to eutrophication for these regions. However, *Gannet*

for the habitats and species components it has sometimes been more difficult to assign 'traffic light' status. The assessment addresses the condition of a component occurring within a region, and the extent of the problems is based on the number of pressures exerted on it, or the impacts it receives, or a combination of the two. For example, the intertidal rock habitat in Region 5 is affected by rising sea levels and climate change and this has led to changes in a number of rocky shore communities. Even though the extent of the rocky shore habitat is small, within the context of Region 5 as a whole it is significant, so it was decided to allocate this component an amber status within Region 5, thus denoting 'some problems'.

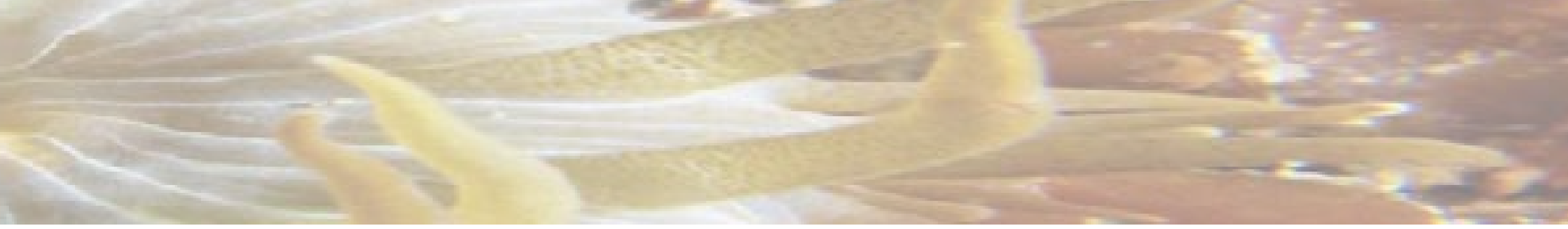
Although we have used all the evidence available, not all aspects have been covered, so we have had to rely on expert judgement in assigning 'traffic light' status to some of the components.

Where there is sufficient trend information available in the Feeder Reports, we have also used trend arrows in the summary tables and maps to indicate whether the state of the component over time is improving, deteriorating or remaining stable. In some cases, this is based on trends since *Charting Progress*, but in others, longer timeframes have been used and this is clearly set out in the Feeder Reports.

Where the Feeder Reports have indicated that there is low confidence in the assessment for a particular component (for example when it is based largely on expert judgement rather than hard evidence), we have indicated this using white bars in the summary tables.

Supporting national and international marine policies

Over the past few decades, policy makers have done substantial work at both the global and European level to agree principles, strategies and regulatory regimes that will protect and control use of the marine environment. The interaction between global/European and national policy-making is dynamic and the UK negotiators in the global and European working groups have been quite successful in influencing the outcomes and ensuring that national policies for protecting and conserving the marine environment are considered in policy decisions at all levels. Obligations at the global level include the UN Convention on the Law of the Sea (UNCLOS), the Convention on Biological Diversity and commitments under the World Summit for Sustainable Development. *Charting Progress 2*



will be an exemplary model to the UN Assessment of Assessments, established by the UN General Assembly to provide the first step towards a global mechanism for reporting on and assessing of the state of the marine environment.

Regionally, the UK has monitoring agreements under the OSPAR Convention for the protection of the North-East Atlantic as well as reporting requirements under regional seas fisheries agreements. At the European level obligations exist under the Habitats (92/43/EEC) and Birds (2009/147/EC) Directives for the conservation of biodiversity, the Water Framework Directive (2000/60/EC) which protects rivers, lakes, groundwater, estuaries and coastal waters, and the EU Common Fisheries Policy controlling commercial fishing. Most recently, the Marine Strategy Framework Directive (2008/56/EC) which will impose significant new obligations, and in particular the requirement to put in place measures to achieve Good Environmental Status by 2020.

Table 1.2 shows the qualitative descriptors for determining Good Environmental Status under the Marine Strategy Framework Directive and where associated information in this report can be found. The Conventions and Directives described above require the UK to undertake mandatory monitoring and assessment activities to demonstrate that its various commitments are working. The UK participates in the global and European frameworks as a single entity and so the approaches and negotiating positions are coordinated closely by the four UK Administrations before the relevant meetings.

Charting Progress 2 will play a key role in helping the UK to fulfil its obligations under all these initiatives and regulations by providing a robust evidence base for the current and projected state of the marine environment.

Outcome of the assessment process

The evidence chapters (Chapter 2: *Ocean Processes*; Chapter 3: *Healthy and Biologically Diverse Seas*; Chapter 4: *Clean and Safe Seas*; Chapter 5: *Productive Seas*) and the climate change chapter (Chapter 6: *Climate Change*) on the following pages represent our best assessment of the overall status of key components of the marine ecosystem and the pressures that affect them. They are followed by the overall assessment chapter (Chapter 7: *Common Issues and Regional Perspectives*) which draws together all the information presented in the previous chapters and identifies issues that are common across UK seas and provides some more specific regional perspectives about the issues that affect how we are progressing toward the vision of clean, healthy, safe, productive and biologically diverse oceans and seas. Specific issues relating to the suitability of the assessment criteria, the level of confidence in the assessments and relevant spatial and/or temporal aspects are highlighted where appropriate.

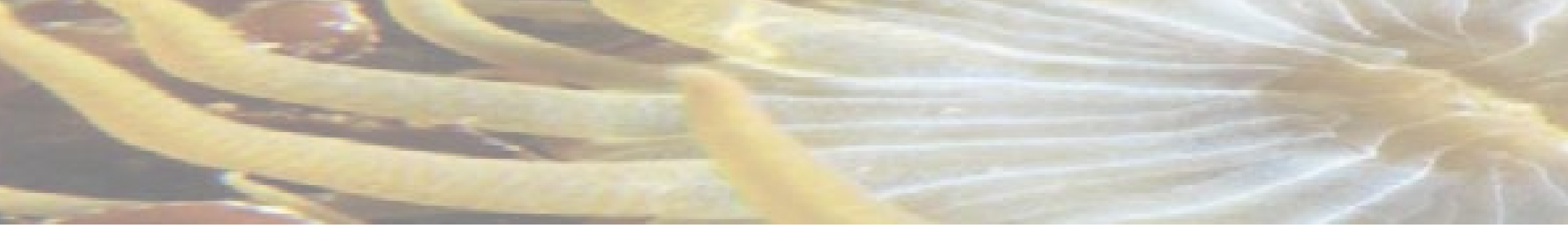
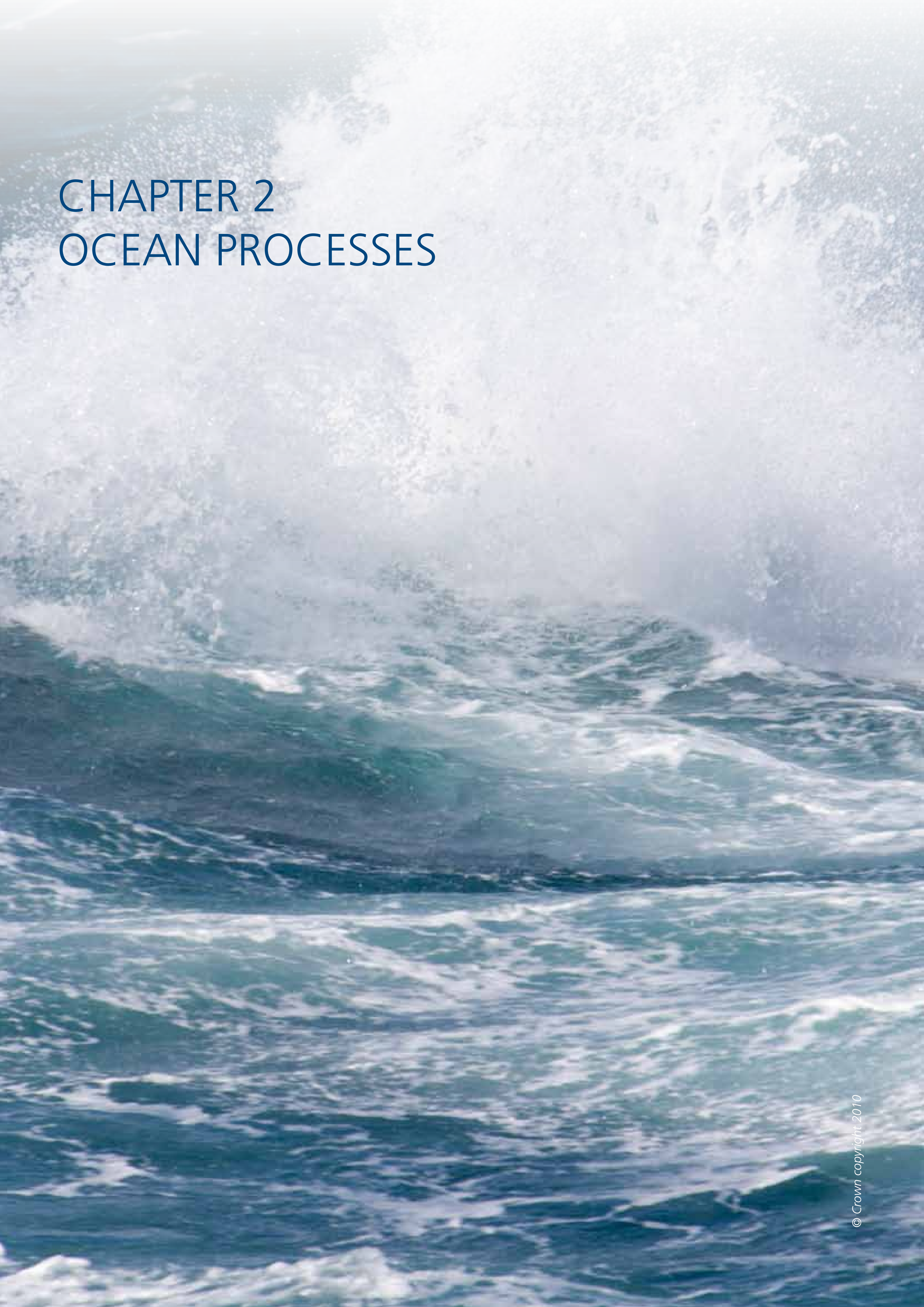
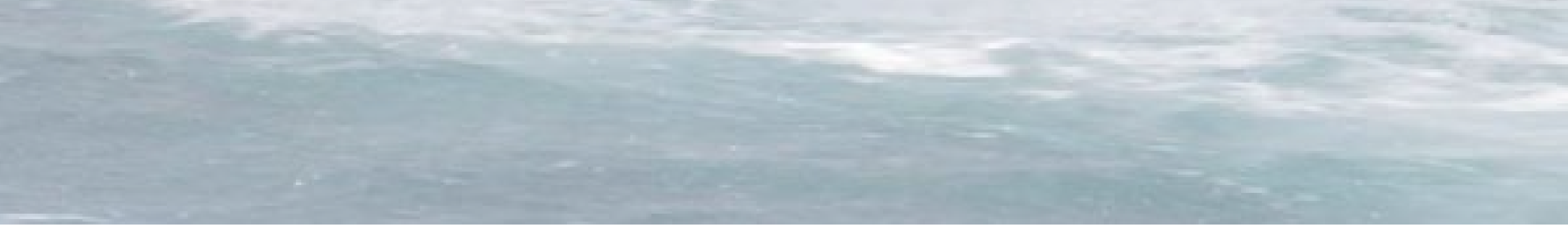


Table 1.2 Descriptors for Good Environmental Status (GES) under the EU Marine Strategy Framework Directive.

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

CHAPTER 2
OCEAN PROCESSES





Introduction

The UK vision of clean, healthy, safe, productive and biologically diverse oceans and seas depends above all on the state of the physical environment. Variables such as the oceans' temperature, salinity, circulation, degree of acidification, sea level, strength of waves, turbidity and morphology, in turn set the context for the different components of the vision. For example, storms and currents affect habitats and offshore operations; acidification affects plankton physiology, especially calcification; sedimentary processes affect the distribution of hazardous material. Thus most ocean process variables are affected by climate and mediate how future climate change will affect the marine environment in many ways.

In this chapter, based on the Feeder Report prepared by the Ocean Processes Evidence Group, we assess the physical state of the UK seas to lay out the framework for the chapters to follow. This chapter bears a strong relationship with Chapter 6 which looks at the impacts of climate change and makes projections about how the ocean process variables might change over time.

In 2005, *Charting Progress* reported evidence that climate change was affecting the marine ecosystem. In the physical environment it identified rising air and sea temperatures, increasing winter wave heights (to the mid-1990s), more frequent winter storms since the mid-20th century, and rising sea level as key evidence.

Since *Charting Progress* we have made considerable progress in our ability to assess the state of ocean process variables. This chapter builds on the findings of *Charting Progress*. Although the conclusions in this assessment generally reinforce those from 2005, recent awareness of ocean acidification, and concerns about the ability of our seas to continue to take up carbon dioxide from the atmosphere, means we have added this issue as an explicit topic.

We have based our assessment on a combination of direct measurements from ongoing and new monitoring programmes, understanding of processes, and models.

This combination is very powerful. The variables that define ocean processes – such as currents, storm surges, waves, temperature and salinity – are typically not distributed according to local inputs by humans but follow patterns that depend on physical laws. Therefore, we do not need to measure them at every point in order to assess the overall state. Rather we can obtain enough measurements to keep the forecast models on track, and then use the models to assess the state in places where there are few or no measurements. This ability has improved since *Charting Progress*.

Since we have no clear reference point, baseline or criterion against which we can sensibly assess the ideal state of the physical environment, we focus here on the present state and trends. Note that Chapter 6 will describe our projections of the future state of the physical environment, based on models of likely changes in climate.

There are two levels at which we affect the physical environment of UK seas. Locally, and directly, design and control of construction and activities can influence temperature, currents, waves and suspended matter. For example, offshore wind farms can affect winds; tidal energy barrages or breakwaters can change currents, the height of the sea surface, waves and suspended matter; coastal developments, defences and dredging can all affect suspended particulate matter and coastal power stations

FRV Scotia *in rough seas*

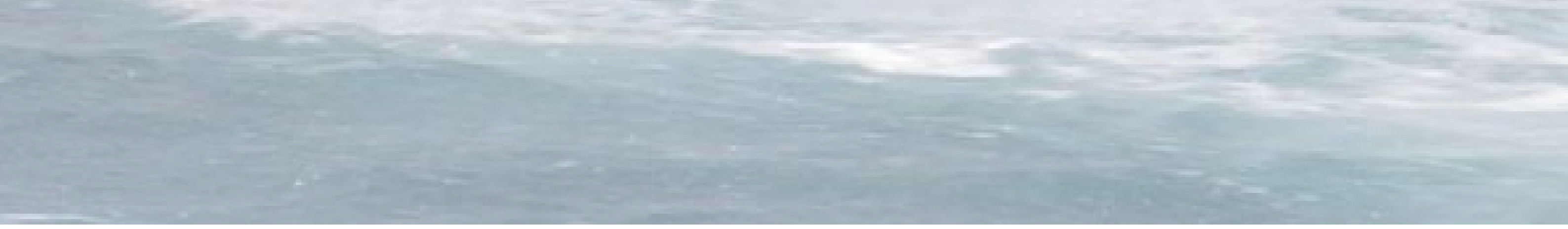
can raise the temperature of the cooling water they release back to the sea. Such activities are subject to environmental impact assessments and/or licensing which require such changes to be considered. Less directly, and more broadly, greenhouse gas emissions will influence future temperatures, salinity, pH, sea level, and possibly winds and waves. At either level, we are restricted as to how much we can control.

Our confidence in the estimated state and variability or trends is generally high. We found representative data on appropriate scales for all variables except where affected locally by shoals, proximity to land or river outflows. Morphology, rainfall, salinity and circulation are most susceptible to variability on small spatial scales.

Weather and climate

Atmospheric weather and climate have important effects on the ocean, influencing its temperature, salinity and circulation patterns on short and long timescales, respectively. For this assessment we have studied variability and trends in these factors using direct observations from the UK and world-wide.

There have been significant changes over the past few decades. The global surface air temperature has risen by about 0.75 °C since the late 19th century, 0.15 °C more than estimated in *Charting Progress* (some more warm years since then have affected trend assessments). The ten warmest years since global records began in 1850 all occurred between 1997 and 2008. The Central England Temperature has risen by about 1 °C since the beginning of the 20th century, as



have annual mean air temperatures over Wales, Northern Ireland and Scotland. 2006 was the warmest year in central England since records began in the 17th century. Most of this rise was very probably caused by increases in human greenhouse gas emissions.

The average number of winter storms recorded at UK stations has increased significantly over the past 50 years. However, this has largely balanced a decline in the first half of the 20th century. Winters are continuing to become wetter in northern and western Scotland. Two out of the five wettest UK summers since records began in 1766 were in 2007 and 2008.

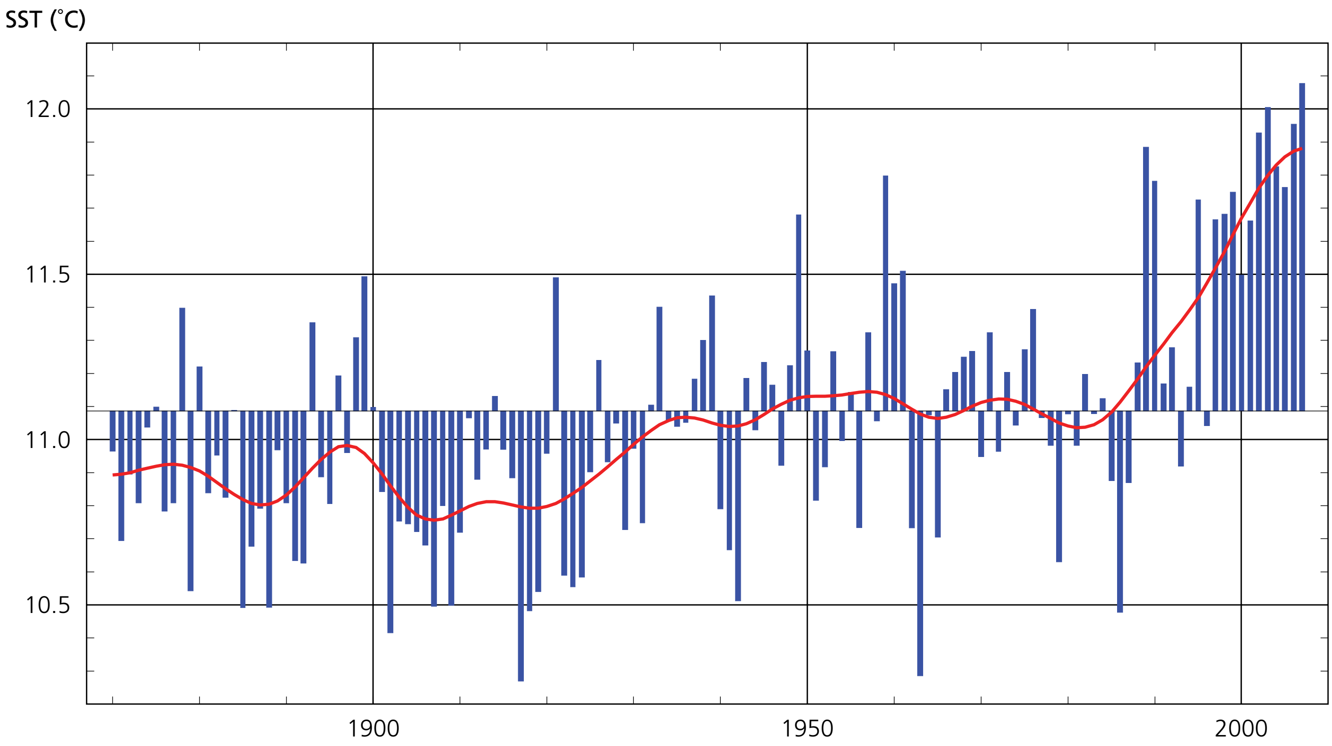
Sea temperature, salinity and circulation

Ocean temperature, salinity and circulation affect marine ecosystems in many ways. Some species are sensitive to temperature and/or salinity; circulation and currents distribute salt, deep-ocean heat and pollutants; currents affect habitats; many species are carried by the flow during their life cycle. Temperature and salinity control water density, which drives its motion in tandem with tides and winds. In return, circulation patterns and currents influence the temperature and salinity of the UK seas. From above, the atmosphere provides warming and cooling and changes the amount of freshwater arriving into the sea, through the balance of precipitation and evaporation as well as via rivers. For the shelf seas, the physical properties of the water column are controlled by a balance between mixing by tides and winds and buoyancy changes through warming, cooling and changes in salinity.

FerryBox system as installed on the RV Cefas Endeavour*. This equipment provides continuous measurements of variables such as temperature and salinity*

We have assessed variability and trends in these factors using time-series that span several decades. Temperature and salinity data come from: volunteer observing ships, drifting and moored buoys, repeated cross-sections measured from ships, bottom trawl surveys, coastal stations, and satellite radiometers. There are also some important recent developments. Over the past ten years the international Argo programme has established a global array of 3000 free-drifting profiling floats, measuring temperature and salinity between the surface and 2000 m depth; these now provide essential monitoring

Figure 2.1 Annual average sea surface temperature (SST) for the UK seas, between 1870 and 2007. The 1961–1990 average was 11.09 °C. The red line smoothes out fluctuations shorter than 5 to 10 years to illustrate the longer-term trend.



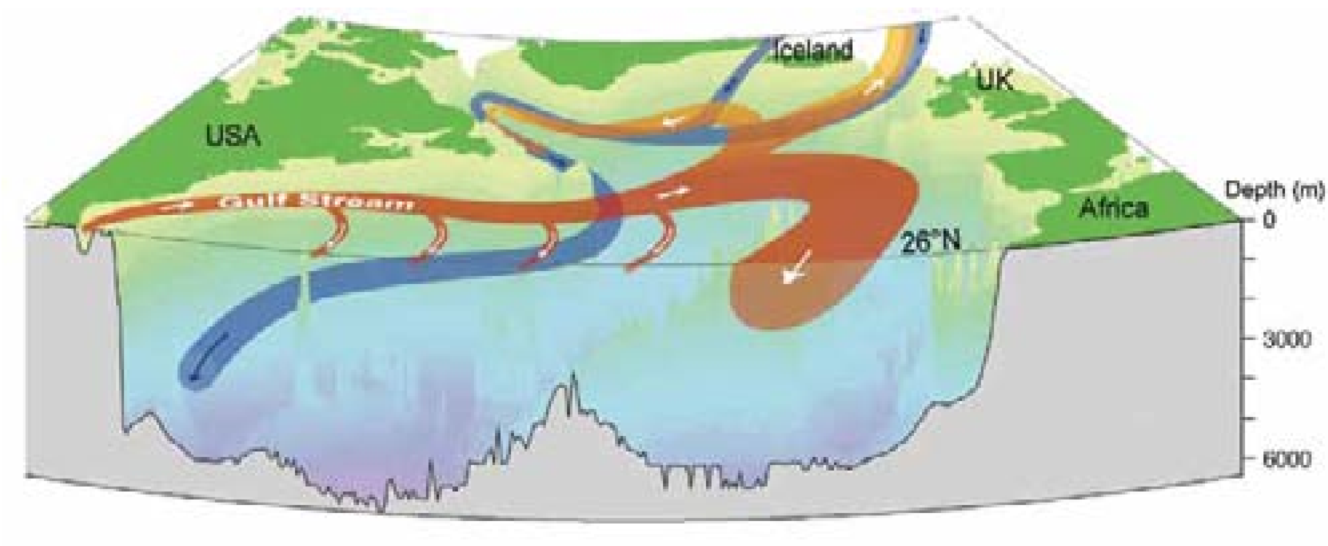
data in deeper waters west of the British Isles. The Natural Environment Research Council (NERC) and The Department for Environment, Food and Rural Affairs (Defra) have supported FerryBoxes on some ferries (see photo), and long-term series in the western English Channel, the Isle of Man and Liverpool Bay.

Temperature

Globally, sea surface temperatures rose by about 0.3 °C from around 1910 to 1940, remained steady until the 1970s and have then risen again by about another 0.4 °C. Since the mid-1980s, Atlantic surface waters adjacent to the UK have warmed by between 0.5 and 1 °C. Superimposed on this background trend are seasonal cycles of many degrees, variations between regions, and interannual-to-decadal variability (for any season) of 0.5 to 2 °C.

In shallower UK shelf seas, mixing of water masses and especially local weather largely control the temperature, on timescales of a day (for 1 m water depth) to a few months (for 100 m water depth). There is also some influence from adjacent Atlantic water where it moves onto the shelf. The annual sea surface temperature, averaged around the UK coastline, has increased by about 0.5 to 1 °C for the period 1870 to 2007 (Figure 2.1). Much of the warming took place in the 1920s and 1930s and again since the mid-1980s; this later warming was especially pronounced in the Southern North Sea, Irish Sea and the Minches and Western Scotland. Spatial and interannual temperature variability in UK waters is of the order of 0.5 °C; but can be up to 2 to 3 °C in shallow areas for an extreme month.

Figure 2.2 Schematic of the North Atlantic ocean circulation showing the northward transport of relatively warm surface water (red/orange) and the southward return of cooler, subsurface water (blue). The Gulf Stream is a component to the overall circulation. Note the partial recirculation of northward-flowing water by the sub-tropical and sub-polar gyres before water enters the far North Atlantic.



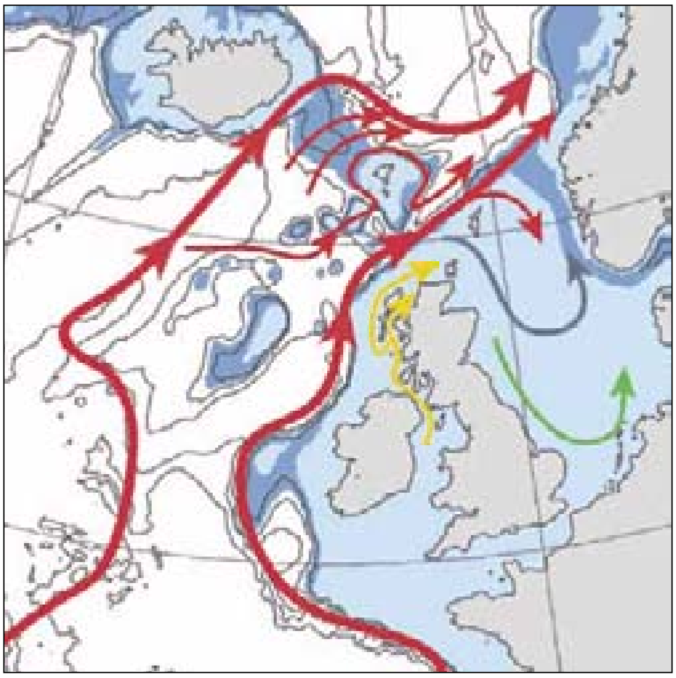
Salinity

Salinity is influenced primarily by Atlantic water, slightly by rainfall and evaporation, and locally by the influx of fresher water from rivers via estuaries; values are usually between 34 and 35.6 in salinity units. Atlantic waters adjacent to the UK have experienced an increase in salinity of 0.05 to 0.1 units since the late 1970s and this in turn has caused a salinity rise in the nearby UK shelf waters. The picture is rendered more complex by spatial and interannual-to-decadal variability, of up to 0.1 in salinity. Irish Sea salinities are especially variable; they are typically between 34 and 35 in the west but sometimes as low as 31 approaching the English coast where freshwater inputs are relatively important. Typically salinity is most variable, with potential impacts on biota, near the head of an estuary where the fresh-salty water transition may move according to river flow and stage in tidal cycles.

Circulation

North-East Atlantic temperature and salinity are controlled by the large-scale circulation (Figure 2.2) and history of these waters. The Atlantic Meridional Overturning Circulation (AMOC) brings warm surface water past the west of the UK, strongly influencing our climate by warming the prevailing westerly airflow. Instantaneous currents in UK shelf seas comprise tidal flows, wind-driven flows and flows driven by differences in density that arise from seasonal heating and salinity differences. 'Residual' flow, after averaging out oscillatory tidal flow, is mainly driven by winds and by density differences in many areas. Tides, winds and density all change on a range of timescales, so that observed and residual flows can be very variable. On the shelf, transport of water in a single storm can be significant relative to a year's total.

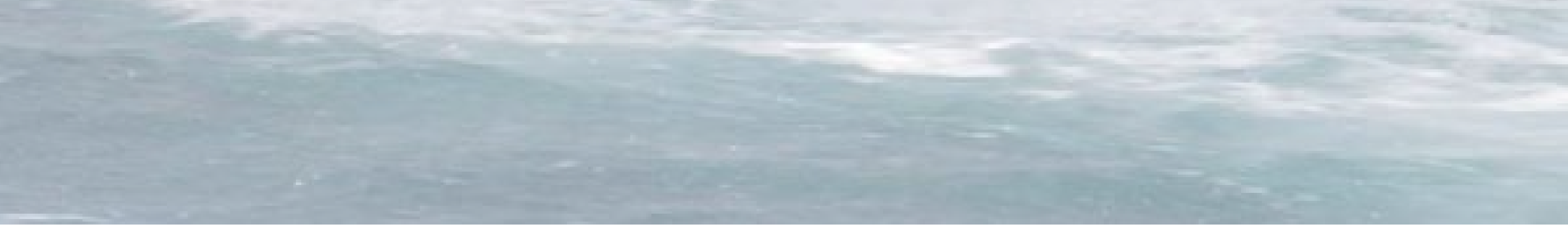
Figure 2.3 Schematic of circulation of surface waters in the North-East Atlantic. Red arrows represent the flow of warm, salty Atlantic waters along the continental slope and further west, while the yellow, blue and green arrows represent the flow of coastal waters. The yellow arrow indicates the path of the Scottish Coastal Current, while the blue arrow indicates the inflow of mixed coastal/oceanic water past Fair Isle (the Fair Isle Current) and the green arrow indicates average anti-clockwise flow in the southern North Sea.



We have assessed the long-term circulation in the adjacent North Atlantic using tracks of drifters and Argo floats, and in shallower UK waters using distributions of tracers, drifter tracks or numerical hydrodynamic models. We have also used data from current-meter measurements in a few long-term mooring arrays and from submarine cables. For components with timescales longer than a day, we inferred circulation from ship-based temperature and salinity measurements. High Frequency radar gives spatial coverage for surface currents, although the range is limited to the order of 50 to 100 km. A recent development is the NERC-funded RAPID programme which maintains an array of moored sensors to study the sub-surface temperature and salinity distribution, and hence monitor transport of the AMOC, across a section of the Atlantic Ocean at 26° N where it is strongest.

Five ship-based cross-sections of the Atlantic near 24° N suggest that the AMOC declined in strength from 1957 to 2004. However, continuous measurements starting in 2004 show this to be within the range of variability on timescales of weeks to months, so that we cannot be sure of an overall trend. Deep outflows of cold water from Arctic seas are likewise too variable to infer any trend.

Future monitoring of the Atlantic circulation in RAPID extends to 2014; this will help to clarify variability and the statistical confidence in any trend. However, changes in circulation at 26° N have proved hard to relate to patterns of sea surface temperature (Figure 2.3), or to circulation at higher latitudes, where AMOC correlation with surface heat fluxes is suggested by models. Other measurements, especially at higher latitudes, may help us to understand how changes in the AMOC are relayed from place to place and possibly to establish proxies for easier monitoring.



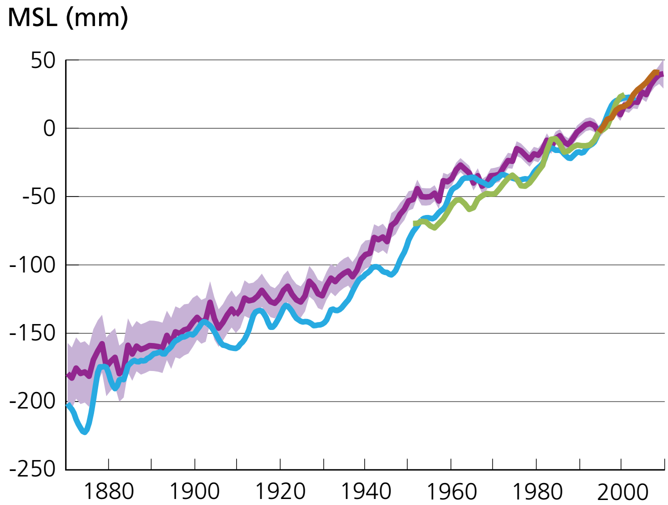
Carbon dioxide and acidification

The oceans play an important role in reducing the contribution of carbon dioxide (CO_2) to climate change, by taking up more CO_2 than they release, which substantially reduces the rate of increase in the atmosphere. However it also makes the oceans more acidic and potentially reduces their capacity to take up CO_2 in the future. Continental shelf seas play a key role in this global CO_2 uptake. Changing the pH of seawater alters the balance of and rate of conversion between different nitrogen compounds, changing their availability to support the growth of phytoplankton and hence eutrophication. Biogeochemical and ecosystem processes affected include planktonic calcification, carbon and nutrient assimilation, primary production and physiology; many marine animals have planktonic larval stages that are likewise vulnerable. Organisms such as bivalves and tube worms may have difficulty forming shells in lower-pH waters. Changes in pH also affect the availability of trace metals, which may be necessary for plankton growth, or may in some cases be toxic. We assessed the state of CO_2 uptake and acidification in UK waters using models of the sea, inverse modelling of atmospheric concentrations and validation with evidence from direct measurements.

We found that the north-west European continental shelf is a net absorber of atmospheric CO_2, but that its capacity to do so is highly variable. More widely, the North Atlantic apparently reduced its net uptake of CO_2 by more than 50% from the mid-1990s to 2005. However, this may be part of a natural cycle rather than a one-way trend.

Since the industrial revolution, ocean acidity has already increased by a third (or decreased by 0.1 in pH units).

Figure 2.4 Global mean sea level estimated by different methods of averaging coastal tide gauge data (purple, green and blue lines – all held by the Permanent Service for Marine Sea Level). The pale purple envelope shows the estimated uncertainties of the purple line. The brown line shows altimeter data, which are independent of tide gauge data.



Because there are currently no baseline measurements of pH against which changes in UK waters can be judged, it will be some time before we can make accurate judgements about the rate of acidification relative to natural annual and interannual cycles of pH. We also need a better understanding of the physical, chemical and biological processes controlling the ocean's ability to absorb CO_2.

Sea level

Growing populations and urbanisation of the coastal zone means that increasing numbers of people are vulnerable to extreme rises in sea level, particularly in south-eastern parts of the UK. Sea level changes affect inter-tidal habitats and groundwater status. Rising sea levels imply more flooding and more coastal erosion by waves, for any given storm scenario.

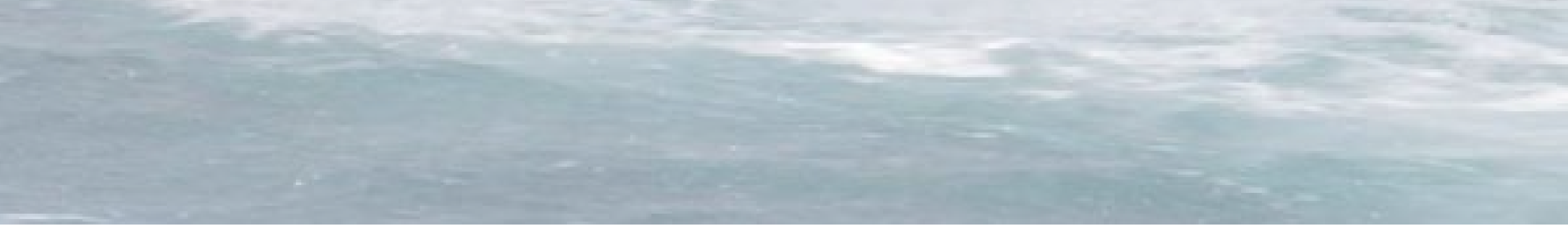
Erosion at Hunstanton cliffs, Norfolk. Rising sea levels are affecting a large proportion of the coast in this region

For this assessment we used data from global and UK-wide networks of tide gauges, satellites, and climate modelling. Most findings are available in the scientific literature and have been included in the periodic assessments published by the Intergovernmental Panel on Climate Change (IPCC).

Global sea level rose by about 1.7 mm per year during the 20th century (Figure 2.4); the few long European records suggest this rate of rise was slightly faster than in the 19th century. The rate of rise around the UK coast, adjusted for land movements, was slightly less at about 1.4 mm per year during the 20th century. However the rise was not steady. For example, in the 1990s sea level rose by 3 to 4 mm per year.

Oceanic tides around the UK generally show some local short-term variations in height and timing, but no long-term trends. However, there is a long-term increase in mean tidal range at Newlyn (south-west Cornwall), notable for its long well-maintained record, open-sea location and lack of harbour works. Extreme sea levels (mean + tide + storm surge) are rising at about the same rate as mean sea level.

The most significant missing piece of this puzzle is a fuller understanding of the connection between the causes of sea level rise and the effects. To address this, scientists are attempting to set up a coherent global monitoring system for sea level (altimetry, space gravity, tide gauges) and for the factors that cause changes in sea level (mass balance of ice sheets and glaciers; temperature and salinity of the ocean; water in rivers, lakes, soils and the rocks below). This will give us greater confidence in model predictions of future change, which should enable more effective coastal planning and management.



Waves, suspended particles and turbidity

Waves affect transport, fishing, offshore industry and coastal communities; they can cause coastal erosion and structural damage, which contribute to flood risk. They influence the stratification of surface layers and the rate at which gases pass between the atmosphere and the ocean surface. In shallow waters, waves cause strong currents within a few centimetres of the seabed, affecting habitats and suspending sediment.

In turn, suspended particulate matter (SPM) influences nearshore and benthic habitats; it affects marine communities including plankton, benthic invertebrates and fish, by carrying pollutants and blocking sunlight, so inhibiting photosynthesis. SPM also includes plankton and so forms part of the marine ecosystem. Hence studying SPM can help us understand the transportation of pollutants and nutrients, primary production and its fate – how much falls to the seabed or contributes to the water-column food web – and perhaps also eutrophication. SPM also affects bathing water quality. Its transport, for example longshore drift, is a factor in coastal erosion and morphology. SPM is driven directly by seabed currents from tides, wind and waves, and so varies greatly with water depth. It also depends on sediment availability, which can be affected by dredging and land use, and varies locally with rainfall and flooding around the coast.

For waves, this assessment uses data from satellite altimetry, wave sensors on moored buoys and lightships, offshore and many nearshore sites. We have also used modelling for wave prediction, forecasts and state estimation, which is well-developed.

In the west (especially the north-west) and the Irish Sea, winter wave heights correlate significantly with the North Atlantic Oscillation Index, which is a measure of the strength of westerly winds at UK latitudes. They increased through the 1970s and 1980s west of the UK and in the North Sea from the relatively calm conditions experienced during the 1960s. However, recent trends are not clear, with some measurement sets appearing to show a decrease in winter wave heights. Year-to-year variability is such that there is no clear longer-term trend and no clear change since *Charting Progress* was published in 2005.

In very shallow waters, for example near coasts, trends in wave heights are less marked because the water depth limits the height of the waves as they break. However, as rising sea levels increase nearshore depths, larger waves may approach the shore, enhance erosion and steepen intertidal profiles.

For SPM, we used data from traditional assessment methodologies such as measuring the depth over which a white disk can be seen suspended in the water. However, more sophisticated optical techniques such as back scatter from light beams are increasingly available for particle size as well as concentration. This has increased our understanding of SPM dynamics and processes in shelf seas, especially the tidal stirring of sediments. Remote sensing measurements of ocean colour provide time series for studying variability of SPM, phytoplankton pigments and coloured dissolved material. However, these techniques can be hampered by clouds and by insufficient understanding of optics in turbid coastal and shelf waters.

There is much ongoing research on SPM and turbidity in coastal regions of the UK and Europe but we still need to understand more about nutrient binding and the breakdown of particulate matter. The data currently available show that SPM concentrations, and therefore turbidity for UK waters, are very variable depending on currents, biological influence on sediment properties and seabed characteristics. However, we have no evidence for any changes in the general state of SPM around the UK since *Charting Progress*.

Sedimentary processes and morphology

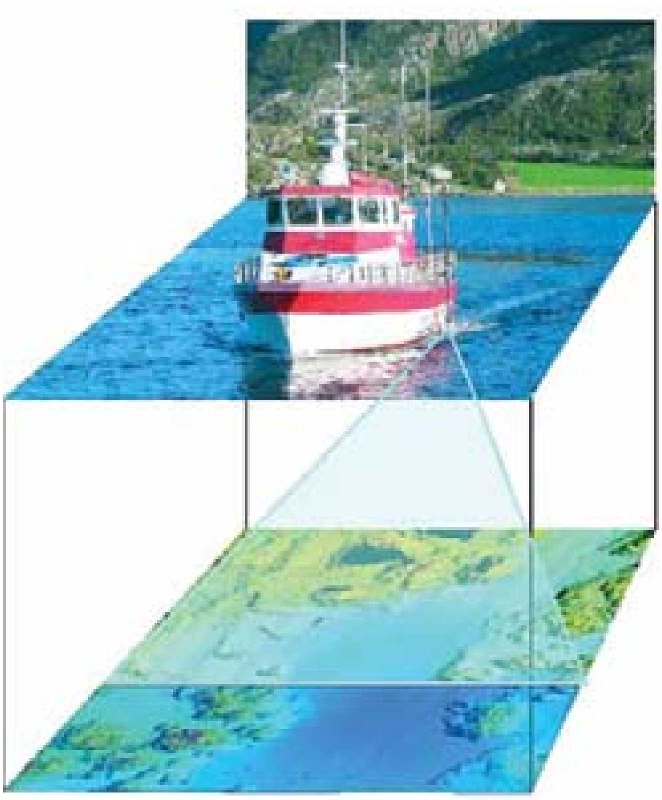
The morphology and sedimentary processes of the seabed play a critical role in the distribution of benthic habitats, which form an integral part of much of ocean life. For this assessment we have brought together data from many sources, including research programmes and commercial surveys.

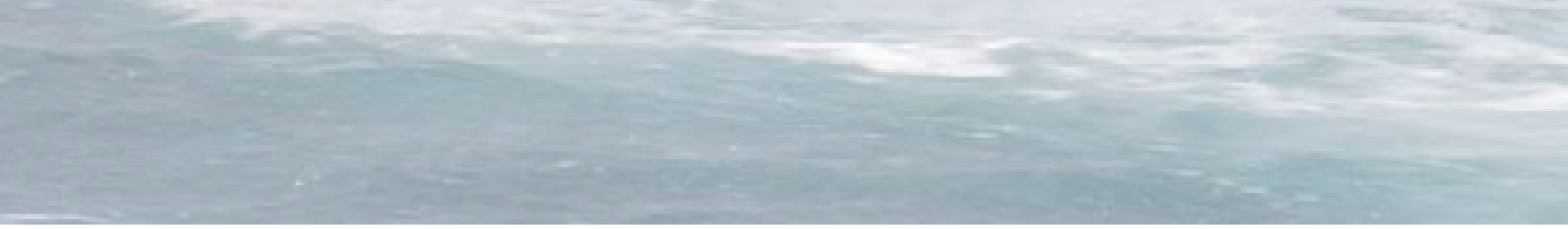
In areas of relatively rapid coastal erosion, rates of change are being monitored. Offshore, there are several means of mapping the seabed. Multibeam Echosounder Systems (MBES; Figure 2.5) provide a new approach, and MBES data collection programmes have expanded dramatically since *Charting Progress*. We now have new measurements from all regions using MBES, although as of 2008 MBES data cover only about 15% of the UK seabed.

As yet we have little information from very shallow waters, where surveying is slow (the rate of coverage is proportional to the water depth) and therefore cost has limited progress. However, the coastal zone is so important in relation to erosion, flooding, habitats, and commercial uses, that this is a key area for future work.

In offshore areas, the rate of change of the seabed is generally low; rapid changes are restricted to shallow areas where wave action is strong or human activities take place (e.g. trawling, aggregate extraction and dredging). Erosion (excluding hard-rock coasts) is occurring along 17% of the total UK coastline (30% of England's coastline; 23% Wales; 20% Northern Ireland; 12% Scotland). Almost two-thirds of the intertidal profiles in England and Wales have steepened over the past 100 years, as rising sea levels have taken waves closer to the base of hard defences or erodible cliffs. Steepening of the intertidal profile is particularly prevalent on coasts defended against erosion (this represents 46% of England's coastline; 28% Wales; 20% Northern Ireland and 7% Scotland).

Figure 2.5 Schematic illustration demonstrating the principles of data collection using Multibeam Echosounder Systems.





To underpin future marine planning and to support commercial exploitation and legislative drivers such as environmental monitoring and conservation, we now need more high-quality bathymetric data and to match this with analysis of the geology and habitats, so forming coherent maps and models. We should optimise use of the several existing UK programmes that collect MBES data for a wide range of different uses (unlike Ireland, for example, which has a single integrated marine mapping programme). Better integration of Government-funded surveys is being achieved through: the Civil Hydrography Annual Seminar (CHAS) meetings organised by the Maritime and Coastguard Agency (MCA); a Memorandum of Understanding between several public sector organisations to share data; and several initiatives to collaborate in the collection and interpretation of data (e.g. Channel Coastal Observatory and MCA; NERC research centres and others). Adding commercial data, and further collaboration between programmes building on the Civil Hydrography Programme, would help in developing marine renewable energy and meeting the challenges of the EU Marine Strategy Framework Directive.

Future work

For the immediate future, we should sustain measurements of ocean process variables at least at their present intensity. However, we could significantly reduce the uncertainties in future assessments by increasing the quality and quantity of these observations, notably for sub-surface temperature and salinity. Moreover, the accuracy of reported variability and trends in several variables is limited by the spatial density of observations. Uncertainty in monthly mean air temperature estimates over the Atlantic near the UK increased many-fold from 1970/74 to 2004/08 owing to fewer voluntary observing ships, implying reduced confidence in marine air temperature trends. In UK shelf seas, salinity, current and wave measurements are sparse and are inadequate for sampling local variations.

Better prediction of short-term variability in circulation will require both model validation and the development of new observational networks. For currents, temperature and salinity, model experiments could help design measurement arrays: i.e. the density, frequency and allowable time-delay in observed data sets (assimilated in forecasting models) that provide the best cost/benefit value both for making predictions, and for assessing the current state of UK waters.

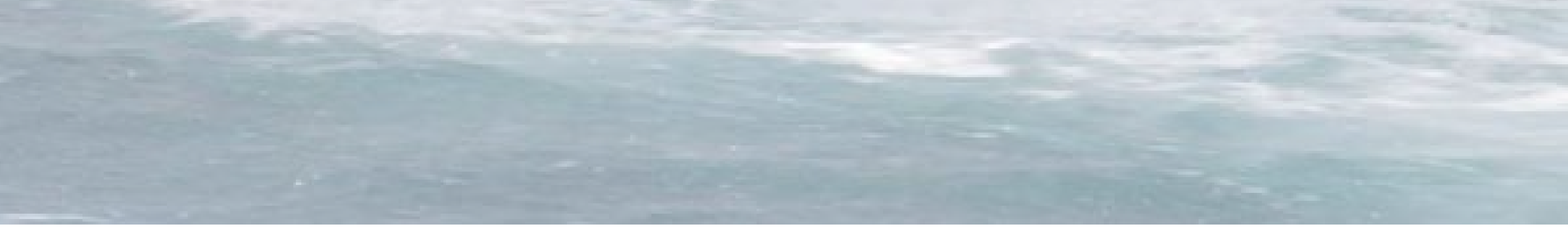
Long-term, decadal-scale trends in variables such as temperature, precipitation, salinity, circulation, waves, and suspended particulate matter and its dependent biogeochemistry, are often obscured by larger short-term variability from year to year, season to season and from one weather event to the next. To separate out the longer-term trends and make a better assessment of the contribution of human-induced climate changes, we will need long-term yet frequent measurements, as in UK coastal observatories, and/or understanding and models that enable shorter-term variations to be estimated from their known causes. Data buoys and ships of opportunity (for example using FerryBoxes – see photo on Page 16) now demonstrate much improved temporal and spatial coverage in a cost-effective manner.

Equipment used to collect water samples and measure a range of variables including temperature

Assessment summary

The summary table on Page 26 shows the status of ocean process, in both the UK atmosphere and the UK seas.

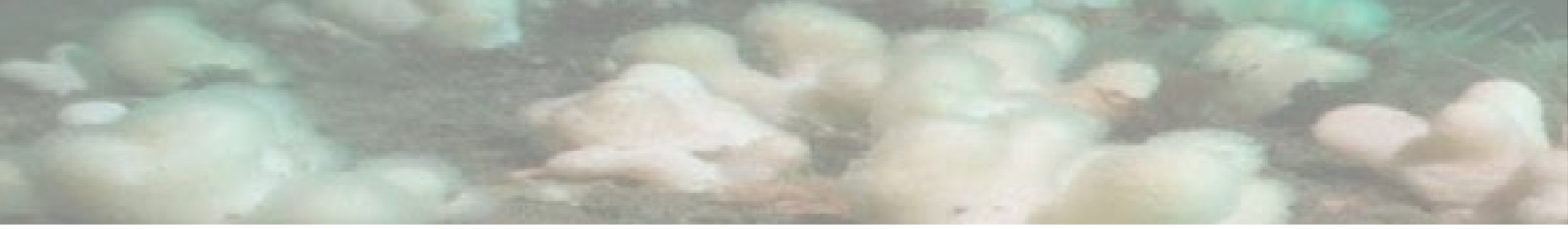
The first column shows the trend in the variable assessed, with ↑ representing an upward trend and ↔ representing no significant trend. The central column describes the timescales over which change has occurred. The assessments in the Feeder Report prepared by the Ocean Processes Evidence Group provide valuable additional information that can be used to give context to the findings given in the summary table.



Ocean Processes – Assessment summary

Trend in variable assessed	*Status in UK atmosphere and seas*	*Influencing factors and significance for UK seas*
Air temperature Upward trend	**Rising in all regions** UK annual mean temperature has risen by about 1 °C since the beginning of the 20th century. 2006 was the warmest year in central England since records began in the 17th century	**Influencing factors** Global climate change mostly resulting from anthropogenic greenhouse gas emissions **Significance** Raises sea temperature
Sea temperature Upward trend	**Rising in all regions** Sea-surface temperature has risen by between 0.5 and 1 °C from 1870 to 2007. Warming since the mid-1980s has been more pronounced in Regions 2, 5 and 6 (Southern North Sea, Irish Sea, Minches and Western Scotland)	**Influencing factors** Air temperature **Significance** Reduces the ability of the oceans to take up CO_2, affects certain species, e.g. forcing them to move or adapt, and contributes to rising sea level. Shifts in plankton populations on which most marine animals feed are associated with temperature rise
Sea level Upward trend	**Rising in all regions** Mean sea level around the UK coast rose by about 1.4 mm per year during the 20th century	**Influencing factors** Temperature (the greater effect to date) and melting land-based ice (potentially more important in future) **Significance** Intertidal habitats and groundwater regimes are affected, and the flooding risk for vulnerable coastal populations will increase, notably in Region 2 (Southern North Sea), if upward trends continue
Carbon dioxide and ocean acidification Upward trend	**Acidification in all regions** Oceans are acidifying (pH decreasing) as CO_2 is absorbed. In UK waters we have no baseline measurements of pH against which changes can be judged, and it will be some time before we can make accurate judgements about the rate of acidification relative to natural annual and interannual cycles of pH	**Influencing factors** CO_2 which is present naturally and released from anthropogenic sources (e.g. combustion of fossil fuel). Various climatic factors influence its concentration in the sea **Significance** There are potential threats to marine species and ecosystems if acidification continues
Circulation, suspended particulate matter, turbidity, salinity and waves No significant trend	**Variable** These processes vary on daily to interannual timescales but show no significant trend over the past decade, except for a slight salinity decrease in Region 2 (Southern North Sea) and a slight increase in salinity in the northern Regions 1, 7 and 8	**Influencing factors** *Circulation:* tides and weather, especially winds *Salinity:* rainfall near the surface and near river outflows; adjacent Atlantic salinity **Significance** *Suspended particles:* can reduce light availability and inhibit plant growth *Waves:* the main cause of damage to offshore and coastal structures

CHAPTER 3
HEALTHY AND BIOLOGICALLY DIVERSE SEAS



Introduction

The first report on marine stewardship, *Safeguarding Our Seas,* outlined a vision of clean, healthy, safe, productive and biologically diverse oceans and seas. In 2005, the first full assessment of the state of the UK seas, *Charting Progress*, showed that they were productive and supported a wide range of fish, mammals, seabirds and other marine life; however, it also reported evidence that human activities such as widespread commercial fishing practices were harming marine ecosystems, and that climate change was affecting the health of the seas.

This chapter builds on the outcome of *Charting Progress*, showing progress that has been made towards the vision of healthy and biologically diverse seas. Based on the Feeder Report prepared by the Healthy and Biologically Diverse Seas Evidence Group – the largest and most comprehensive assessment ever completed of the health of marine ecosystems in UK waters – *Charting Progress 2* focuses on the biological aspects of the UK seas. The chapter begins with an assessment of benthic habitats, which are of interest for the communities and species they contain, moving on through the primary producers at the base of the food chain (microbes and plankton) up through fish to top predators such as seabirds and cetaceans. Figure 3.1 shows the six broad habitat types found in UK waters.

The chapter includes sections on two important groups that were not included in the *Charting Progress* assessment: microbes and turtles. In the past few years, microbes – bacteria, archaea, viruses and many protists – have become more widely recognised as vital parts of the marine ecosystem. All marine turtle species found in UK waters have international protection and the UK therefore has a responsibility to contribute to their conservation and report on their status. We have also added waterbirds to the assessment of marine birds as they depend on marine habitats for foraging and other activities.

Where there were sufficient data, the assessments are based on formal protocols. However, where the data and available assessment techniques were inadequate we have relied on the judgement of experts to fill the gaps. It is important to note that although we are reporting on change in the past five years we have also looked at data over the longer term to set this in context. The timeframe for each assessment varies depending on the information available for each topic. Full details concerning methodologies, data sources and assessment timeframes can be found in the Feeder Report.

Benthic habitats

Benthic marine habitats include all biological communities associated with the sea floor, from the top of the intertidal zone and inner reaches of estuaries down to the deep sea. UK waters encompass the transition zone between north-eastern, cold-water communities and south-western, temperate-water communities found along western Europe. For this reason our waters are particularly important at a European scale for their exceptional variety of benthic habitats and thus high overall biodiversity. However, many of these habitats are affected by human activities.

We assessed whether human activities were putting pressure on the different habitats, using thresholds derived from the EU Habitats Directive and work by OSPAR. These assessments were based on the area of habitat considered to have been impacted by each pressure.

Since habitat maps derived from survey data cover just 10% of the UK continental shelf, we had to rely on models for much of this

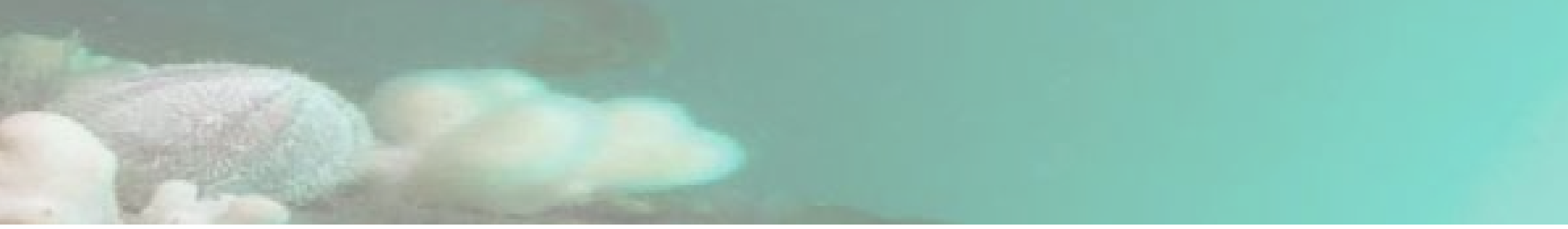
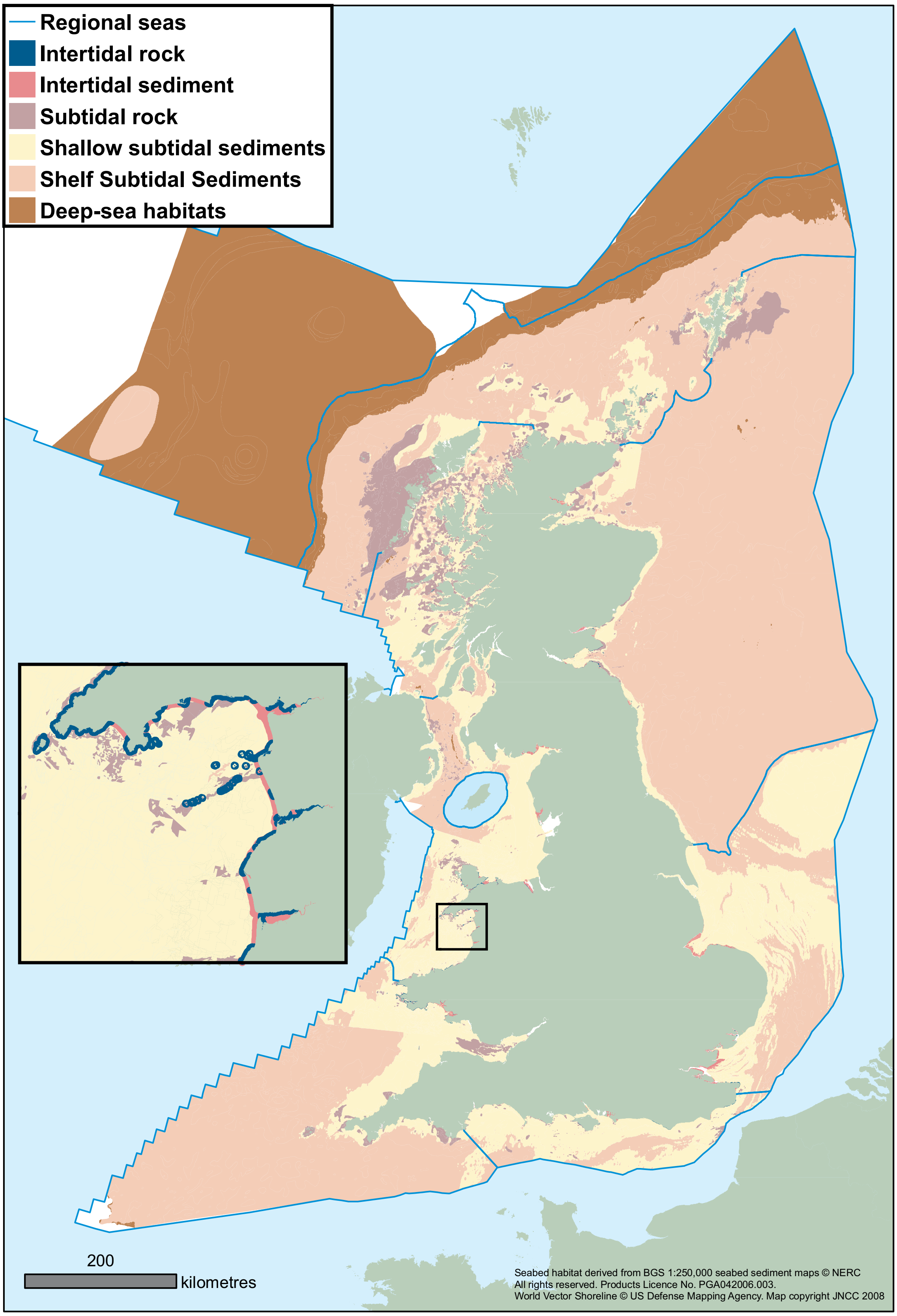
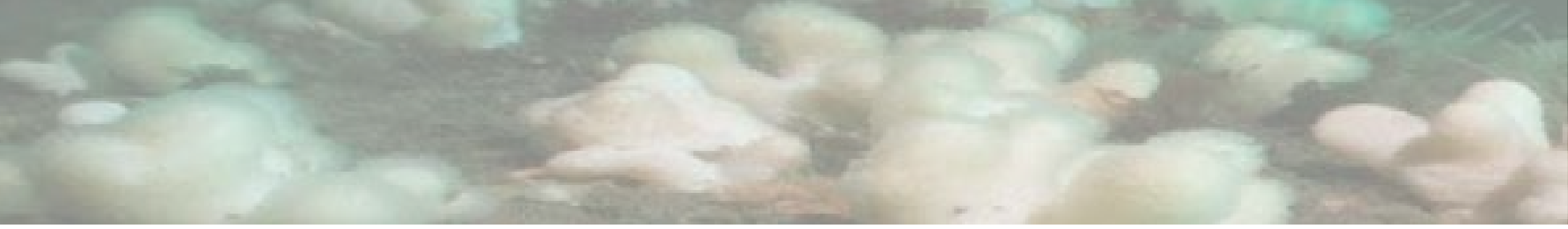


Figure 3.1 Distribution of six broad habitat types found throughout UK waters. Subtidal and deep-sea habitat types are derived from modelling; intertidal habitat types are derived from survey data. The inset box shows an example of intertidal habitats in the Cardigan Bay area in larger scale. The white space in the map indicates where there are insufficient data to model the habitats.





Red sea fingers

assessment. Where the data were incomplete or unavailable, we based our assessments solely on expert judgement (in such cases, this is reflected in a low confidence ranking in the assessment).

We made separate assessments for six broad habitat categories: intertidal rock; intertidal sediments; subtidal rock; shallow subtidal sediments; shelf subtidal sediments, and deep-sea habitats. In each case, we judged the current status of the habitat relative to an expert view about former natural conditions (i.e. in the absence of human pressures), the trends over the past ten years, and the prospects for the next two decades.

Intertidal rock

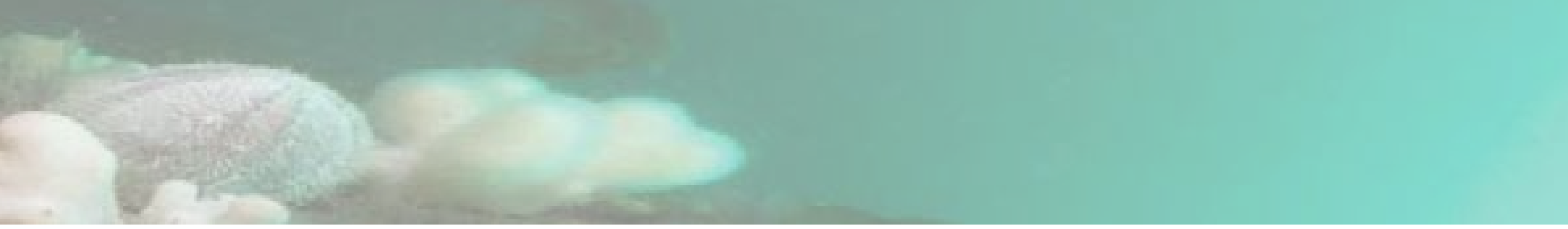
Intertidal rocky habitats, including rocky and boulder shores and sea cliffs, occur in all UK seas. Although these habitats are generally in good condition the harvesting of edible shellfish and the occurrence of non-native species are adversely affecting some local rocky shore communities. In addition, species composition of intertidal rocky communities in the Western Channel and Celtic Sea region is already impacted by warmer waters due to climate change.

Intertidal sediments

Along the south-eastern and north-western coasts of England and parts of Wales, intertidal sediments form extensive beaches, sandbanks, saltmarshes and muddy shorelines. In Scotland and Northern Ireland, such stretches of intertidal sediments are often interspersed with rocky promontories and headlands. Human pressures have adversely affected moderate to large areas of these habitats, notably mudflats and saltmarshes, in most of the UK seas apart from those around northern and western Scotland. Historical land claim and the construction of coastal defences and other structures have caused widespread habitat loss, particularly in England. Such structures also affect these habitats by changing current patterns and sediment distribution. In the Southern North Sea and Eastern Channel, the presence of non-native species such as common cordgrass (*Spartina anglica*) has led to widespread changes to saltmarshes and mudflats. Water quality can affect these habitats and although water quality has improved overall, there are still some small inshore areas where hazardous substances and nutrient enrichment are a problem. Beach litter levels are high in most regions but impacts remain largely unknown.

Subtidal rock

Expanses of subtidal rock are less common in UK waters than sediments (see Figure 3.1). The largest known areas occur in Scottish waters, particularly to the west of the Hebrides and around Shetland, although some extensive areas also occur off Devon and Cornwall. Elsewhere this habitat occurs mainly as a narrow band adjacent to rocky shores. There are also offshore biogenic reefs built by marine species including horse mussels (*Modiolus modiolus*, found mainly to the north), and ross worms (*Sabellaria*



spinulosa), which are more common in the south and east. Overall, only limited areas of subtidal rocky habitats appear to be directly impacted by human activity. Some have, however, been permanently damaged or removed by mobile fishing gears such as bottom trawls. Bottom trawling has had a particular impact on fragile habitats such as biogenic reefs. Locally (such as near some large ports around England and Wales), subtidal rocky habitat has also been lost because of construction, coastal infrastructure or disposal of dredged materials.

Shallow and shelf subtidal sediments

Subtidal sediments – sand, gravel, muds and mixed sediments – cover almost all the continental shelf around the UK as well as coastal habitats such as sea lochs and lagoons. Shallow subtidal sediments, which can be regularly disturbed by surface waves are especially widespread in the Irish Sea, the Eastern Channel and the Southern North Sea, where they occur out to considerable distances offshore; they also occur in coastal lagoons, particularly in southern England and western Scotland.

Shelf subtidal sediments are only rarely disturbed by surface waves because of their greater water depth, and can therefore support more stable communities. They occur throughout offshore areas of most regions, but also much closer to coasts where the water deepens rapidly, such as around most of Scotland, Northern Ireland and Cornwall. They are also found on Rockall Bank, west of Scotland.

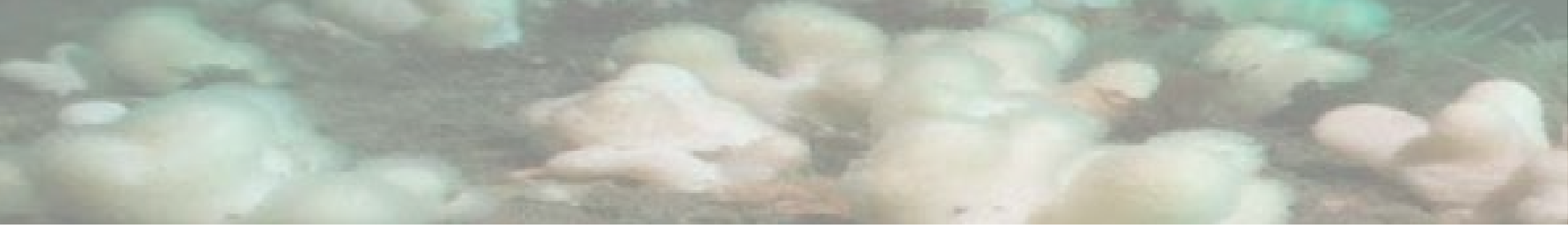
Large areas of subtidal sediments in most regions have been adversely affected by mobile fishing gears such as bottom trawls and dredges, with less severe impacts on the Scottish Continental Shelf and the Eastern Channel. Locally, extraction of aggregates has damaged the seabed in the Eastern Channel and Southern North Sea. Some estuaries and subtidal coastal habitats along the south coast of England and in the Irish Sea continue to experience nutrient enrichment and pollution. Non-native species are spreading in the subtidal coastal areas in most regions.

Deep-sea habitats

Deep-sea habitats occur below 200 m, beyond the edge of the continental shelf. Within UK waters they mainly occur to the north and west of Scotland and west of Rockall, although there are also small areas in the extreme south-west Celtic Sea. Most of these are sediment habitats, with rocky habitats and reefs largely confined to seamounts and similar structures. Similar to other subtidal habitats, deep-sea habitats are vulnerable to the impacts of some types of mobile fishing gears. Although this represents the main pressure on these habitats, their current status varies by region, with large areas of habitat impacted in the Scottish Continental Shelf Region, and limited areas known to be impacted in the Atlantic North-West Approaches.

Future work

We have based most of this assessment on benthic habitats on expert judgement, considering the relationship between habitats and pressures and drawing upon limited evidence from monitoring studies and research. While the present approach represents a significant advance in methodology since *Charting Progress* there are still many uncertainties. These would be greatly reduced and the approach enhanced if more robust evidence were available on the distribution and intensity of pressures, and the distribution and condition of a wider range



*Examples of the diversity among benthic marine habitats in UK waters. Top left to right: Intertidal rock with brown algae (*Fucus *sp.); Intertidal mudflats; Middle left to right: Soft corals and other colonial invertebrates on subtidal rock; Shallow subtidal sediments with lugworm casts; Bottom left to right: Brittlestars on shelf subtidal sediment; Deep-sea coral reef.*

of habitats. We do not know how some of the pressures identified as currently impacting habitats (e.g. bottom trawling and aggregate dredging on subtidal sediments) will change in the future in their intensity and likely distribution. Some specific small-scale habitats at significant risk from particular pressures which were not captured in the assessment process have been identified separately.

Finally, the threshold values against which benthic habitats were judged in this chapter need to be reviewed to ensure that they are set at an appropriate level. The targets that will be established for Good Environmental Status under the EU Marine Strategy Framework Directive will help to address the main causes of human impacts on marine habitats.

Base of the food web

Nearly half the Earth's basic food supply comes from photosynthesis performed by microbes and phytoplankton in the oceans. Since they are the basis of the marine foodweb, changes in these primary producers transfer upwards through to higher trophic levels either directly or through their grazers, the zooplankton. Their success can potentially affect the size of fisheries, and the survival and success of such key species as sharks, turtles, seabirds and marine mammals in UK waters. Microbes and plankton are also sensitive indicators of environmental change at both the regional and global level; through various feedbacks they can both influence, and be influenced by, climate change. However, in spite of their great importance, until recently they have been very poorly understood.

Primary production

Primary production is the generation of organic matter through photosynthesis and almost half of the Earth's supply, ~45 Gigatonnes (Gt) or 45 × 10^9 tonnes of carbon per year, comes from the oceans. Of this, some 70 Megatonnes or 70 × 10^6 tonnes of carbon per year is generated in UK waters.

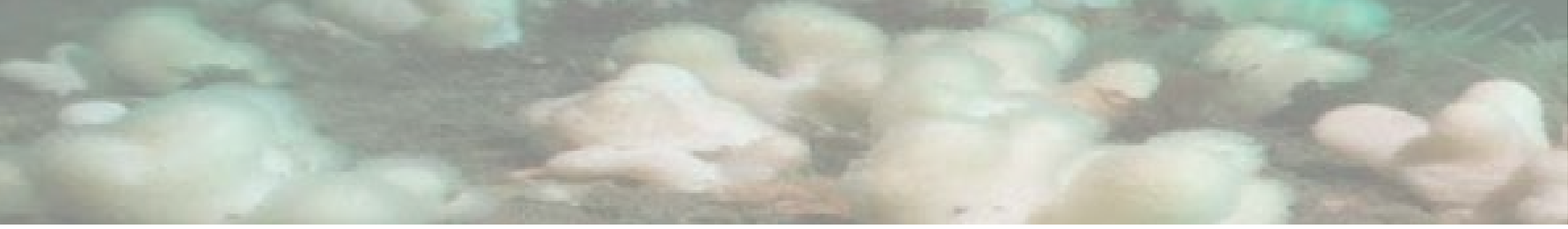
Microbes

Microbes, which include many protists and all archaea, bacteria and viruses, are invisible to the human eye yet make up one of the most important and extraordinarily diverse forms of life on our planet. In the marine environment they exist in complex, interdependent food webs with the rest of the oceanic biosphere.

Microbial cyanobacteria account for a substantial proportion of the ocean's primary productivity, especially in tropical and subtropical waters and even in UK waters are responsible for up to 50% of primary productivity – although this varies by region and season.

However, we still lack a fundamental understanding of the complex roles they play in UK waters. There is thus insufficient evidence to assign a current or future health status to microbes.

We do know, though, that because of their large population sizes and quick generation times, microbes can evolve rapidly in response to a changing environment. UK waters are important custodians of microbial diversity; we need to improve our knowledge of the environmental pressures that affect this key dynamic community.



Plankton

Through their production, plankton sustain almost all other marine organisms and determine the carrying capacity of ecosystems around the British Isles. In particular they regulate larval fish development and survival, and thus the success or failure of recruitment to the adult fish stocks. This free-floating life of the sea is divided into phytoplankton (plants) and zooplankton (animals). Copepods, the dominant zooplankton group in the North Atlantic, are small crustaceans, generally between 0.5 mm and about 8 mm long.

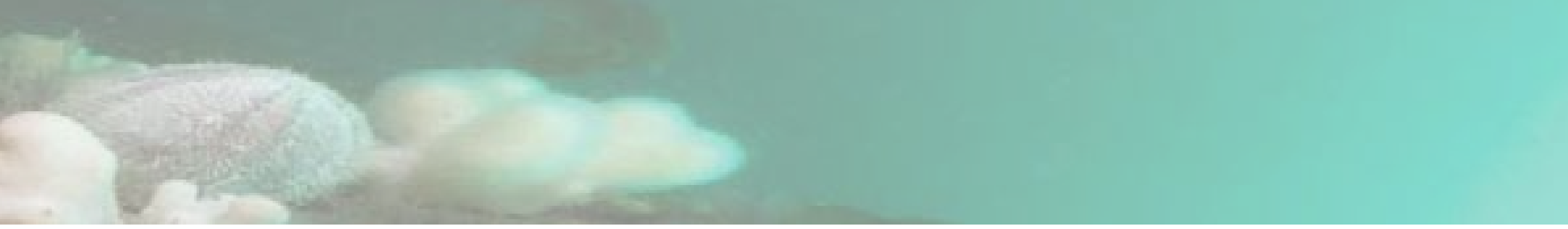
Plankton also modulate climate change through a range of feedbacks, especially by exporting carbon to the deep ocean via what is known as the 'biological pump'. A reduction in the carbon exported by this pump would lead to an increased build up of atmospheric greenhouse gases and accelerated global warming. This role played by plankton in ameliorating or increasing the rate of global warming is probably great, but as yet unquantified. There is clear evidence for large and extensive changes in the composition, abundance and spatio-temporal occurrence of both phytoplankton and zooplankton in waters adjacent to the UK and in the North Atlantic. However, we do not have enough information to determine plankton variability and its contribution to atmospheric levels of carbon dioxide (CO_2) at a UK, regional and global scale, and this is one of the key missing factors in modelling global climate change.

Large-scale changes have occurred to the distribution of plankton in UK waters. However, based on the large amount of data gathered on plankton from long-term observations, we consider that the plankton as a whole are healthy and subject to few direct anthropogenic pressures. The 'traffic light' status allocated to plankton has been graded amber because of the consequences to ecosystems and fisheries of the observed changes in the plankton due to rising sea temperatures and because it is still unclear to what extent natural variability, climate change and cascading effects from fishing may be contributing to change.

Continuous Plankton Recorder (CPR) being deployed

Phytoplankton

Photosynthesis by phytoplankton makes up at least 50% of the primary production in UK waters. Based on data from the Continuous Plankton Recorder (CPR - see photo) survey, there has been a large increase in phytoplankton biomass over the past two decades in offshore



waters around and to the west of the British Isles and in the past decade in the subpolar gyre. These changes probably reflect increased phytoplankton production, but there are no field measurements of production rates to confirm this. While the seasonality of the peak spring bloom of phytoplankton has remained relatively stable in time, the marine growing season has lengthened, particularly in the summer months and to a lesser extent during winter, due to rising sea temperatures.

Recent studies based on CPR phytoplankton surveys suggest that climatic variability and water transparency are more important than nutrient concentration to phytoplankton production at offshore regional scales, at least for the North Sea. Despite the overriding influence of climate, elevated nutrient and chlorophyll levels are sometimes of concern in localised areas around the British Isles.

Toxic blooms

A number of phytoplankton found in UK waters are harmful or toxic to some marine life. They tend to reoccur often in areas where they have previously been recorded, but there is no recognisable pattern in their timing. These events are closely monitored and warnings issued when needed. Higher sea temperatures may favour an increase in the intensity and frequency of bloom events for some harmful and/or toxic species in the future.

Mass blooms of jellyfish may at times (rarely) cause serious economic damage to tourism and aquaculture. (Jellyfish are classed as plankton as they rely totally on tides, waves and currents for large-scale movement; species (such as fish) that can determine their own large-scale distributions are known as Nekton.) While there are some suggestions that jellyfish abundances may be increasing, we do not understand when and why blooms occur.

Zooplankton

As a result of changing climate, many phyto-plankton taxa have begun to bloom sooner in the year, putting them out of synchrony with the zooplankton and fish larvae that rely on them for food. This in turn may lead to failure of fish recruitment. Copepods in particular are a key food item for higher marine animals. Their composition and seasonal abundance/timing is crucial for fish recruitment. Since the 1950s, the abundance of total copepods has fallen considerably in UK waters. There has also been a marked shift from a cold boreal community dominated by holoplankton (plankton that spend all their time in the water column) to one characterised by warm temperate species. There has been a large increase in the abundance of meroplankton (planktonic larvae of benthic animals living on the bottom) in the North Sea since the mid-1980s but the causes are not clear. The net result of overfishing and changes in the hydroclimate of the North Sea appears to be a change in the balance of productivity in the pelagic environment and on the seabed.

There has been a progressive shift northward in warmer water zooplankton and a retreat to the north of colder water species over the past 50 years. The relative proportions of the cold-water indicator copepod *Calanus finmarchicus* and its warmer water sister species *C. helgolandicus* have shown a similar northward movement (see Figure 3.2). Such geographic shifts in these dominant species will affect the recruitment, growth and survival of fish and seabirds. For example, the zooplankton now present in the North Sea which have more 'warmer water' characteristics are also smaller and have a lower

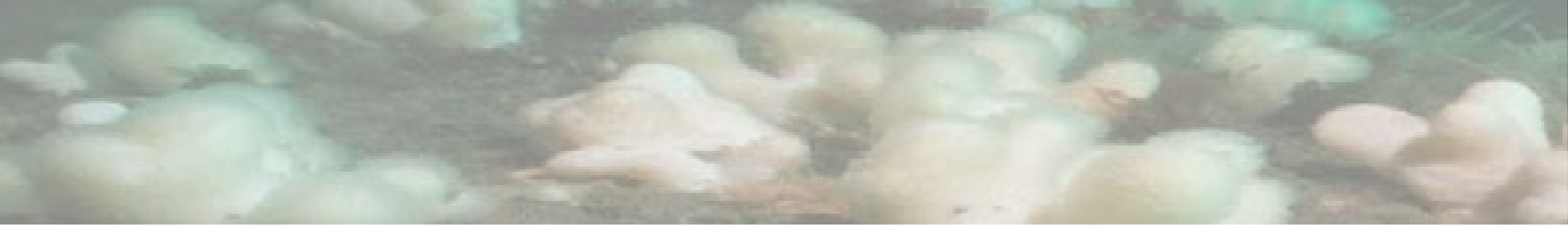
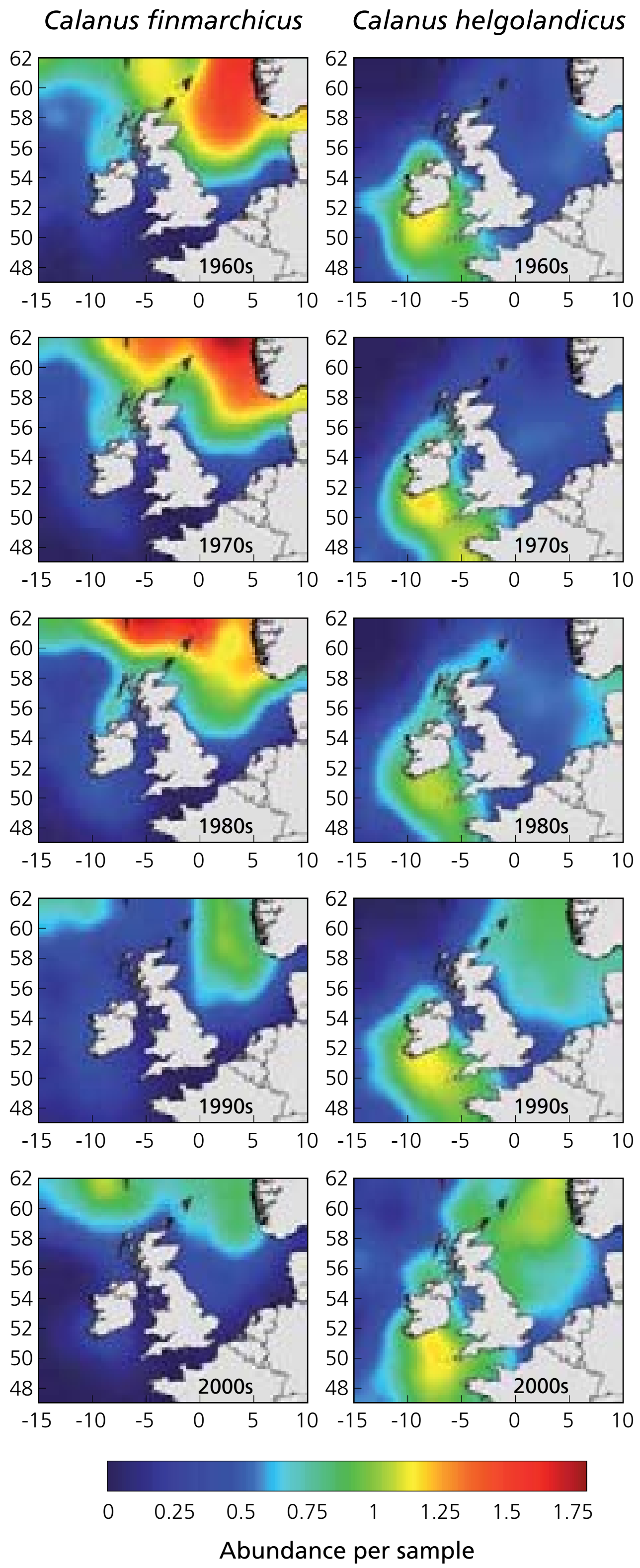


Figure 3.2 Changes in the mean decadal abundance of Calanus finmarchicus *and* Calanus helgolandicus *in the North-East Atlantic.*

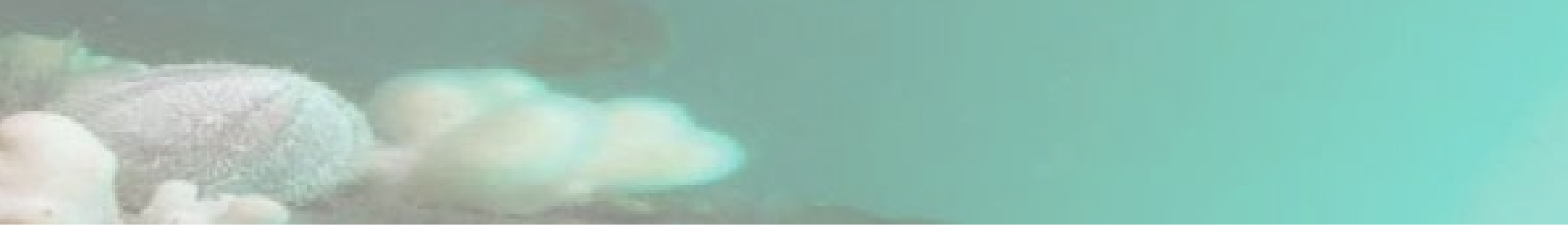


Calanus finmarchicus

biomass and oil content than the previously dominant cold-water zooplankton, making them less nutritious. Because the new zooplankton community also blooms at a different time of year, there is now a mismatch in its availability as a food for fish larvae. There is well documented evidence that these changes have influenced the numbers of cod and other fish as well as seabirds.

If, as predicted, sea temperatures around the UK continue to rise, comparison with more southerly latitudes suggests that planktonic diversity will increase, but that the total carrying capacity will reduce.

As sea temperatures rise the introduction of non-native species could increase. The ranges of a number of existing introduced species are already extending due to rising temperatures and are expected to expand further. These changes will have unknown consequences for biodiversity, ecosystem functioning and living marine resources. The summer melting of Arctic ice, and consequent opening up of links between the Pacific and North Atlantic, is likely to exacerbate this problem. It is important that an adequate monitoring programme is funded to assess the rates of introductions and their impacts.



Ecosystems, especially on the western margins of the UK are strongly influenced by changes in the adjacent ocean. Our understanding of the processes modulating interactions between plankton and hydrodynamics between ocean and shelf regions is poor.

Ocean acidification is expected to impact planktonic ecosystems and especially vulnerable calcareous organisms in the future. Research is still at an early stage and the evidence to date is equivocal. However, the potential consequences through impacts on the foodweb and on higher trophic levels, including fish, are serious.

Future work

For this assessment we have gathered as much information as possible about the vital, small and little understood creatures in our seas. However, there is still much to do. In order of priority:

- We need to begin more widespread plankton sampling to address geographical gaps in the coverage of UK waters, particularly to the west of Scotland and in parts of the Atlantic to the west of the UK.
- We need more information about the role of plankton in the carbon cycle and biological pump and its contribution to atmospheric levels of CO_2 at a UK, regional and global level. This will require international partnerships to fund monitoring and research in key areas of the ocean that are currently under-sampled.
- We have no long-term measurements of changes in primary production in UK waters. We need to begin routine *in situ* measurements at one or more sites to calibrate satellite and modelling output.
- We need to increase our efforts to sample smaller biological groups (such as microbes, nanoplankton and picoplankton) to understand their occurrence and role in UK waters.
- We need to know more about the interactions between microbes and other plankton and higher trophic levels, including fish and seabirds, and how these interactions may change in response to climate change and ocean acidification.
- Greater use of models will help. These could be used to develop scenarios of change for a warming climate, and could eventually produce short-term forecasting and longer-term prediction.
- Finally, since *Charting Progress* there has been considerable development in the use of new genetic tools to study microbial and planktonic populations and their variability through time and space. We need further efforts in this area to improve our understanding of the diversity and occurrence of the many planktonic organisms that are not sampled or cannot be clearly identified by traditional techniques.

Fish

More than 330 fish species inhabit the seas surrounding the British Isles. For *Charting Progress 2* we have assessed three aspects of this fish community, ranging from the species commonly found in coastal waters and estuaries to those in the deep sea.

We have provided assessments of the following. First, the demersal (bottom-living) fish community which includes both commercial and non-commercial species, using data from scientific demersal trawl surveys (trawls on the seabed), usually over a systematic grid of stations. Second, transitional and estuarine fish, which includes those marine fish that tend to be found in lower salinity water, particularly in their juvenile stage and 'transitional' or 'diadromous' fish that migrate between marine and freshwater, such as salmon, eels, sturgeon and lamprey. The data used for this category are more piecemeal and the analysis is based on community information (e.g. diversity of fish species in estuaries) as well as numbers of salmon and eels counted returning to rivers. Finally, for completeness, we have also included the assessment in Chapter 5 carried out by the Productive Seas Evidence Group which focuses on assessed commercial species and the proportion of these that are either not at full reproductive capacity and/or not being harvested sustainably. This assessment consists of an analysis of the number of stocks exploited sustainably within each region. The data for this come from commercial catch statistics, via complex fish stock assessment models.

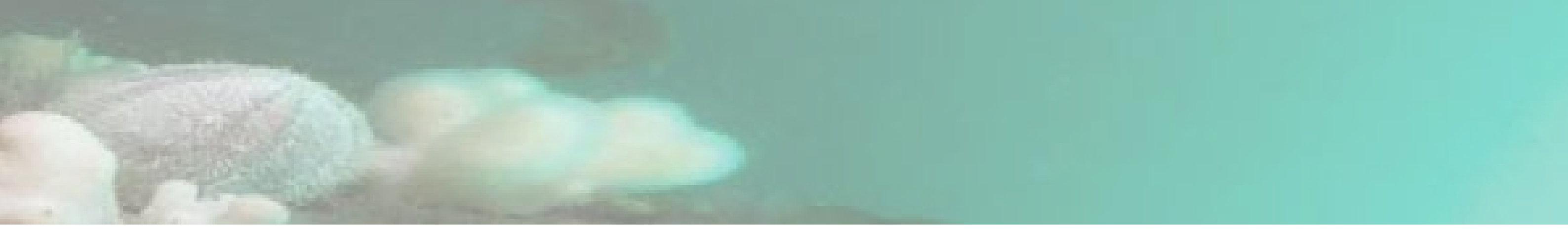
Glass eels

Although these assessments include many of the 330 fish species found in the UK seas, there are notable gaps. For example, for fish associated with rocky habitats, deep sea fish and open water pelagic fish such as sharks or tuna.

The demersal fish assessment compares status within the community or population, to that of 10 to 25 years ago, when rigorous monitoring programmes were generally established. However, this chapter also refers to a wider discussion of status in relation to historic baselines covered in more detail in the Feeder Report prepared by the Healthy and Biologically Diverse Seas Evidence Group, and in particular how current populations compare to those that existed 100 years ago.

We have made a detailed quantitative assessment for each region, using fish surveys from institutes in England, Scotland, Wales and Northern Ireland as well as in France and the Netherlands. We have constructed time series for 15 community and ecosystem indicators, to assess changes over the past 20 years, and particularly since *Charting Progress* was published in 2005. This is the most comprehensive assessment ever performed for fish communities in the UK. We have also supplemented this assessment with existing data on the status of fish communities in estuaries and transitional waters.

Since *Charting Progress* many new sources of data have emerged. In particular, there are now regular monitoring programmes for deep-water fish assemblages off the west of Scotland and around Rockall; new initiatives to involve commercial and recreational fishermen in data collection; and programmes to collate information from members of the public, to capture incidences and occurrences of rare and unusual fish around the UK that are otherwise difficult for fisheries agencies to monitor.



Cod

The diversity and overall abundance of soft-bottom demersal fish have improved appreciably in most regions over the past five years. This probably reflects reduced fishing, although life-history traits such as average size and age-at-maturity typically show little or no change, and seem to respond more slowly to reductions in human pressures.

The *Fisheries* section in Chapter 5, suggests that this reduction in pressure has been largely associated with a combination of EU controls on total allowable catches and the large-scale decommissioning of fishing vessels in the UK. The UK whitefish (demersal trawl) fleet was reduced in size by around 15% by the two decommissioning schemes in 2001 and 2003.

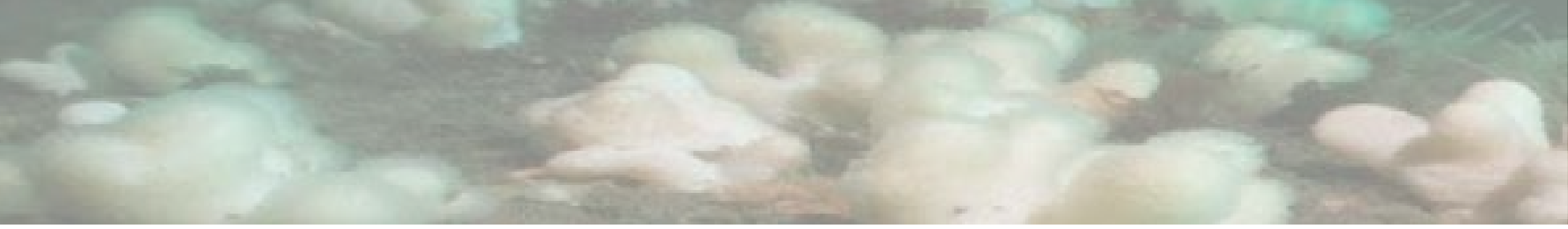
The condition of many estuaries has improved in recent years because of higher levels of urban waste water treatment and reductions in the input of hazardous substances. A gradual increase in fish diversity and overall numbers in estuaries has been linked to better conditions. As a result, the number of adult salmon and sea trout returning to rivers has increased on many rivers, although there have been declines in the River Thames where they were previously re-stocked, Rivers Awe and Morar in western Scotland and the Bush in Northern Ireland.

The number of European eel juveniles has fallen in many of the regions where this species occurs as has the abundance of yellow or silver eels, and this reflects an Atlantic-wide downturn in the numbers of elvers returning to rivers. Causes of this decline are unclear but suggestions include changes in oceanic conditions, over-exploitation, freshwater habitat destruction, contaminants and introduction of the parasite *Anguillicola crassus* from Asia.

Although the general situation for most estuarine and marine fish communities seems to have improved in recent years, the prospects of certain vulnerable fishes have continued to deteriorate. This includes many deep-water fish species; sharks, rays and skates; and transitional/diadromous species that move between fresh and salt water, such as the European eel and sturgeon. Many of these fish are listed as requiring protection under appropriate legislation.

Recent improvements in the status of fish communities need to be considered within a longer historical context since the populations of many species remain severely depleted compared to those of 50 or 100 years ago. To place current values into a longer historic context, we have used the limited data that exist for earlier periods. This suggests that fish are smaller on average than before but that species diversity may have increased in some regions, compared to historic times.

Commercial fisheries continue to exert a significant pressure on target and non-target fish populations, both directly through fishery removals, and indirectly by removing



Lamprey previously attached to cod

predators, prey, competitors or essential habitats. There are other pressures which may have an impact on fish, including the impact of new offshore infrastructure; the release of endocrine-disrupting substances from sewage works; pesticides and plastics manufacturing; the extraction of sand and gravel; the loss of coastal habitats; and the extraction of water or alteration of river flows in estuaries.

Climate change is beginning to have a detectable impact on fish populations, with marked changes in distribution, the timing of migration, overall reproductive output (recruitment) and growth rates.

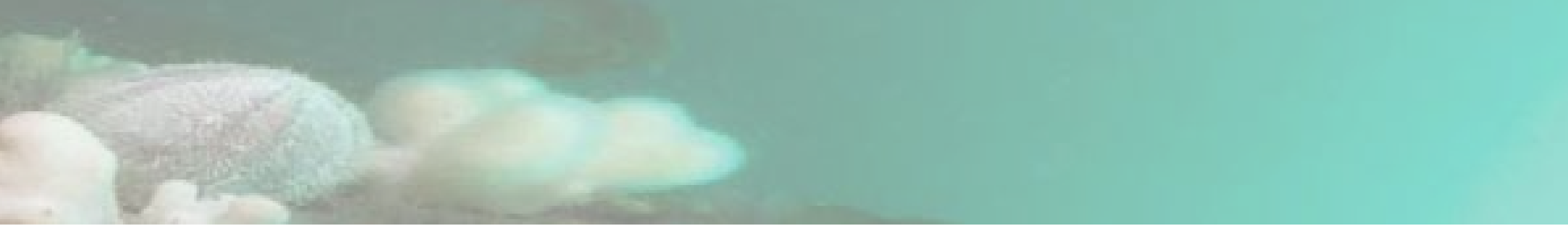
The mix of species present in each region has changed appreciably over the past 50 to 100 years and predictions suggest that a very different assemblage of fishes might exist in UK waters in years to come. Warm-water fishes such as red-mullet, seabass, anchovy and John Dory are spreading rapidly around the UK, whereas cold-water species such as cod have retreated northwards in recent years. Such distribution shifts will have profound consequences for commercial fisheries and for the achievement of stated conservation objectives.

In the UK we consume an average of 23.6 kg of fish products per person per year, and predictions based on consumer preferences and trade projections have suggested that this will continue to be the case for the foreseeable future. The UK human population is however, anticipated to rise from 61 million to 78 million by 2050. This equates to a total UK demand for fish products of 1.8 million tonnes compared to 1.4 million tonnes today and aquaculture in the UK is increasing to meet this demand. It is clear that indigenous and global fish resources will come under increasing pressure in the future.

After more than 100 years of intensive fisheries research in the UK, we know a lot about fish. However, much of the analysis has focussed on soft-bottom demersal species; trends with respect to estuarine, coastal, deepwater and migratory species are much more uncertain and we need to interpret these trends with care.

To improve our assessment there is a need for research into the state of open-water meso-pelagic species, fishes that occupy rocky habitats and some diadromous species – notably lampreys, sturgeon and shads. We also need to understand the causes of decline in salmon and eel recruitment in some catchments, as well as the population status of highly migratory fishes, for example oceanic sharks.

In the future, we will need to understand much more about the potential impact of climate change (including ocean acidification), the risks posed to fish populations by introduced and potentially invasive species such as the newly arrived comb-jelly (*Mnemiopsis leidyi*), but also incoming pathogens, toxic algae and jellyfish that are known to cause occasional ‘fish kills’, and the consequences of increasing pressures, such as from construction in the marine environment.



Seals

The UK has two species of seal: about 36% of the world's population of grey seals live here as well as about 4% of the world's population of harbour (or common) seals. Although both species can be seen all round the UK coast, they are considerably more abundant in some areas than others. Some 90% of grey seals and 80% of harbour seals live in Scotland. Grey seal pup production has been monitored since the early 1960s; harbour seals have been monitored since the late 1980s. Both grey and harbour seals are probably more numerous now than in the recent past, when they were locally hunted.

Under the Conservation of Seals Act 1970, the Natural Environment Research Council has a statutory obligation to provide the UK government with '*…scientific advice on matters related to the management of seal populations*'. A major component of the advice required is up-to-date information on the size and distribution of UK seal populations. Although grey and harbour seals are not protected species (apart from in Northern Ireland), some protection comes from the Conservation of Seals Act 1970 and the EU Habitats Directive. The Scottish Government will extend seal protection measures under the Marine (Scotland) Act 2010. Five species of Arctic seal occasionally visit the UK coast.

Grey seals

The UK has around 182 000 grey seals. Grey seal populations are estimated on the basis of pup production, which is monitored annually at colonies that contribute some 85% of pups born in the UK. Most colonies are surveyed using aerial photography, others through ground counting. The great majority of colonies in

Grey seal (female)

Wales and south-western England are extremely difficult to survey because grey seals breed in caves or on beaches at the foot of remote cliffs. Figure 3.3 shows the breeding colonies.

After decades of increase, following the end of culling in the 1970s, total grey seal pup production appears to be levelling off in the UK and is now rising at only a small number of colonies. At least part of the previous increase in grey seal pup production is due to the increased availability of breeding sites following the abandonment of human settlements on remote islands, including through automation of lighthouses. The current reduction in the rate of increase is probably because of density dependent factors affecting the population as a whole. It is not yet clear whether factors affecting survival are more important than factors affecting fecundity.

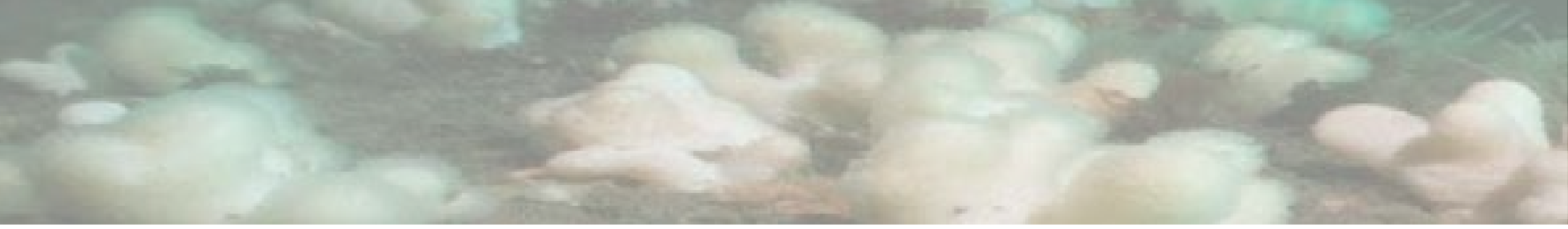
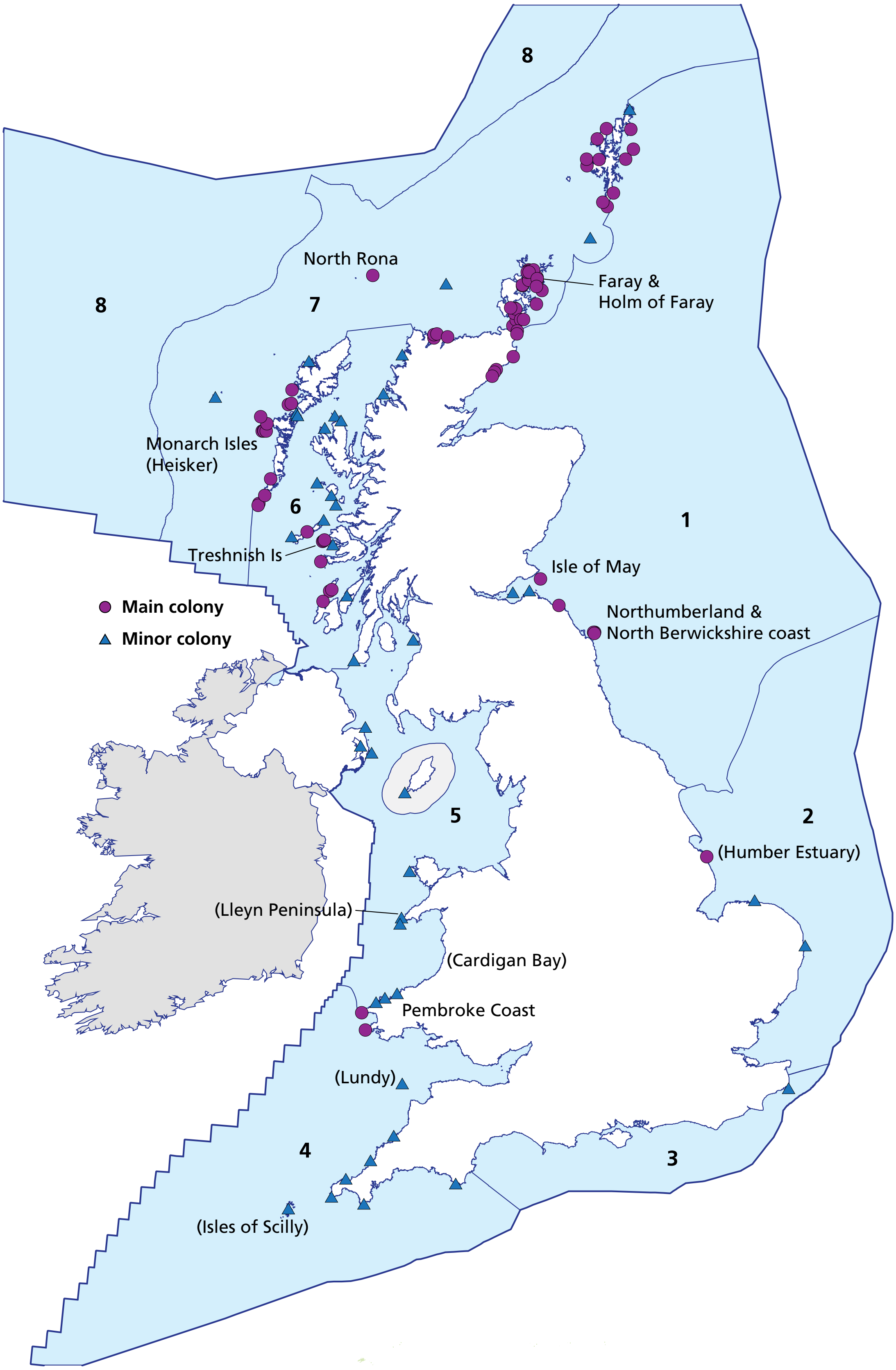


Figure 3.3 The location of grey seal breeding colonies in Great Britain and Northern Ireland. Text labels identify the Special Areas of Conservation (SACs) where grey seals are one of the main reasons for the creation of the protected site. Site names in brackets are SACs where grey seals have only contributed to the reasons for designation and are not the main reason for the creation of a SAC.



Harbour seals

Harbour seals do not aggregate when breeding and mothers with young pups are highly mobile. However, they are less dispersed during their August annual moult, which is when aerial surveys take place. In south-eastern England and parts of Scotland surveys are annual; in the rest of Scotland harbour seals are monitored at four to five year intervals due to the large area involved and the cost of undertaking the monitoring. In specific parts of Northern Ireland, counts are monthly.

Harbour seal numbers have declined significantly in Shetland, Orkney and the on east coast of Scotland, by more than 50% since 2001. There has been a smaller decline in the Outer Hebrides but numbers on the west coast of Scotland have remained relatively stable. The causes of these localised declines are not yet known. Contributing factors could be either natural or anthropogenic or both and could include: competition with grey seals, predation by killer whales (in the Northern Isles), and declines in important prey species (such as sandeels) and unregulated shooting (in some local areas). As a charismatic species, harbour seals are often highly valued (e.g. to the local tourist industry). Thus, even when populations are very small such as in southern England, pressure on these individuals is considered significant. Figure 3.4 shows the distribution of harbour seals.

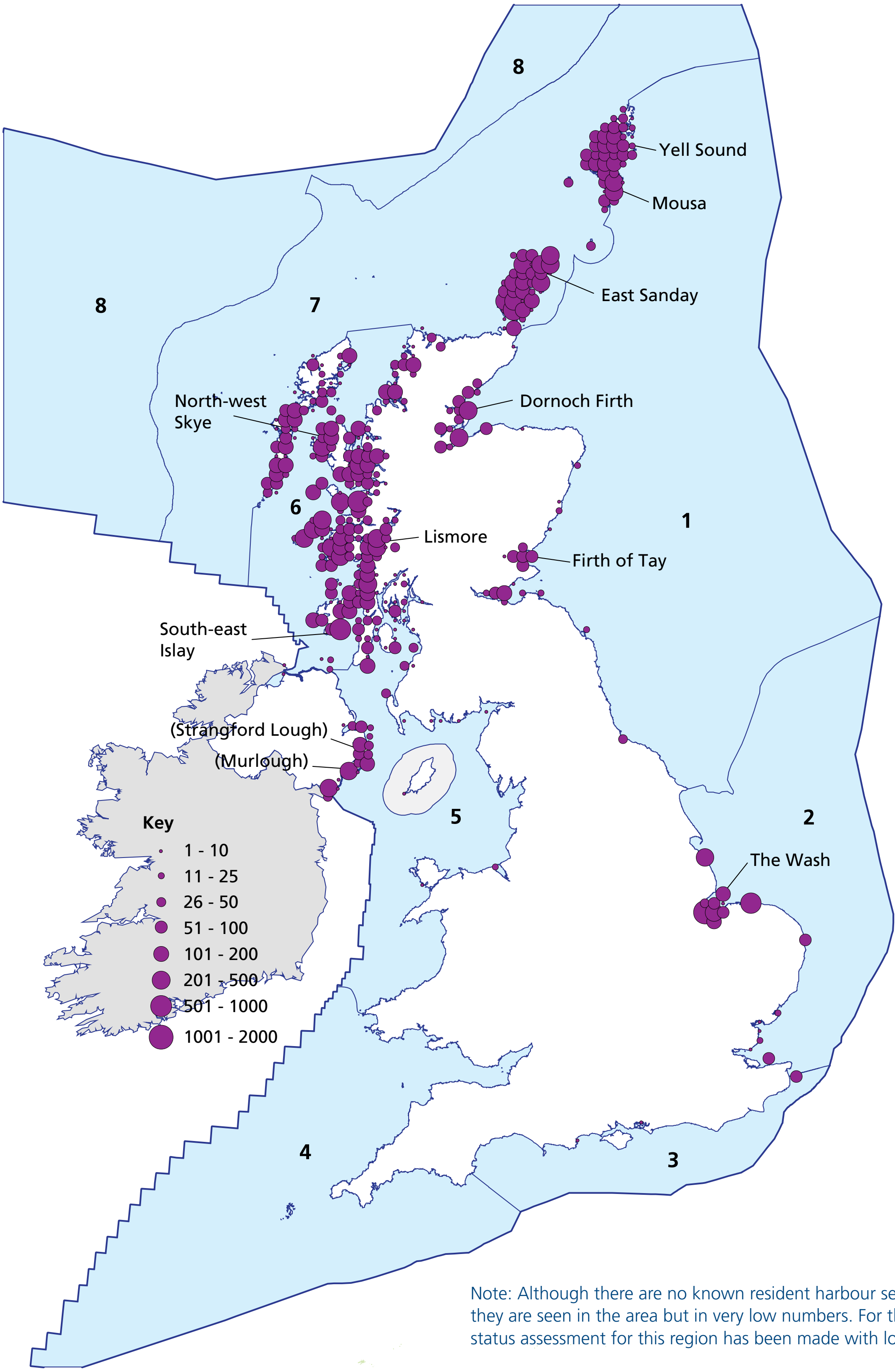
Two outbreaks of phocine distemper virus (PDV) seriously affected the harbour seal population in eastern England with 50% dying in 1988 and 22% dying in 2002. In Scotland, an estimated 5% died in 1988 and far fewer in 2002. In marked contrast to populations elsewhere in Europe which showed an immediate and rapid recovery, harbour seals in eastern England took three years to recover from the 1988 outbreak

Harbour (or common) seal

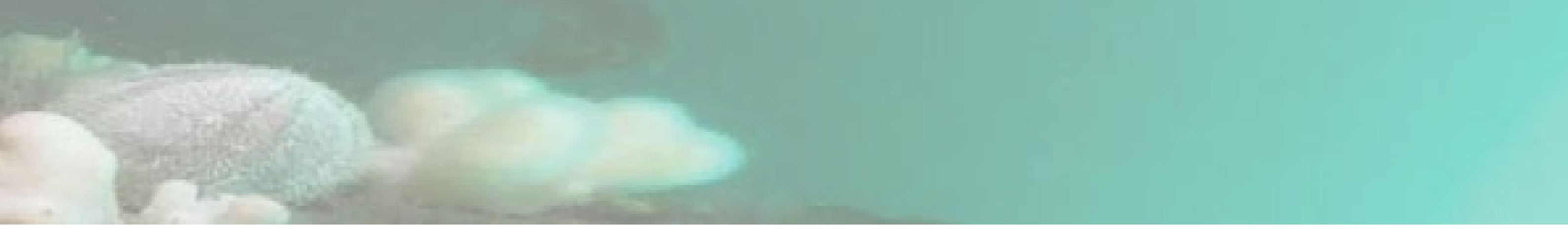
and have yet to begin recovery following the 2002 outbreak. PDV outbreaks are likely to recur in the future but it is not possible to predict the proportion of the population that might be affected, which populations are most vulnerable (besides eastern England) or precisely when outbreaks will occur. It is even harder to predict the future susceptibility to PDV of harbour seal populations in northern and eastern Scotland, given recent declines and the lack of any obvious cause. The limited impact of PDV on harbour seals in Scotland and Northern Ireland in 2002 may result in reduced population immunity and increased susceptibility to a future outbreak.

The Scottish Government and Scottish Natural Heritage have funded a number of projects investigating the declines in harbour seals in northern and eastern Scotland. Increasing renewable energy production, which may impact on marine mammal populations, may require more up-to-date and detailed information on seal distribution in relevant areas. Harbour seal monitoring frequency in Scotland is infrequent compared with grey seal monitoring.

Figure 3.4 The distribution and number of harbour seals in Great Britain and Northern Ireland in August, by 10 km squares, from surveys carried out between 2000 and 2006. Text labels identify the Special Areas of Conservation (SACs) where harbour seals are one of the main reasons for the creation of the protected site. Site names in brackets are SACs where harbour seals have only contributed to the reasons for designation and are not the main reason for the creation of a SAC.



Note: Although there are no known resident harbour seals in Region 4, they are seen in the area but in very low numbers. For this reason the status assessment for this region has been made with low confidence.



Turtles

The UK is committed to the conservation of marine turtles nationally and internationally. Of the four species occasionally reported from UK waters, the leatherback turtle is the most common and regarded as a true member of the British fauna. The leatherback turtle is a wide-ranging species, migrating throughout the Atlantic; UK waters represent a small peripheral part of its summer foraging habitat.

The primary source of data for marine turtles in the UK is the 'TURTLE' database, including historical and current records of strandings and sightings by the public and fishermen. There are on average 33 records per year for leatherback turtles. Although globally this species is critically endangered, these data are too sparse to be able to assign a conservation status within UK waters or to interpret any trends.

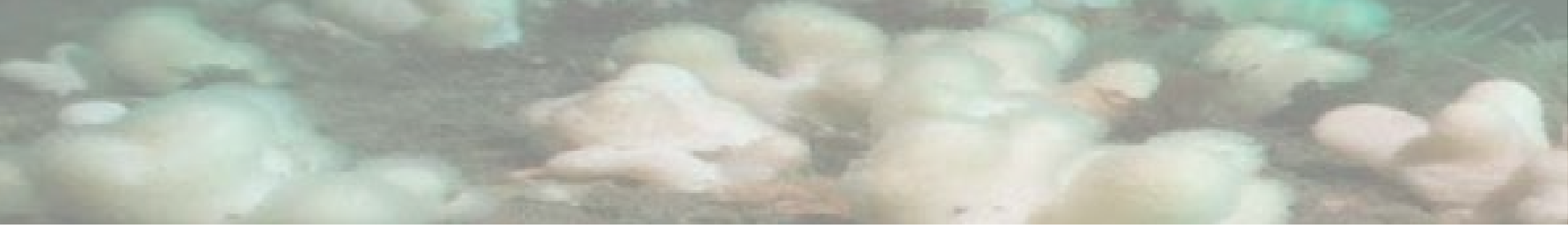
To be effective, data collection must have a strong international component and be able to assess status at the level of the entire North-East Atlantic as this is the geographical scale most appropriate to this species. Progress in research through tagging, and genetic and by-catch studies is of highest priority to turtle conservation.

Entanglement in fishing gear and ingestion of plastic debris constitute a threat to marine turtles in UK waters. The overall effect of climate change on turtle numbers in UK waters is far from predictable; a rise in sea temperature might result in an expansion of the range at high latitudes, but the overall population size might be negatively impacted by a reduction in nesting habitat and biased sex ratios as sea level and air temperature rise at nesting sites in the tropics.

Leatherback turtle

Loggerhead turtle

Kemp's Ridley turtle



Cetaceans

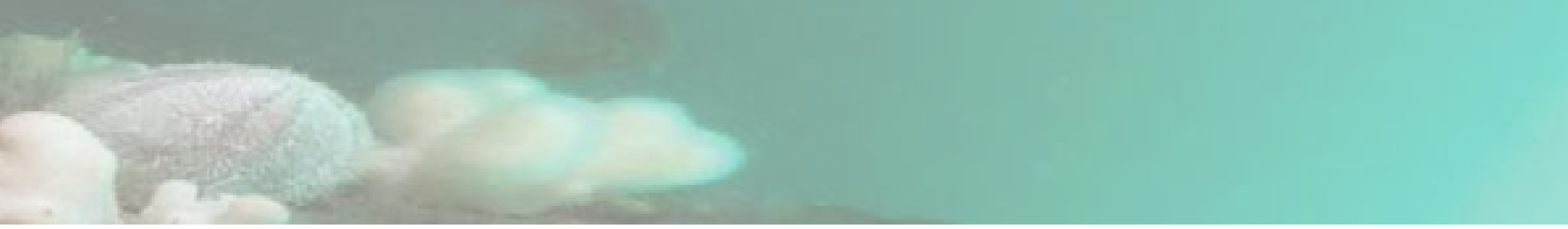
Although the UK has only a relatively small section of the North Atlantic Ocean, these waters have very diverse topography, habitats and food resources. Thus, we have a large diversity of cetaceans – whales, dolphins and porpoises. Some 28 species of cetacean have been recorded here, of which 11 appear regularly. The greatest diversity occurs off the continental shelf, particularly in waters to the north and west of Scotland and in the south-west. Cetaceans as a group have a long history of direct exploitation by humans and continue to be impacted both directly and indirectly by a range of human activities. As a result, all species are protected by various international conventions and agreements.

Cetaceans are very mobile, and some range widely including regular seasonal migrations. This means that most of the animals found in UK waters are part of much larger and more widespread biological populations. Also, the number of individuals present at any one time may be only a small proportion of those that make use of UK waters at some point during their lives.

We based our assessment for this report on expert judgement, using mainly the 2007 Favourable Conservation Status (FCS) assessments of all cetacean species occurring in UK waters. The assessments used a baseline of the Cetacean Atlas and/or data from the large-scale dedicated surveys undertaken in 1994, which generated information on summer distribution and abundance estimates for a range of species. We supplemented these with data collected in 2005 during SCANS II, and with additional survey work undertaken in 2007 off the continental shelf, as well as continued collection of strandings and by-catch data and assessments of bottlenose dolphins in nearshore Special Areas of Conservation (SACs). The judgements also took into account the approach used for the OSPAR Quality Status Report 2010 assessments. The final status assessments were therefore a combination of the FCS and OSPAR approaches, using OSPAR terminology for the final condition statement.

The FCS assessment was considered favourable for the five species that are most abundant in UK waters. (This paragraph is a summary of the Article 17 report required under the EU Habitats Directive, hence the term 'favourable' here.) The status of a further six species was unknown due to a lack of suitable abundance estimates. The remaining 17 species are considered rare or vagrant and therefore we could not assess their conservation status in UK waters.

Overall, cetaceans as a group are considered to be in good condition in both the Northern North Sea and Southern North Sea; although we cannot assess them with a high degree of certainty. Cetaceans are considered to be in poor condition in the Eastern Channel, and in moderate condition in the Western Channel and Celtic Sea, the Irish Sea and the Minches and Western Scotland waters. The status of cetaceans is unknown in the Scottish Continental Shelf area and offshore waters north and west of Scotland. Site-based assessment of certain SACs, designated specifically for bottlenose dolphins, suggest that these populations are stable. With the possible exception of the inshore populations of bottlenose dolphins, it should be noted that for most cetacean populations it is not appropriate to report on status for individual regions since most populations cross these boundaries and, data collection is of insufficient resolution to allow such an assessment.



Direct mortality through by-catch in fishing gears remains the most important human impact on cetaceans in UK waters, predominantly affecting harbour porpoise and common dolphins. Nevertheless, by-catch has declined in the Northern North Sea, the Southern North Sea, and the Irish Sea due to a decline in static net fishing. Historic by-catch probably contributed to the current low densities of harbour porpoise in the Eastern Channel. The number of cetaceans caught accidentally appears to have remained stable in the Western Channel and Celtic Sea. By-catch seems less of a problem in Scottish waters compared to other areas of the UK. However, the entanglement of minke whales in nets is recognised as an issue in the Minches.

Cetaceans are particularly vulnerable to persistent organic pollutants, such as polychlorinated biphenyls (PCBs) and flame retardants, which can affect development, growth and reproduction and can increase vulnerability to infection. In the early 1990s there were high concentrations of pollutants in the tissues of several species of cetacean in UK waters, but more recently the concentration levels seem to be declining.

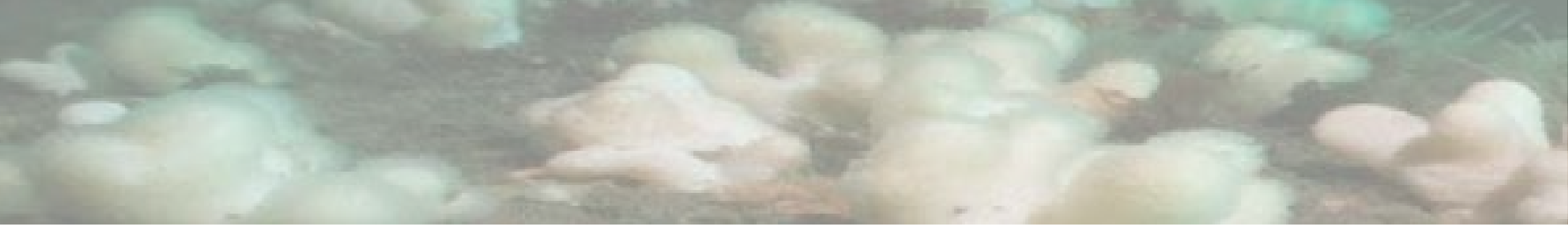
The impact of climate change on cetaceans remains poorly understood. It is extremely difficult to separate changes in abundance or distribution as a result of short-term regional variability in the prey resource from changes due to longer-term environmental change. The direct impact of any future climate change on cetaceans in UK waters is only likely to be observed in those species for which the UK represents the edge of their range, such as white-beaked dolphins. Cetaceans may, however, be impacted indirectly through changes in prey distribution and greater susceptibility to disease and contaminants.

In addition to the current monitoring of designated sites, a strategic monitoring and surveillance programme will be essential to meet the requirements of the EU Habitats Directive and the Marine Strategy Framework Directive. As cetaceans are so mobile and range so widely, the work will need a fully international approach.

A better understanding of the abundance and distribution patterns of cetaceans, including any seasonal variation, as well as basic life history parameters such as growth rates, age at sexual maturity, reproductive rates and mortality, would help determine the magnitude of any impacts on populations and also potentially aid industry in reducing the risk of impacts.

Although the UK's by-catch monitoring scheme is recognised as one of the best in Europe, there is a need for further monitoring of static-net fisheries where cetacean by-catch is greatest. This will inform possible management measures, which will need to be implemented at a European rather than national level. Work will need to continue on assessing the effectiveness of acoustic deterrent devices in fisheries. We also need more information about the potential impacts on cetaceans of other anthropogenic

Net marks on a harbour porpoise carcass



activities that generate noise in different sea areas and under different environmental conditions. The possible synergistic effects of chronic exposure of cetaceans to various environmental pollutants also require further consideration.

Finally, we need to develop the frameworks and methods for assessing conservation status, review the thresholds above which change can realistically be detected, and set the baselines for future assessments.

Marine birds

The UK's marine environment holds internationally important numbers of birds. Since these birds are top predators in several different marine habitats, changes lower down the food chain are likely to be manifested in their populations, making them a useful indicator of the state of our seas.

More than 100 species regularly use the marine areas in the UK. The majority of these species are waterbirds such as waders, herons, egrets, ducks, geese, swans, divers and grebes, and seabirds such as petrels, gannets, cormorants, skuas, gulls, terns and auks.

Seabird and waterbird populations in the UK have increased in size over the past century as a direct result of increased protection from hunting and persecution in the UK and overseas. But since around the mid-1990s, declines in numbers of both wintering waterbirds and breeding seabirds indicate that pressure is once again being exerted on marine bird populations.

We made a separate assessment of the magnitude of the impacts of pressures from human activities on seabirds and

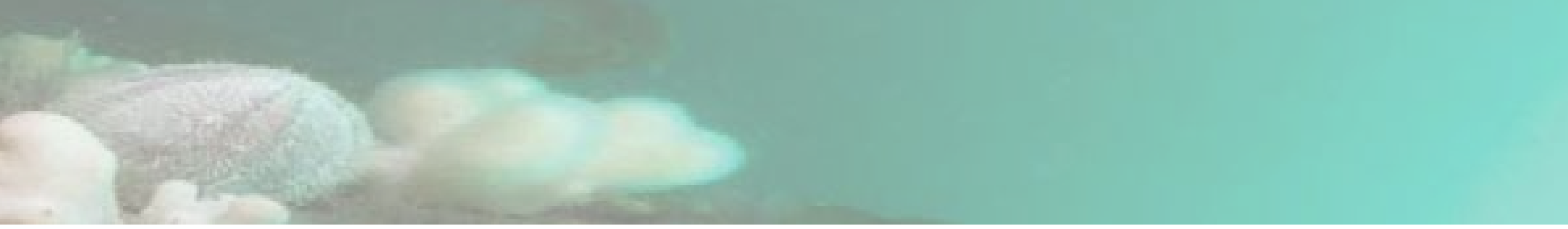
Sanderling (waders) are common visitors to open sandy shores around the UK

waterbirds, using eight broad pressure themes, encompassing 22 pressures. We based our assessments on expert judgement, supported by published evidence where possible.

Waterbirds

Most internationally important aggregations of waterbird species in the UK marine environment occur during spring and autumn migrations and during winter in areas such as estuaries where food is accessible and abundant.

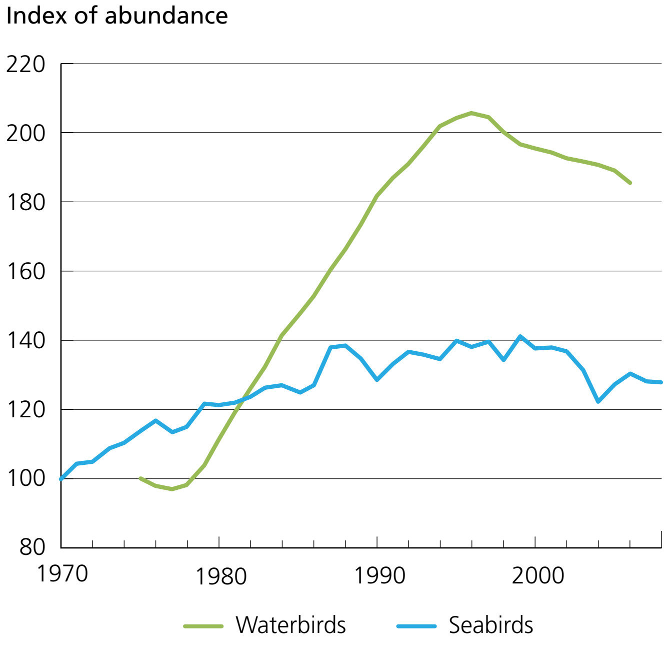
Our assessment of the status of waterbirds in the UK used data on non-breeding birds collected by the Wetland Bird Survey (WeBS), that have baseline levels from winter 1975/76. Numbers of waterbirds (based on a subset of 32 out of 57 species) wintering in or migrating through marine areas in the UK doubled on average (they increased by 106%) between the mid-1970s and the mid-1990s. Since then, average numbers have declined slightly, but in the winter of 2006/07, they were still 85% higher than in the mid-1970s when co-ordinated monitoring began (see Figure 3.5). However, some species of diving duck and estuarine wader have recently declined



more substantially: in 2006/07 there were 43% fewer goldeneye, 54% fewer dunlin and 28% fewer bar-tailed godwit than in 1975/76 (see Figure 3.6).

The trends in abundance of most species of waterbird in coastal Special Protection Areas (SPAs) have been similar to those at other sites around the coast of Britain (comparative data were not available for Northern Ireland): waterbirds are faring no better or no worse on sites that are not SPAs.

Figure 3.5 Trends in relative abundance of non-breeding waterbirds (winters 1975/76 – 2006/07) and of breeding seabirds (1970–2008) around the UK coast.



Relative abundance is expressed as a population index, whereby the number of birds in a sample of sites in a particular year is expressed as a percentage of the value for the same sites in the first year of the time-series. The plots show the geometric mean indices of 19 seabird species and 32 waterbird species.

Potential pressures and impacts on UK waterbird populations

Climate change; Temperature changes (local); Salinity changes (local); Hydrological changes (inshore/local); **Contamination by hazardous substances**; De-oxygenation; Nitrogen and phosphorus enrichment; Organic enrichment; Visual disturbance; Barrier to species movement; Introduction of non-indigenous species; **Removal of species (target and non-target)**; Death or injury by collision; Siltation rate changes; **Habitat damage**; **Habitat loss**.

Of the sixteen pressures identified as having potential impacts on the UK waterbird populations, the five most significant were: climate change, contamination by hazardous substances, removal of species (target and non-target), habitat damage, and habitat loss.

Severe winter weather in the past has increased the mortality of some species. It follows that the milder weather in recent years as a consequence of climate change has enabled more birds to survive through the winter. However, such benefits may be countered in the future by the negative impacts of 'coastal squeeze' as rising sea levels lead to the loss of intertidal feeding areas. Climate change may already be contributing to recent declines in the numbers of some species, including bar-tailed godwit, grey plover, dunlin and ringed plover, by encouraging a north-eastwards shift in their distribution. As a result, more birds are now wintering on the east coast of Britain and fewer birds are wintering in the south-west. We do not yet know if in the future, the birds will continue to move north-eastwards and relocate elsewhere in Europe, or if total numbers migrating through and wintering in Europe will decline as a consequence of

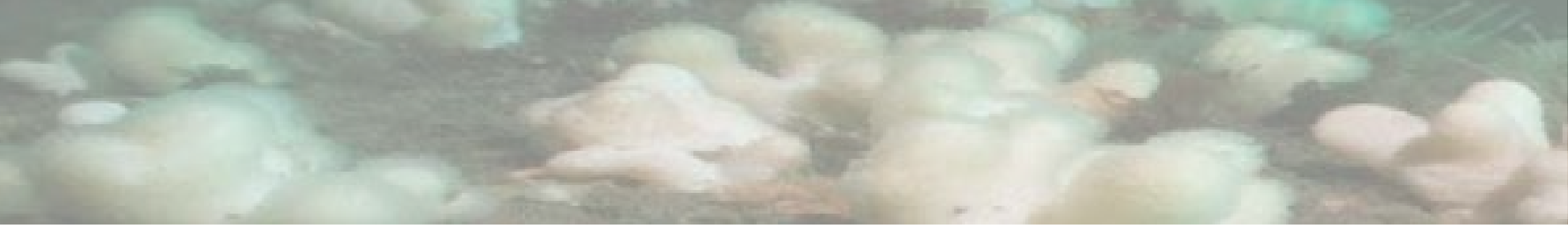
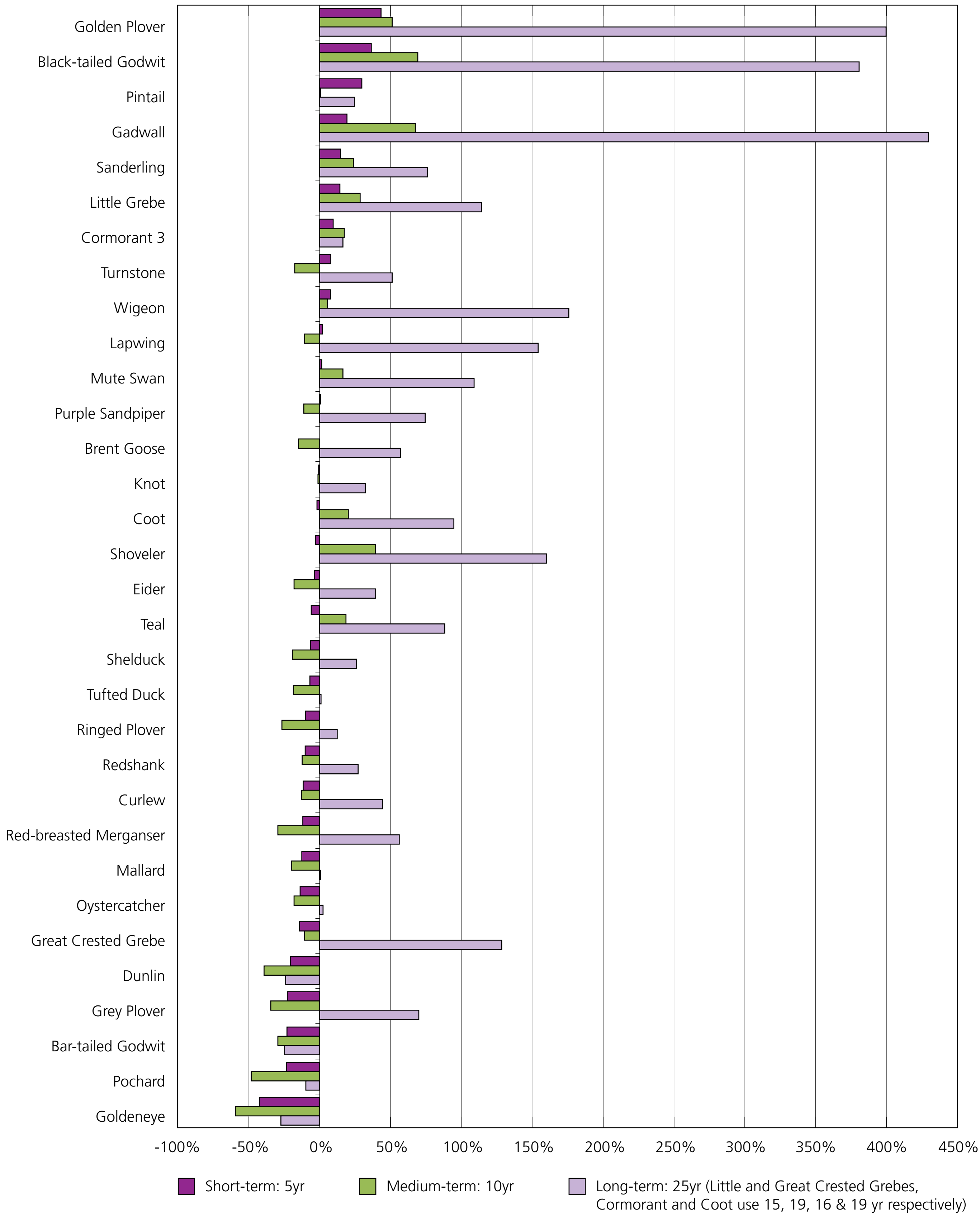


Figure 3.6 Percentage change in the numbers of non-breeding waterbirds around the coast of the UK over the short-term (past 5 years), medium-term (past 10 years) and long-term (past 25 years).



Bar-tailed godwit

these climate-related changes. A trend towards milder winters has allowed more birds to take advantage of the richer feeding in the muddier east coast estuaries with a much reduced risk of cold weather mortality. Total numbers of waders wintering in the UK may be starting to decline as more birds move eastward and overwinter along the coasts of mainland Europe.

Waterbirds such as seaduck, divers and grebes have a low resistance to the effects of contamination by surface pollutants such as oil. However, while oiled birds can be found on beaches, there have been no major oil spills in the past five years that would have an effect on waterbird populations.

Detailed studies carried out on The Wash found marked reductions in waterbird survival as a result of shellfish harvesting. Shellfisheries can also cause substantial changes to marine ecosystems; disturbance of the seafloor leads to mortality of benthic organisms, and re-working of the sediment, which in turn reduces the availability of food to waterbirds.

Most species of waterbird, but especially waders, are affected by activities such as coastal defences, land claim, construction of tidal barrages, and the construction and extension of marinas or harbour developments that result in the loss of suitable habitat. Habitat damage caused by bottom trawling, shipping activities, dredging and sand/gravel extraction, can substantially reduce the availability of some invertebrate prey (e.g. bivalves) that is likely to drive changes in the numbers and distribution of seaduck, divers and waders that feed on them.

Seabirds

Large numbers of seabirds occur in UK waters all year round, but some species are only present during the breeding season, over winter or during migration. Most seabirds spend the majority of their lives at sea: some are confined to inshore waters, but others venture much further offshore. Seabirds feed mainly on fish, squid and plankton, or pick detritus from the surface, while gulls also forage on exposed inter-tidal areas.

The state of seabird populations was assessed using data on numbers and breeding success collected by the Seabird Monitoring Programme (SMP). The number of seabirds breeding in the UK increased from around 4.5 million in the late 1960s to 7 million by the end of the 1990s. Since *Charting Progress* the total number of breeding seabirds has decreased by around 9% (Figure 3.5) although changes in breeding numbers have varied greatly between individual species (Figure 3.7). Of the seabird species breeding in the UK, only northern gannet and great skua have sustained a positive trend in population size since 1969 when comprehensive monitoring of breeding numbers began. Conversely herring gull and roseate tern numbers have declined the most since 1969 – by more than 50%. The

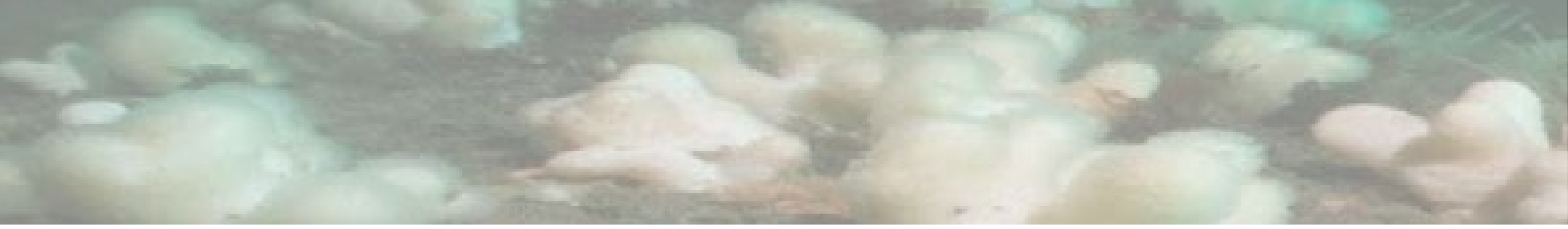
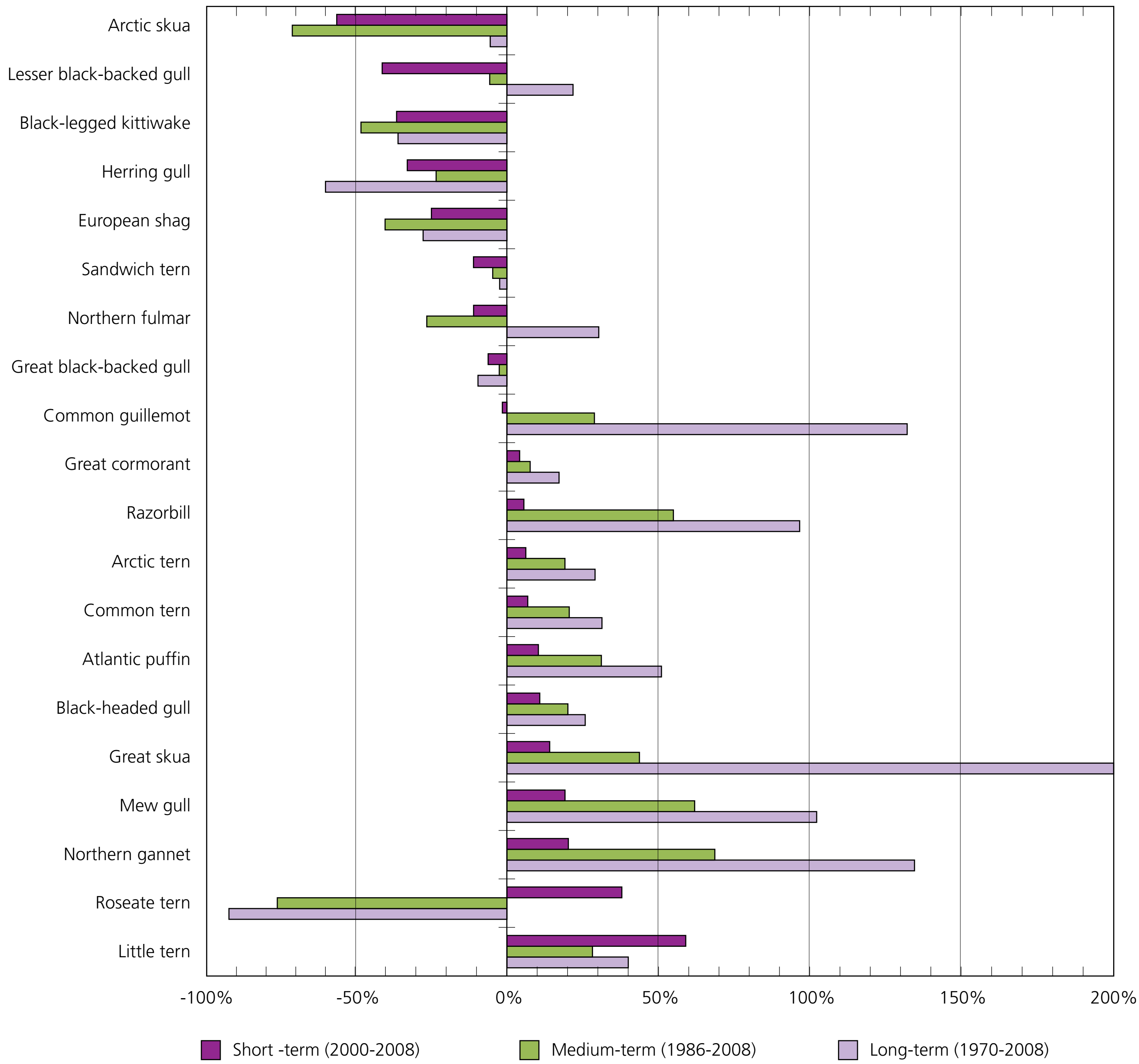


Figure 3.7 Percentage change in the numbers of seabirds breeding in the UK over the short-term (2000-2008), medium-term (1986-2008) and long-term (1970-2008).



mean breeding success of a sample of 21 seabird species was at its lowest levels in 2004, 2005 and 2007 since monitoring began in the mid-1980s (Figure 3.8). These falls in breeding success have been most acute in black-legged kittiwakes and other species such as common guillemot that rely on sandeels (Figure 3.8), and more so on Britain's North Sea coast. There is strong evidence that climate-driven changes in the food chain have had acute negative impacts on seabirds. Changes in the North Sea plankton community in the late 1980s caused by rising sea temperatures has led to large reductions in abundance of the zooplankton on which larval fish feed and poor sandeel productivity is associated with warmer sea-surface temperatures.

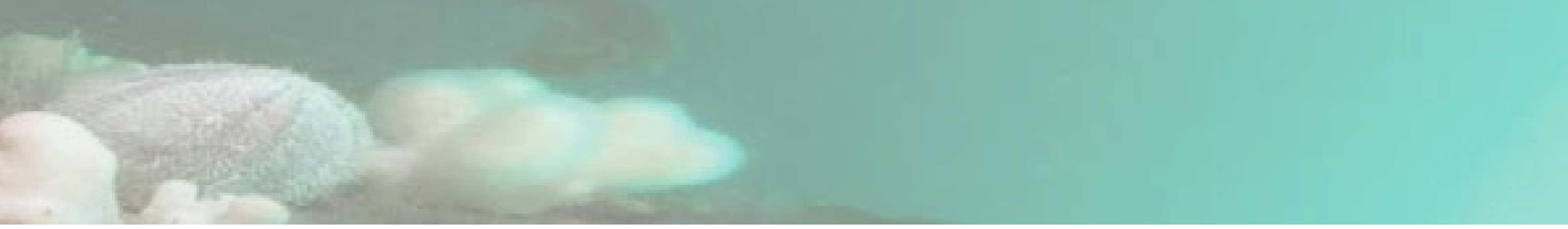
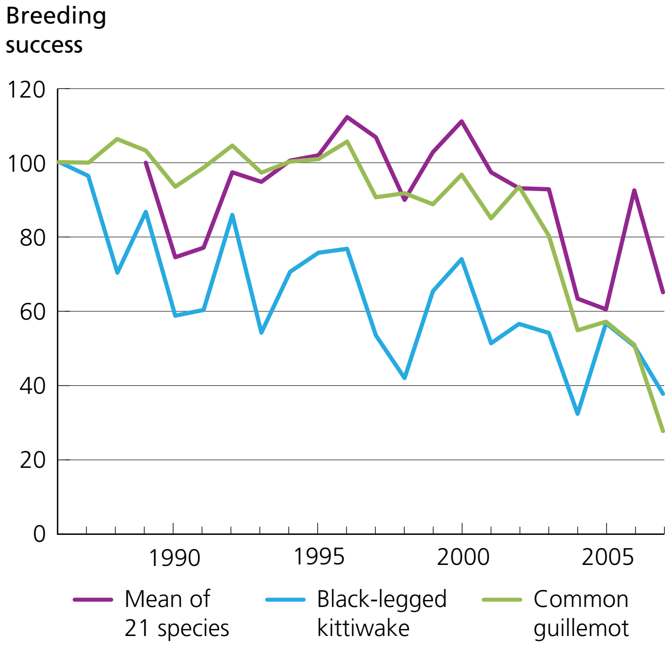


Figure 3.8 Trends in relative breeding success of seabirds in the UK (1986–2007).



Relative breeding success is expressed as an index, whereby the breeding success of each species (measured as number of young fledged per pair) at a sample of sites in a particular year is expressed as a percentage of the value for the same sites in first year of the time-series. The plots show the geometric mean index of 22 species.

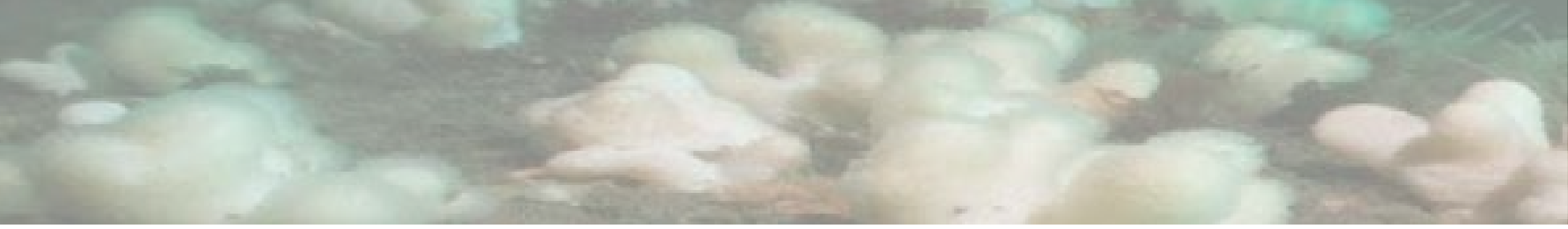
Black-legged kittiwakes

Fisheries may also have contributed to a reduction in sandeel availability and quality. For instance, off south-eastern Scotland in the 1990s, a sandeel fishery significantly depressed the adult survival and breeding success of black-legged kittiwakes compared with years prior to the fishery opening and after it was closed in 2000.

For decades, some seabirds have benefited from fisheries through food provided at sea by discharging offal and discarding undersize fish. As a result, the abundance of scavenging species such as great skua and northern fulmar may have been elevated above levels that naturally occurring food sources could sustain. A subsequent decline in numbers of northern fulmar since the 1990s may be linked to a reduction in fisheries effort. However, there was insufficient evidence for us to assess the scale of the pressure from fisheries.

In addition to climate change and the removal of target and non-target species through fishing, five other pressures were identified as having potential impacts on the UK seabird populations (contamination by hazardous substances, litter, visual disturbance, introduction of non-indigenous species, habitat loss); the most significant of these was the introduction of non-indigenous species.

The long-term existence of non-indigenous predatory mammals such as brown rats on offshore islands, following intentional or accidental introductions, has significantly reduced the numbers of ground-nesting seabirds such as storm-petrels and Atlantic puffins. Depredation of seabird eggs, chicks and adults by North American mink has led to reductions in seabird breeding success, breeding numbers and eventual extinction of whole colonies in



Atlantic puffin

Common guillemot

the Western Isles and on numerous islands throughout the Minches and Western Scotland. However, the control of mink and hedgehogs in parts of the Western Isles (funded under the EU Life programme) and elsewhere in north-western Scotland and the eradication of rats from some offshore islands in western Britain such as Canna and Lundy has led to increases in numbers and breeding success at some seabird colonies and to the complete recovery of others.

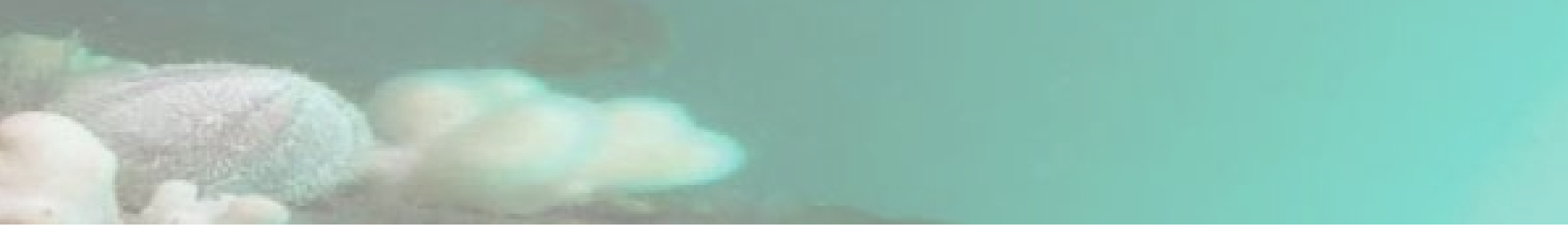
Future work

The limited availability of data meant that we had to confine our assessment to breeding seabird populations and to migrant and over-wintering populations of waterbirds in intertidal areas or close inshore.

Although we considered the impact of climate change on seabirds to be high, much of the evidence for this is correlative rather than demonstrably causal. We need to better understand the nature of the interactions between climate, plankton, sandeels, fishing and seabirds in order to predict the likely magnitude of future impacts on seabirds and to devise measures that may mitigate the impacts of climate change. We also need more research to determine the extent of the impact of non-indigenous mammalian predators on island seabird colonies around the UK.

There is as yet no data on how many seabirds from UK colonies are killed as a result of becoming entangled in fishing nets or taking the baited hooks of long-line fisheries operating within and outside UK waters. Past evidence from the Norwegian long-line fleet suggests that large enough numbers could be killed to have a significant effect on the populations of some species.

We had only low confidence in the assessment of impacts of habitat loss on both seabirds and waterbirds. Habitat loss and damage are likely to increase in the future due to coastal squeeze and through expansions in offshore renewable energy generation and in sea



defence/realignment. It is important to assess the cumulative impact of all these activities and pressures.

We will also need further work to establish indicators and targets for determining Good Environmental Status as part of the UK's implementation of the EU Marine Strategy Framework Directive.

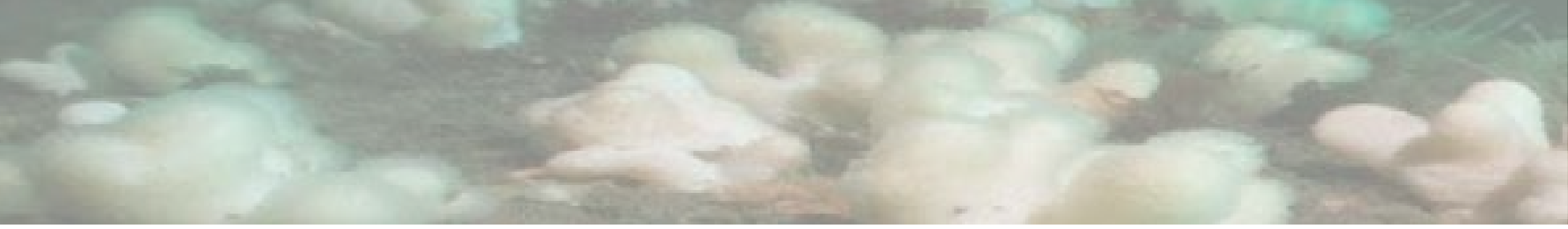
Assessment summary

The summary table presents our expert opinion on a single comparable assessment of status and trend across all components assessed for healthy and biologically diverse seas (please note no assessment has been made for microbes or turtles). We have done this by assigning a single colour for status where: green indicates few or no problems, amber indicates some problems and red indicates many problems. Trend arrows are also provided based on the evidence available, showing whether the state or condition of the component is improving (↑), remaining stable (↔) or deteriorating (↓). Details of the reference conditions and baselines against which state is assessed for each component can be found in the Feeder Report prepared by the Healthy and Biologically Diverse Seas Evidence Group, along with the time period over which the trend is measured. The confidence rating of each assessment is also estimated in the Feeder Report, based on criteria developed by the Marine Climate Change Impacts Partnership (MCCIP). Assessments which have been made with low confidence are indicated in the summary table.

A more detailed discussion of the rationale for this approach, 'traffic-light' status, and the confidence assessment is given in Chapter 1.

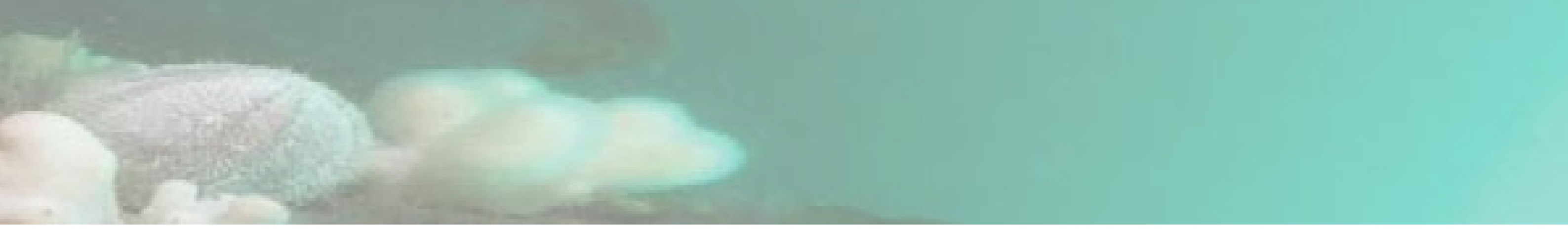
The 'traffic light' status assigned originates from the detailed assessments made for each component in the Feeder Report. Each component assessment section in the Feeder Report was accompanied by a table which summarised the findings if sufficient evidence was available. It is important to note that other than the six broad habitat assessments, the status assessments here are additional to those included in the Feeder Report chapters. The Feeder Report chapters focus on assessments of state, trend, pressures and impacts, with this varying between chapters depending on the information that was available.

The Feeder Report assessments provide valuable additional information that can be used to give context to the summary assessments in the summary table presented here and provide a greater understanding of each component, its status and the pressures to which it is subject.



Healthy and Biologically Diverse Seas – Summary Table

Components currently assessed	*Region*							
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Habitats								
Intertidal rock	↓	↓	↓	↓	↓	↓	↓	*
	Regions 4 & 5 are already affected by rising sea levels and by rising air and water temperatures. This has lead to changes to rocky shore communities. Localised shellfish harvesting is a pressure in some Regions as is the presence of non-native species. Intertidal rock found at Rockall Island in Region 8.							
Intertidal sediments	↓	↓	↓	↓	↓	↓	↓	NP
	Main pressures are historical land claim and the presence of coastal structures, non-native species and beach litter; the extent of these pressures varies considerably around the coast. Rising sea level is also resulting in loss of intertidal sediments in some locations							
Subtidal rock	↔	↔	↔	↔	↔	↔	↔	↓
	Sub-tidal rocky habitats are generally only subject to local pressures such as construction/maintenance of coastal infrastructure (e.g. large ports), and bottom trawling							
Shallow subtidal sediments	↔	↑	*	*	↔	↔	*	NP
	All Regions are affected to varying degrees by fish dredges and trawls. Smaller fishing vessels tend to fish these shallow habitats so the extent of their activities is less certain than for larger vessels. Other local pressures include occurrence of non-native species, aggregate extraction and pollution							
Shelf subtidal sediments	↔	↑	*	*	↔	↔	*	↓
	All Regions are affected to varying degrees by dredging and trawling by large fishing vessels. Their movements are generally better known and understood. Region 3 experienced less fishing than other Regions. Other local pressures include occurrence of non-native species and renewable infrastructure							
Deep-sea habitats	NP	NP	NP	↓	NP	NP	↓	↓
	Region 7 deep sea habitats are affected by bottom trawling and litter such as discarded nets which damage vulnerable cold-water coral communities							
Species								
Plankton	↔	↔	↔	↔	↔	↔	↔	↔
	Plankton communities are not generally subjected to anthropogenic pressures. Significant changes in species have been recorded as a result of rising temperatures, which can have knock-on effects on foodwebs and marine ecosystems							
Bottom-living marine fish	↔	↔	↔	↔	↑	↑	↔	↑
	Status has improved since the 1980s due to recent reductions in fishing effort although communities are still thought to have deteriorated with respect to historical conditions. The main pressures are removal of fish through commercial fishing activities and changes to species distribution and composition as a result of changes in water temperature that are a result of the changing climate							



Components currently assessed	*Region* 1	2	3	4	5	6	7	8
Commercial fish stocks	Amber ✚	Amber ✚	Amber ✚	Amber ✚	Red ✚	Red ✚	Amber ✚	Lack of evidence
	Based on the assessment in Chapter 5 (Productive Seas), fishing mortality has declined significantly in many of the assessed fish stocks in UK waters and although there is some way to go before the majority of commercial stocks are considered to be exploited at safe levels, there have been marked improvements. The main pressure is removal of fish through commercial fishing activities. However, for some stocks the change in water temperature is thought to be a contributing factor							
Estuarine fish	Green ↑ (low confidence)	Red ↓ (low confidence)	Red ↓ (low confidence)	Amber ↔ (low confidence)	Amber ↔ (low confidence)	Red ↓ (low confidence)	Amber ↔ (low confidence)	NP
	The lack of data available for estuarine fish makes any conclusions tentative. What evidence there is suggests an overall increase in diversity and number of fish linked to cleaner estuaries but with a significant reduction in eel recruitment reflecting an Atlantic-wide trend. Although estuarine communities have improved in some Regions, the recent decline in eels (and salmon) often reduces the overall score							
Harbour seals	Red ↓	Red ↓	Amber ↔	Amber ↔ (low confidence)	Amber ↔	Amber ↔	Red ↓	NP
	Harbour seals have been decreasing in abundance, dramatically in some areas (up to 50%), particularly in Regions 1, 2 & 7. Although subjected to various pressures (competition with grey seals, predation by killer whales, unregulated shooting, and declines in important prey species such as sand eels) the reason for this decline is still unknown							
Grey seals	Green ↑	Green ↑	Amber ↔ (low confidence)	Amber ↔	Amber ↔	Green ↔	Green ↔	NP
	Although grey seals are generally not experiencing any problems, populations in Regions 4, 5 & 6 are no longer increasing. The reasons for this apparent plateau in the population are not clear at present							
Cetaceans	Green ↔	Green ↔	Red ↔ (low confidence)	Amber ↔ (low confidence)	Amber ↔ (low confidence)	Amber ↔ (low confidence)	Lack of evidence	Lack of evidence
	Historic by-catch is suspected to be responsible for low numbers of cetaceans in the Eastern Channel (Region 3) but more data are required to confirm the cause. Impact of persistent contaminants is decreasing							
Seabirds	Amber ↔	Green ↔	Red ↓	Green ↔	Green ↑	Red ↓	Red ↓	NP
	There have been substantial declines in seabird abundance in north and north-west Scotland where the main pressures are climate change and the introduction of non-indigenous species (e.g. rat and mink affecting nesting sites). Tern numbers breeding in the Eastern Channel have declined due to natural causes (i.e. predation and storm events)							
Waterbirds	Green ↑	Green ↑	Green ↑	Green ↑	Amber ↑	Lack of evidence	Lack of evidence	NP
	Waterbirds are generally not experiencing any problems and their status has been improving since the mid-1970s. An exception is Region 5 where waterbird populations are moving east, away from traditional sites; the reasons for this change are unknown but may be due to climate change							

Green	Few or no problems	↔	Stable
Amber	Some problems	↑	State improving
Red	Many problems	↓	State deteriorating
(Chequered)	Lack of evidence and/or robust assessment criteria	*	No trend information available
NP	Component not present in the region	(Striped)	Low confidence in assessment
		✚	Assessment of trend for each region not made

CHAPTER 4
CLEAN AND SAFE SEAS

Introduction

The UK Government's first report on marine stewardship, *Safeguarding Our Seas,* outlined a vision of clean, healthy, safe, productive and biologically diverse oceans and seas. In 2005, the first full assessment of the state of UK seas, *Charting Progress*, showed that recent regulations and recommendations had led to a marked fall in the amounts of measured contaminants reaching the sea. It also found that levels of contaminants in water, sediments and biota were generally low, apart from in a few estuaries that had been heavily contaminated by historical industrial and domestic discharges.

This chapter builds upon *Charting Progress*, showing what progress we have made towards the vision of clean and safe seas. Based on the Feeder Report produced by the Clean and Safe Seas Evidence Group, it assesses the impacts of six major components associated with the cleanliness of the sea (hazardous substances, radioactivity, eutrophication, oil and chemical spills, litter, and underwater noise). It also assesses the safety of seafood to consumers and bathing waters to swimmers through reporting on algal toxins and microbiological contamination.

For this assessment, we used criteria developed in accordance with the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic. We highlight where relevant assessment criteria are lacking.

Assessments of the potential impact of individual chemicals use an environmental quality standard (EQS), derived from the concentration at which laboratory data suggest that the chemical could be harmful. Most of these standards are for water. For sediments and biota, we have data on background assessment concentrations (BACs) and environmental assessment criteria (EACs), the latter based on toxicological information and which often also add a margin of safety to give a very conservative estimate of potential harm. Alternative approaches involve combining modelling, laboratory and field toxicity data to generate a range of concentrations within which potential effects may occur. For example Effects Range-Low (ERL) and Effects Range-Median (ERM) concentrations. This approach, first developed for the United States Environmental Protection Agency, is now widely used around the world.

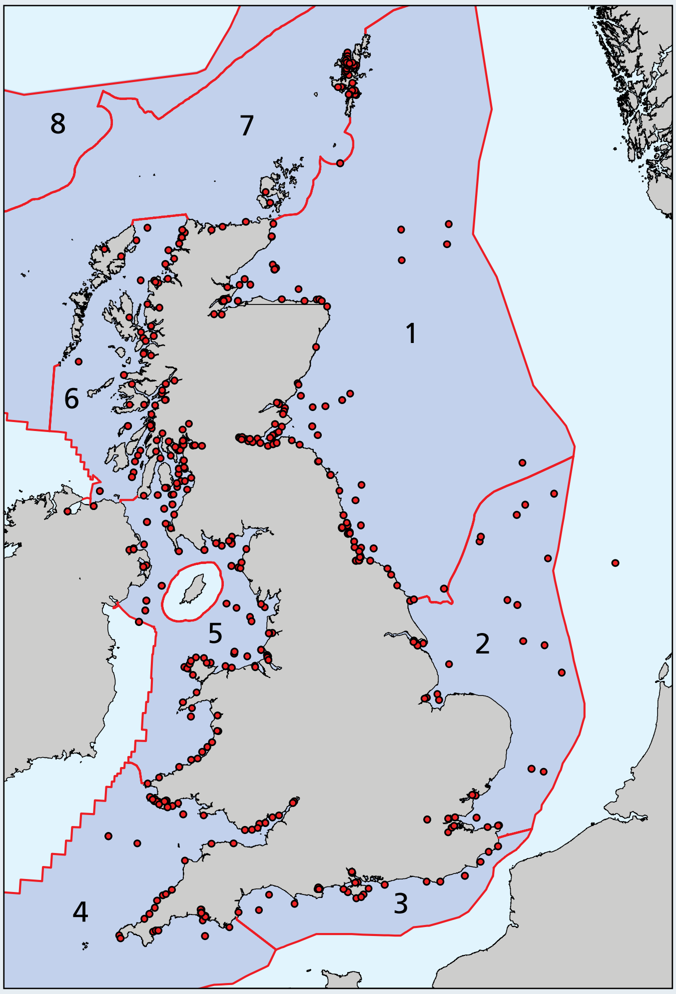
We have outlined the specific approach taken within each section, and made individual assessments for each of the eight biogeographical areas see Figure 1.1 on Page 6. The chapter concludes with a table summarising the outcome of the assessments by topic and region. More detailed information is available in the Feeder Report prepared by the Clean and Safe Seas Evidence Group.

Sampling off Stonehaven, North-East Scotland

National Monitoring for Environmental Quality

The main programme for monitoring the status of contaminants in UK waters is the *Clean Seas Environmental Monitoring Programme (CSEMP)*. CSEMP measures the concentrations of specific chemicals which are persistent, toxic and have the ability to accumulate in food chains, at almost 500 sites around the UK (see map). Concentrations of nutrients are also measured at some locations. The CSEMP measures the levels of biological effects in animals which can reflect the influence of many of the potentially hazardous chemicals in the environment. Finally, it assesses the ecology of the benthic communities at some of these sites to separate out the effects of hazardous substances from other causes of change. The results are used to report on progress made in delivering the vision of clean and safe seas, and are stored in the MERMAN database and sent annually to the International Council for the Exploration of the Sea (ICES) to fulfil the UK commitment under the OSPAR Convention.

CSEMP monitoring sites (●) around the UK in 2007



Data on the loads of contaminants entering our seas from river basins are submitted to OSPAR under their *Comprehensive Study on Riverine Inputs and Direct Discharges (RID)* programme. Data on contaminants in air are also submitted to OSPAR under their *Comprehensive Atmospheric Monitoring Programme (CAMP)*.

To dispose of dredged material, to remove seabed sediments for use as aggregate or to build structures at sea all require a licence or consent. Several organisations check regularly for compliance at key disposal sites, particularly those receiving large quantities of dredged material or those close to sensitive or conservation areas. This monitoring, conducted mainly by government agencies, assesses the concentration of contaminants and the presence of fauna of various species in the sediments, as well as the physical distribution and transport of material. The findings are published regularly in journal articles and reports.

The *Cetacean Strandings Investigation Programme* undertakes post-mortems of stranded and accidently caught whales and dolphins in order to establish causes of death. It also provides a bank of tissue samples, some of which are analysed to determine contaminant concentrations. These data provide information on variations in the levels of contamination between species, and on spatial and temporal differences in the levels of contaminants in harbour porpoises.

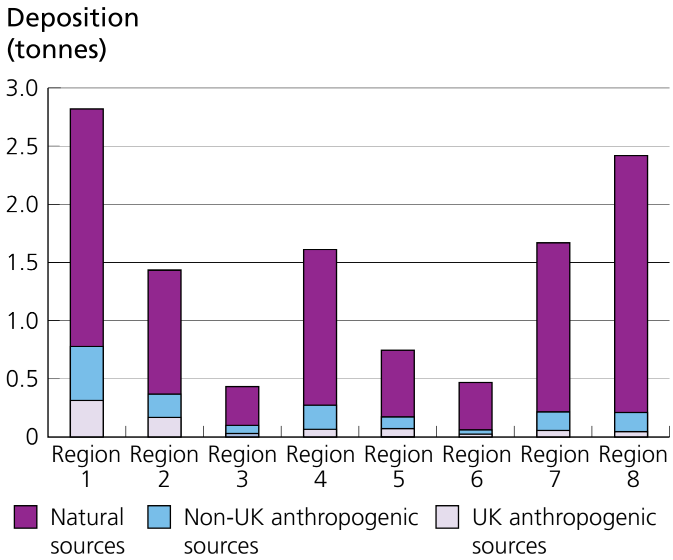
Clean Seas

Hazardous substances

Hazardous substances enter the marine environment from natural sources (e.g. polycyclic aromatic hydrocarbons (PAHs) from oil seeps, volcanoes and forest fires) and as a result of human activities, and reach the sea via direct discharges, through rivers and estuaries or via the atmosphere. The potential hazard associated with the different substances depends on their individual properties and behaviour following release. As explained on Page 60, we have identified concentration thresholds above which these substances could be toxic both to marine organisms and to human consumers of seafood. The Clean Seas Environmental Monitoring Programme (see box on previous page) directly monitors a limited number of hazardous chemicals, selected on the basis of a risk assessment and subject to there being agreed methodological guidelines, quality assurance procedures and assessment criteria available. For other contaminants, such as tributyltin (TBT), we can assess impacts by studying the biological effects they cause.

Data are still sparse at the regional scale; we may have too few sampling sites to characterise a region with high confidence. However, a major development since *Charting Progress* has been a redesign of the hazardous substances monitoring programme to make it more effective at detecting changes over time. For the first few years, the old and new programmes have run side to by side to provide continuity.

Figure 4.1 Deposition of cadmium to sea areas surrounding the UK in 2006.



Inputs of hazardous substances

The downward trend in inputs of contaminants over time reported in *Charting Progress* for rivers, sewage works and industrial discharges has continued for mercury, cadmium and lindane to both the Celtic Sea and the North Sea, but for polychlorinated biphenyls (PCBs) concentrations have stabilised.

Between 1990 and 2007, anthropogenic emissions of cadmium to the atmosphere decreased by 84%, of copper by 57%, of lead by 96%, of zinc by 55% and of mercury by 80%. Figure 4.1 shows deposition of cadmium to sea areas surrounding the UK in 2006.

While industrial change has caused some of these decreases, improved abatement at the remaining sources has also contributed.

Produced water from offshore oil and gas platforms contains natural toxic aromatic hydrocarbons which are a component of oil as well as treatment chemicals. Discharges of oil in produced water fell by about 25% during the

period 2002 to 2006, largely due to reductions in the volume of water discharged. The oil content of the discharged water remained constant at about 20 ppm until 2006, but reduced to about 15 ppm in 2007 thanks to improved produced water management. This brought the overall reduction in the amount of oil discharged from 2002-2008 to close to 50% (see Figure 4.2). This is a good example of effective regulation, in which the UK exceeded the reduction required by OSPAR.

Emissions of PAHs to the atmosphere have decreased by 84% since 1990. In 2007, the largest source of PAHs was road transport combustion, followed by domestic combustion (Figure 4.3). Twelve years earlier, the major source was the aluminium smelting industry, which contributed around 50%. Since then, thanks to improved practices, this industry is now responsible for only 1% of total PAH emissions.

Seawater

The evidence from seawater measurements is very encouraging. Inputs and concentrations of the most commonly monitored contaminants in seawater have fallen since *Charting Progress* as a result of earlier controls placed upon their use and are generally below UK EQS limits (for more information on UK EQSs, see www.environment-agency.gov.uk/research/planning/40295.aspx).

In addition, we found virtually no toxicological hazard from metals in water samples analysed for the EU Directives on Dangerous Substances (mainly in estuarine waters) and Shellfish Waters (mainly in coastal waters); nearly 99% of metal concentrations were below the UK EQS values in 2007, although 6% of copper concentrations exceeded the EQS (e.g. see Figure 4.4). Biological water quality (assessed using the percentage of

Figure 4.2 Oil discharged in produced water by the offshore oil and gas industry, 2001–2008.

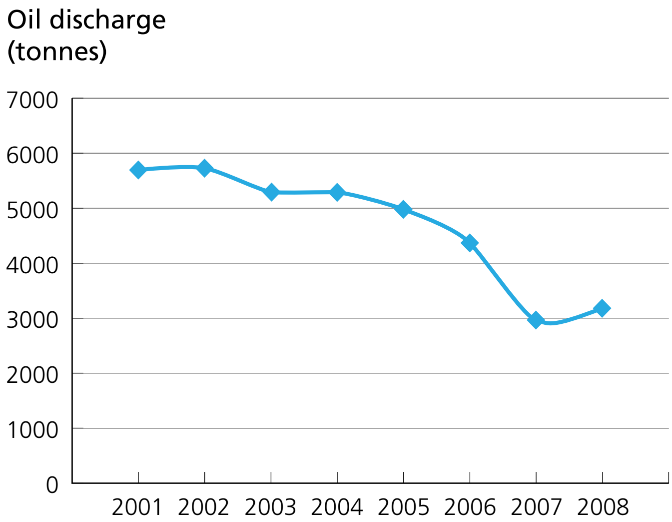
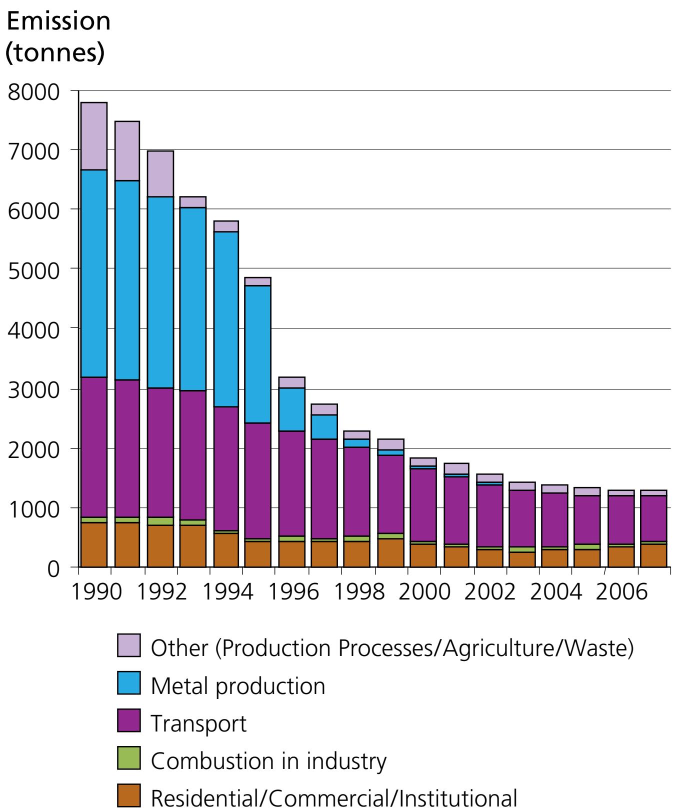


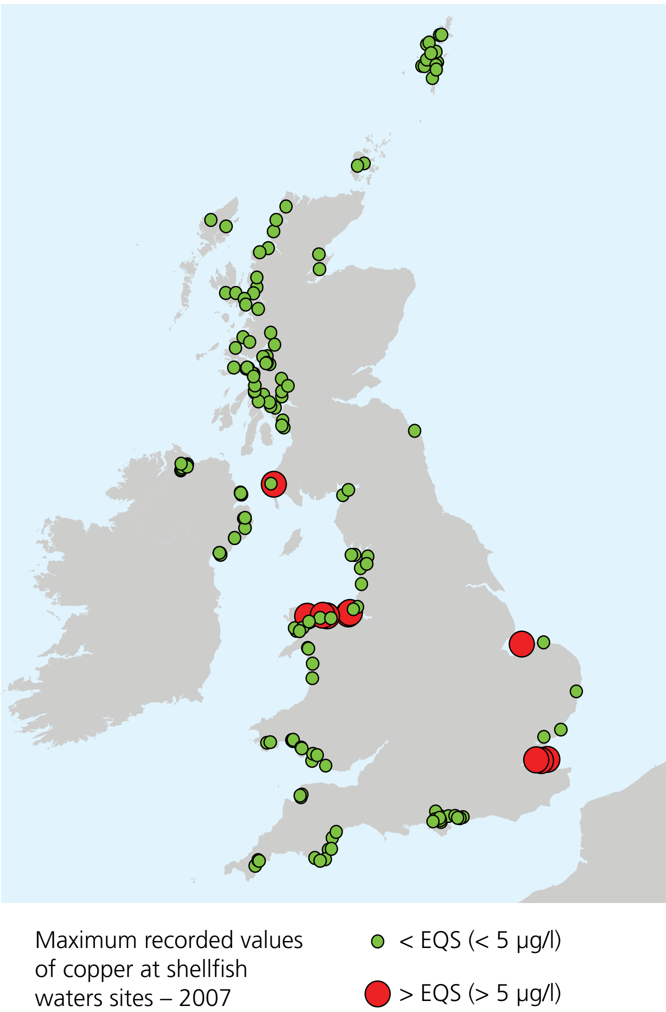
Figure 4.3 Emissions of PAH to the UK atmosphere, 1990–2007.



oyster embryos that develop successfully in the water samples) is good or very good everywhere, except in the Tees estuary close to industrial discharges.

However, because concentrations of many contaminants in water are both low and very variable, the UK marine monitoring programme under CSEMP focuses on measuring contaminant levels in biota and sediments, where accumulation means that concentrations are generally higher and less variable. This increases the power of the monitoring programme to observe changes in concentrations over time.

Figure 4.4 Copper concentrations in filtered water samples relative to the UK EQS.



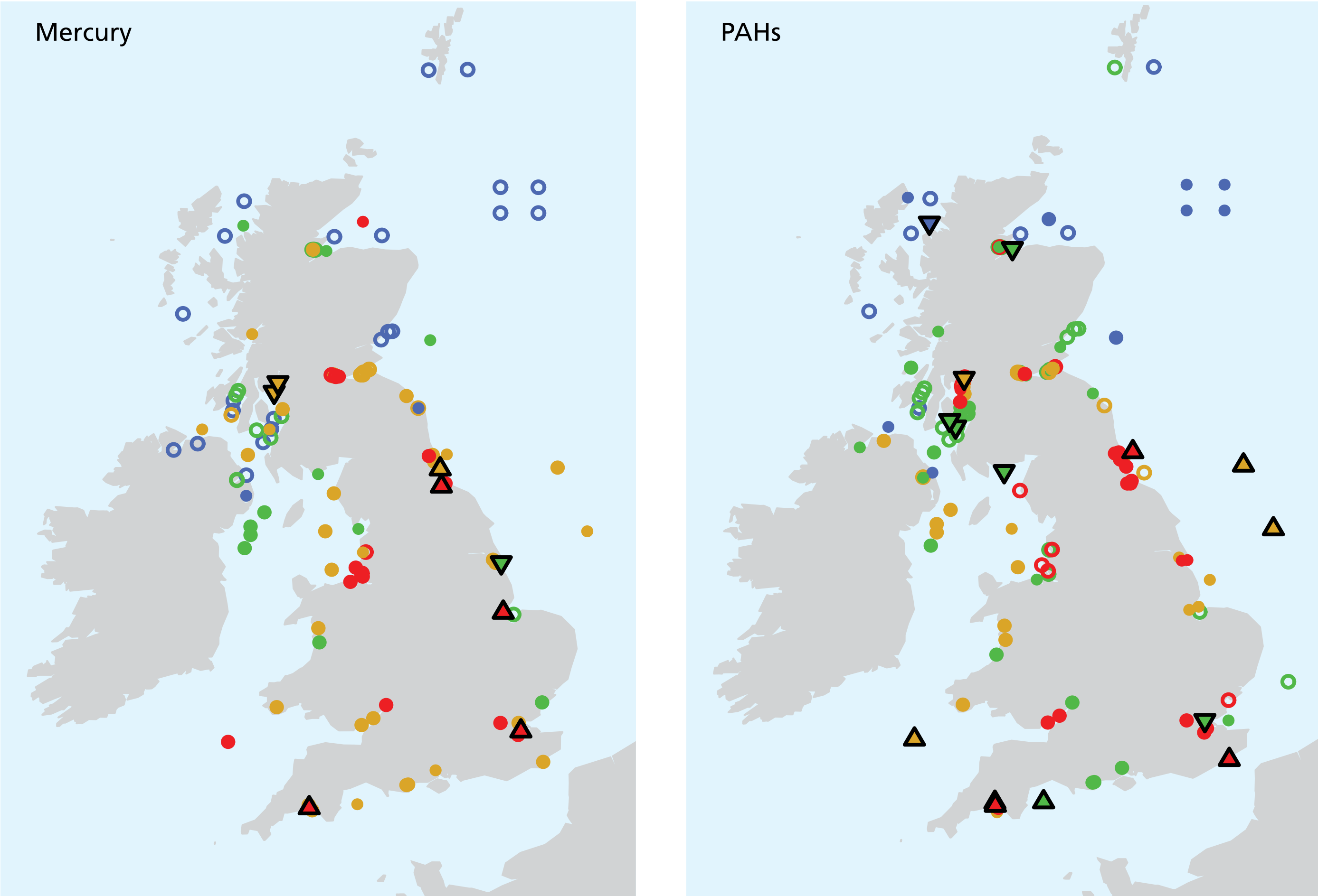
Sediments

Analysis of contaminants in sediments reveals more clearly where there are problems, particularly in estuaries that have been heavily industrialised over time. While metal concentrations in sediments are generally lower in Scotland and the western Irish Sea, they are higher in England and Wales, with a number of industrialised estuaries, such as the Tees, Tyne, Thames, Severn and Mersey (in the case of mercury), showing levels that are high enough to have potential toxicological effects (Figure 4.5). Similarly, sediment PAH concentrations were high in the Tees, Tyne, Wear, and Milford Haven estuaries, and hence potentially toxic to sediment-dwelling organisms (Figure 4.5). The capacity of the sediment to support biota is generally good at all locations studied, except in parts of the Tees, Wear and Thames estuaries where the presence of adverse biological effects may be linked to the high PAH concentrations.

There has been no significant overall trend in the concentrations of metals in sediments since *Charting Progress*, although both upward and downward trends can be seen at specific locations for all eight metals (cadmium, mercury, lead, arsenic, chromium, copper, nickel, zinc) determined. However, if metal inputs from rivers, sewage discharges and industry continue to decline, we would expect future assessments to find decreasing concentrations in the sediments where anthropogenic inputs have exceeded natural sources.

Concentrations of PCBs, were also determined in surface sediments. They are present in the environment as a result of widespread historical use of these products, mainly in electrical transformers. In particular, we found that concentrations of the most toxic congener included in the analyses are above the EAC in

Figure 4.5 Normalised mercury and PAH concentrations in sediment.



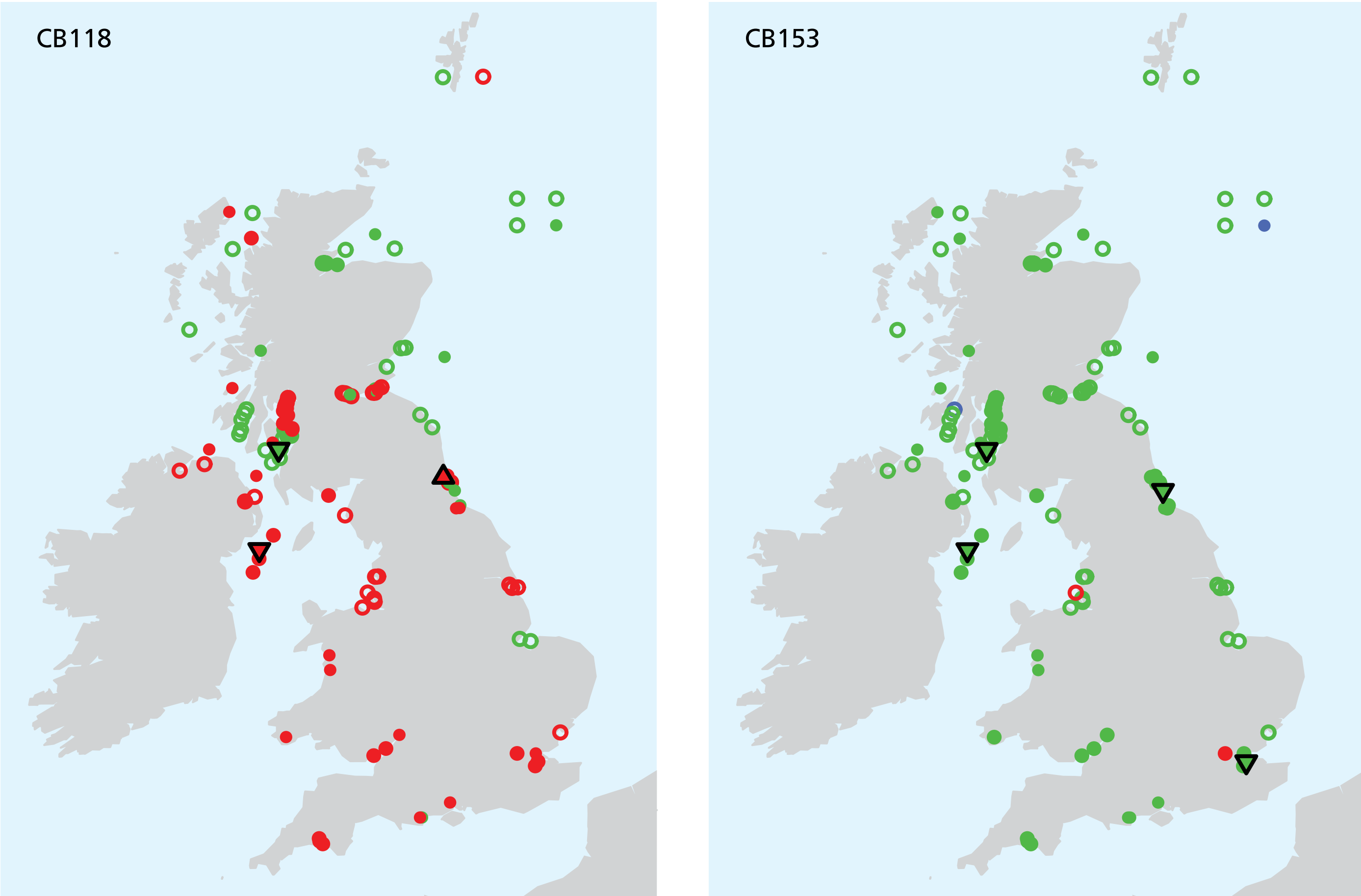
Blue, green and amber symbols indicate concentrations below the BAC, ERL and ERM concentrations respectively; red symbols indicate concentrations above the ERM.

Key to Figures 4.5, 4.6 and 4.7

- ● *5+ years of data, no trend*
- ▲ *5+ years of data, upward trend*
- ▼ *5+ years of data, downward trend*
- • *3–4 years of data, trend not investigated*
- ○ *1–2 years of data, insufficient data to assess trend*

most areas (CB118: Figure 4.6). This is significant because CB118 can affect neurological, immunological and reproductive processes in marine biota and humans. Generally speaking, we found the lowest concentrations of CBs at Scottish offshore sites, and the highest around south-eastern England (CB153: Figure 4.6). The few temporal trends we saw were mostly downward, although in many instances there was no apparent trend. Although the ban on new uses of PCBs was put in place in 1981, these compounds are very persistent in the environment and significant falls in environmental concentrations may take decades.

Figure 4.6 Normalised CB118 and CB153 concentrations in sediment.



Blue and green symbols indicate concentrations below the BAC or EAC respectively; red symbols indicate concentrations above the EAC. Key to symbols on Page 65.

CB congeners

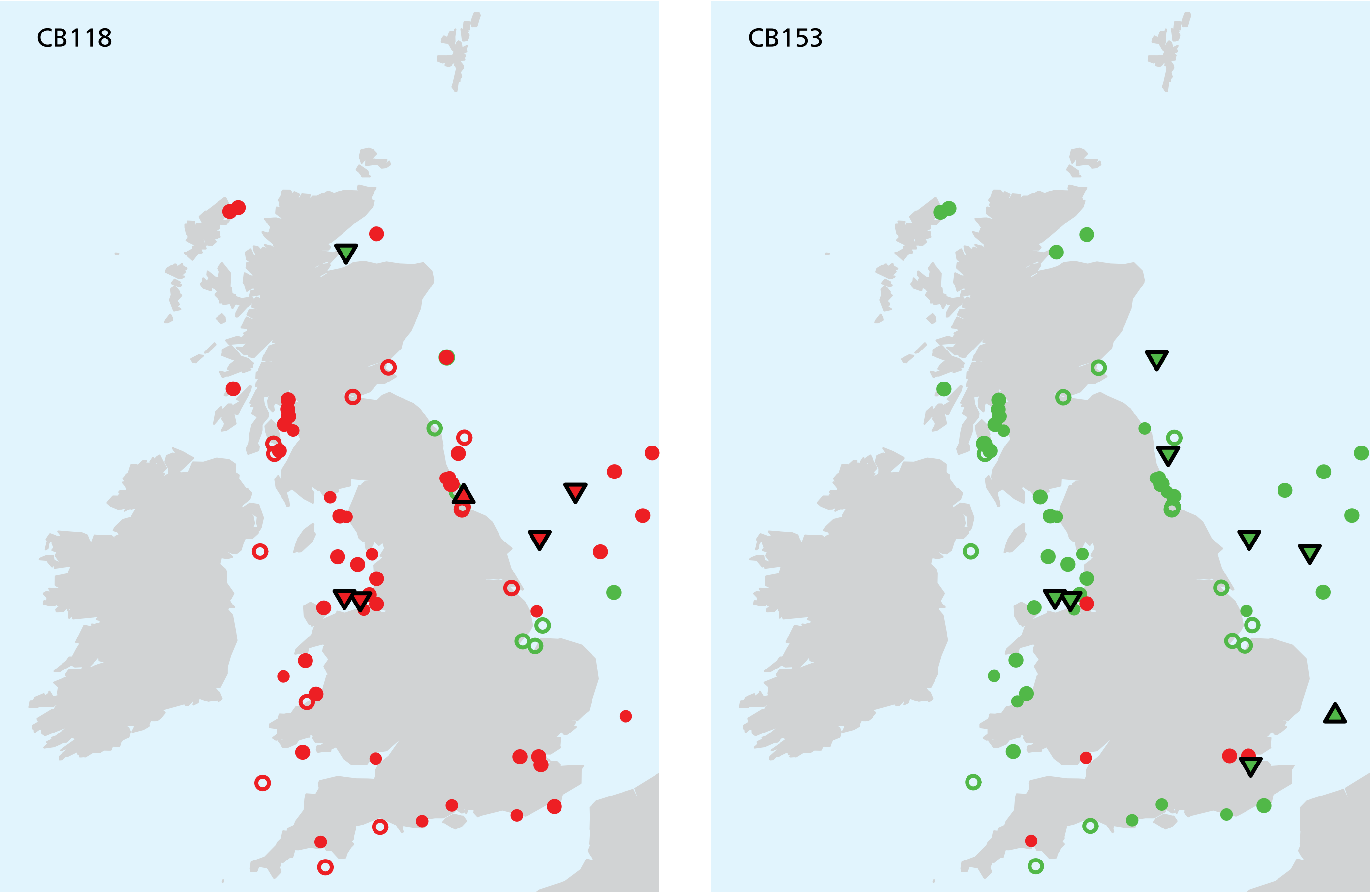
For this assessment we used the ICES7 CBs, selected by the ICES Marine Chemistry Working Group so as to facilitate comparison between different studies in which different sets of CB congeners are determined. If this minimum set of congeners is included in all studies, as is generally the case, then their sum can be used for comparative purposes.

The seven CB congeners are: CB28, CB52, CB101, CB118, CB138, CB153 and CB180.

Biota

In fish and shellfish, we found the highest concentrations of contaminants in industrialised estuaries. Mercury levels in fish flesh are high in the Mersey and Thames estuaries, and lead concentrations in fish liver are similarly high in many estuaries including the Forth, Tyne, Tees, Wear, Severn, Mersey and Bann as well as in a few other coastal areas. Cadmium, mercury and lead concentrations were slightly elevated in mussels from some industrialized estuaries: Dee, Humber and Thames for cadmium; Thames and Mersey for mercury; Tyne, Tees and Forth for lead. Silver concentrations were higher in mussels from the Severn and Thames estuaries than

Figure 4.7 Normalised CB118 and CB153 concentrations in fish liver.



Green symbols indicate concentrations below the EAC^{passive}; red symbols indicate concentrations above the EAC^{passive}. There were no concentrations below the BAC. EACs for CBs in sediment are expressed for sediment of 2.5% organic carbon. It is possible to calculate lipid-normalised concentrations of CBs in fish liver in equilibrium with sediment containing CB concentrations equal to the EACs in sediment. These so-called EAC^{passive} values are used as the green/red boundary for CBs in biota. Key to symbols on Page 65.

elsewhere. Historically, the major inputs of silver were due to its widespread use in photography, which should be declining with the growth in use of digital cameras. However, the increasing use of silver nanoparticles as an antimicrobial agent may result in increased inputs. Although these metal concentrations are higher than background values, none pose a risk to human health because, in general, the shellfish tested were not from commercially harvested beds.

Although concentrations of CB138, CB153 and CB180 in fish liver are below the respective EACs, those of the more toxic CB118 are above the EAC and thus potentially toxic to the fish (see Figure 4.7). Fish liver is not eaten in the UK, and fish liver oil for use as a dietary supplement is cleaned-up during processing to reduce CB levels. We found the lowest concentrations in Scotland (Region 6) and highest in eastern England (Region 2). We found high levels of ethoxyresorufin-*O*-deethylase (EROD) enzyme activity in fish liver, which reflects exposure to contaminants such as dioxins, furans, planar CBs and PAHs, at sites in the North Sea and Liverpool Bay and at two historic sewage disposal sites close to the Scottish east coast.

Figure 4.8 *Site classifications for mussels, assessed for individual PAH compounds.*

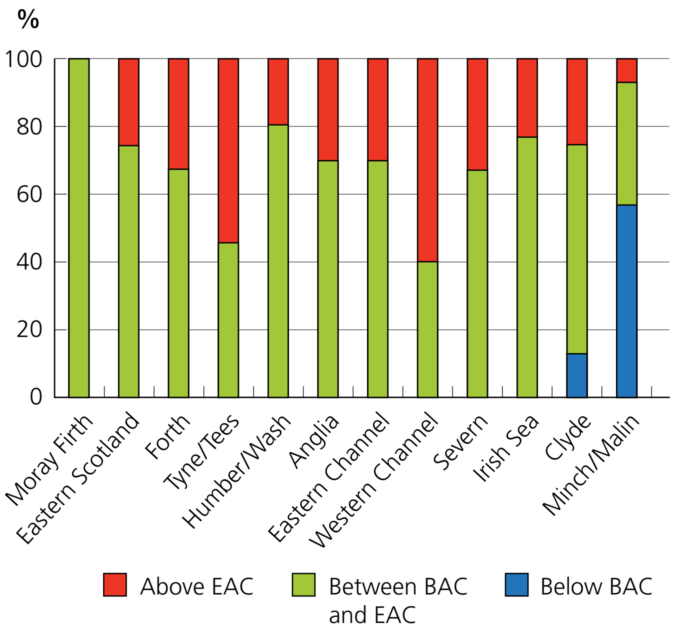
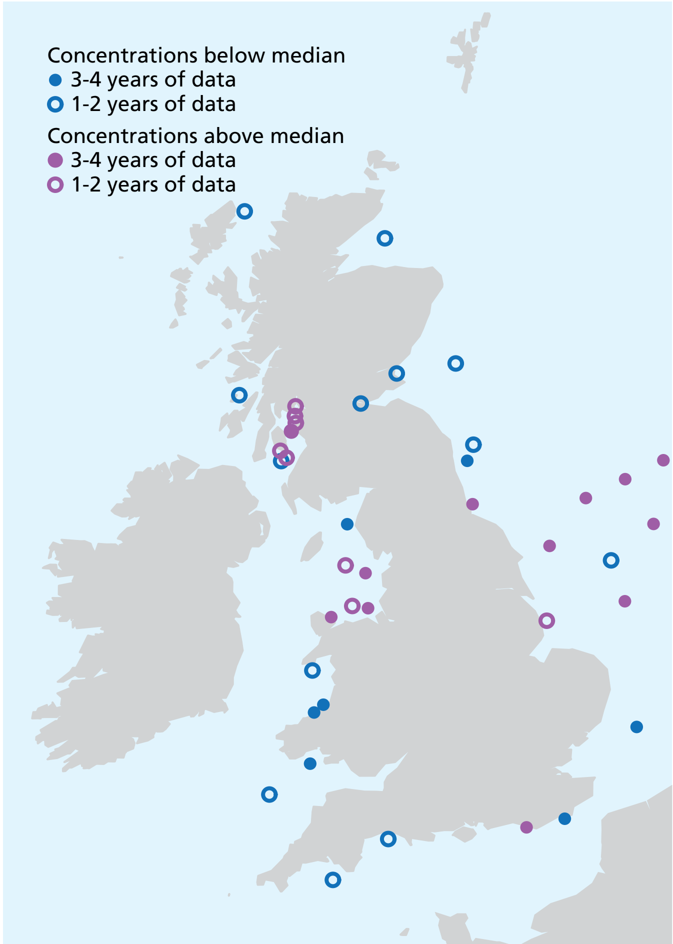


Figure 4.9 BDE47 concentrations in fish liver.



PAHs are potentially dangerous to fish (and humans) as, when metabolised, some PAH compounds can form potentially carcinogenic compounds that can bind to DNA. We found little change in the levels of these DNA adducts in the fish from some industrialised estuaries since *Charting Progress*, when high concentrations were reported, suggesting that marine organisms are still at risk due to PAH contamination at these locations. PAH concentrations in mussels are illustrated in Figure 4.8.

With their introduction into the formal monitoring programmes, more data are now available for the polybrominated diphenyl ethers (PBDEs), than was the case for *Charting Progress* (see Figure 4.9). However, we do not have enough information to identify trends over time other than in harbour porpoises, nor have assessment criteria yet been developed within OSPAR. We found the highest concentrations in fish in industrialised estuaries, including the Clyde, Tees and Humber, and the lowest off the Scottish coast, in the Western Channel and off eastern England. In harbour porpoises from UK waters, a rapidly rising trend in blubber concentrations of the brominated flame retardant hexabromocyclododecane (HBCD) after 2001, has been reversed since 2003. This is probably because of the closure of two UK plants, one manufacturing HBCD and the other using HBCD in the manufacture of expanded polystyrene.

Concentrations of CBs in harbour porpoise blubber are reacting more slowly to controls on the use of PCBs, although these have been in place since the 1980s, and levels are declining only slowly. Concentrations of BDEs in harbour porpoise blubber have also been declining over the period 1998 to 2008, following EU

BDE congeners

Brominated diphenyl ethers (BDEs) are flame retardant compounds. For this assessment we determined the nine OSPAR congeners.

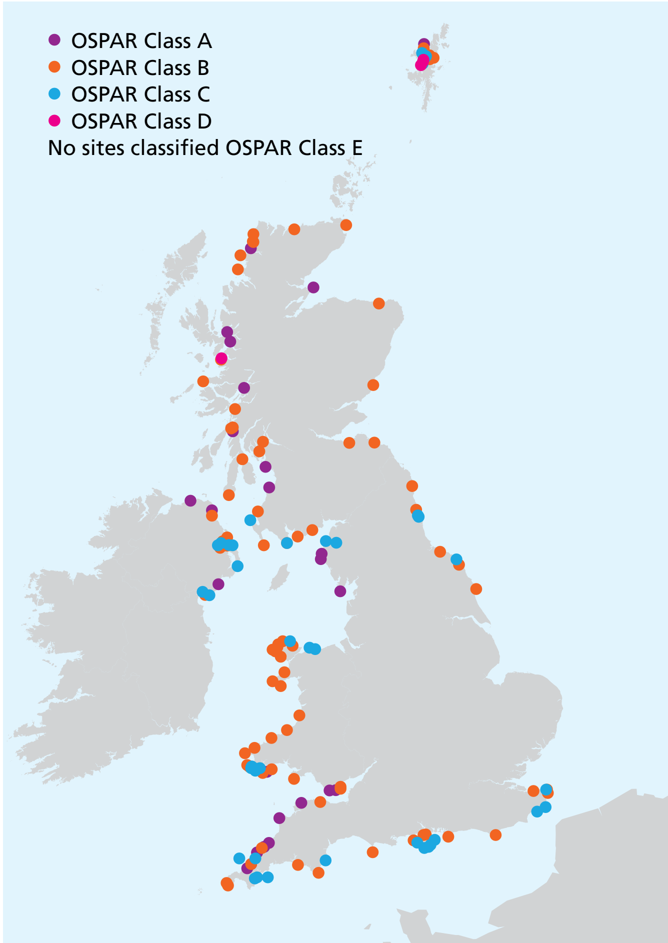
The nine BDE congeners are: BDE28, BDE47, BDE66, BDE85, BDE99, BDE100, BDE153, BDE154 and BDE183.

risk assessment and regulation. The tissues in deep-sea fish collected from the Rockall Trough to the west of the UK contained both CBs and BDEs, but not HBCD or tetrabromobisphenol-A (TBBP-A).

Fish liver pathologies, including cancers, are higher and potentially increasing at certain Irish Sea sites, higher but static at some North Sea sites, and low and static (approaching or at background levels) at Inner North Sea and English Channel sites. The causes of the higher levels are unknown, but cancers do not result solely from exposure to hazardous substances.

Another indicator of poor health in marine biota is imposex – the imposition of male characteristics on female organisms caused by exposure to tributyltin (TBT; Figure 4.10) or hybrid male/female conditions caused by a wider range of chemicals. The extent of imposex in marine snails as a result of exposure to TBT has declined since 1998, showing that the bans on the use of TBT in antifouling paints for ships have been very effective, with evidence of recovering populations and wider improvements in the range of bottom-dwelling organisms in previously impacted areas.

Figure 4.10 OSPAR classification of dogwhelks from UK sampling sites in relation to imposex, 2007. OSPAR classifications go from A (no incidence of imposex) to E (populations unable to reproduce).



Marine snail (dogwhelk)

Charting Progress reported evidence of endocrine disruption resulting from exposure to oestrogenic chemicals in flounder from a number of UK estuaries (Tyne, Tees, Mersey, Clyde and Forth). It assessed endocrine disruption, in this case feminisation, using vitellogenin (VTG). This is a protein normally only found in the blood of female fish. Thus, finding it in male fish indicates exposure to oestrogenic chemicals. There has been no further work since then, so we cannot say what the current status is, or assess trends since *Charting Progress*. Although the concentrations of VTG in males of offshore species of fish, cod and dab, are generally close to background levels, in cod from the North Sea and around Shetland, we found a marked increase in the amount of VTG at a body mass of 5 kg. This is about the size at which cod switch their diet from eating benthic invertebrates to eating other fish, both benthic and pelagic. We saw similar results in dab from UK offshore waters, suggesting that the affected fish are gradually accumulating persistent oestrogenic compounds through their diet. One report also showed the presence of egg cells in the testes of male peppery furrow shells, a filter-feeding bivalve sampled in a number of estuaries in south-west England during 2004 to 2005, including the Avon estuary previously considered to be a reference site due to the low population level and lack of industry. These findings suggest continuing impacts from oestrogenic compounds, although we cannot assess their scale. Similar studies in cod and bivalves were not reported in *Charting Progress*.

Our assessment shows that reductions in emissions, discharges and losses are having an impact, since we find downward trends for certain contaminants in specific contexts such as the BDEs in harbour porpoise blubber. However, it is also clear that, for some legacy chemicals, concentrations in sediments are reducing only very slowly and contaminated sediments will act as a source of persistent organic pollutants for years to come. However, even their concentrations are generally below those likely to cause effects except for historically contaminated estuaries and very coastal locations.

During 2009, there were initial assessments of the status of the UK seas under the EU Water Framework Directive (WFD). Extensive data collection within monitoring implemented for the EU Dangerous Substances and Shellfish Waters Directives, etc, informs these WFD chemical status assessments. All Scottish transitional and coastal waterbodies achieved good status for contaminants. In England and Wales, 69% of transitional waters and 91% of coastal waters assessed were at good chemical status. Less than good chemical status was, in the majority of cases, related to TBT contamination. There were few breaches of the contaminant standards at sites in Northern Ireland, with the exception of ammonia. Programmes of measures will be developed where necessary.

The WFD monitoring uses EQS limit values for water developed by the EU which are in many cases lower than those used in this assessment, with the aim of achieving improved environmental protection. For a list see Common Position (EC) No 3/2008, at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2008:071:0001:01:EN:HTML.

Within the EU Marine Strategy Framework Directive, monitoring will be undertaken with a view to assessing Good Environmental Status against 11 attributes, including whether concentrations of contaminants are at levels not giving rise to pollution effects; and whether concentrations of contaminants in seafood are below the regulatory limits set to protect human consumers.

Future work

We need to understand more about the effects of mixtures of chemicals. Classical toxicology has provided a huge amount of information on the hazards of individual compounds but, in their environment, animals are exposed to more than one compound at a time. For endocrine disruptors, the effects of different chemicals might just be additive, but they could also cancel each other out or exacerbate each other's effects. We also need more data to determine the significance of pharmaceuticals in the marine environment.

OSPAR and ICES are currently developing guidelines for monitoring and assessing integrated chemical and biological effects, initially for use within OSPAR. These will also be adopted within the CSEMP, where appropriate, and so integrated data will be available for the next in this series of UK status reports.

Radioactivity

Radioactivity in the marine environment arises from both naturally occurring and man-made sources, and can be harmful to humans and non-human species. The major sources of discharges are shown in Figure 4.11. For this assessment we have used data on changes in radioactivity concentrations in the environment from national monitoring programmes and OSPAR periodic reports.

Generally we have found that radioactive discharges are strictly controlled, discharge levels have reduced and a strategy is in place to further reduce discharge levels in the future.

Figure 4.11 Licensed nuclear sites discharging radioactive material into the marine environment.

The aims of the OSPAR Radioactive Substances Strategy are to reduce radioactive discharges, emissions and losses, so that concentrations in the marine environment will eventually be near background values for naturally occurring radioactive substances and close to zero for artificially produced radionuclides. The revised UK Strategy for radioactive discharges, published in July 2009, sets out how the UK intends to achieve OSPAR's interim objective that additional concentrations above historic levels are close to zero by 2020. This builds on the UK Strategy for radioactive discharges published in 2002, widening its scope to include aerial as well as liquid discharges from the decommissioning and operational activities of the nuclear and

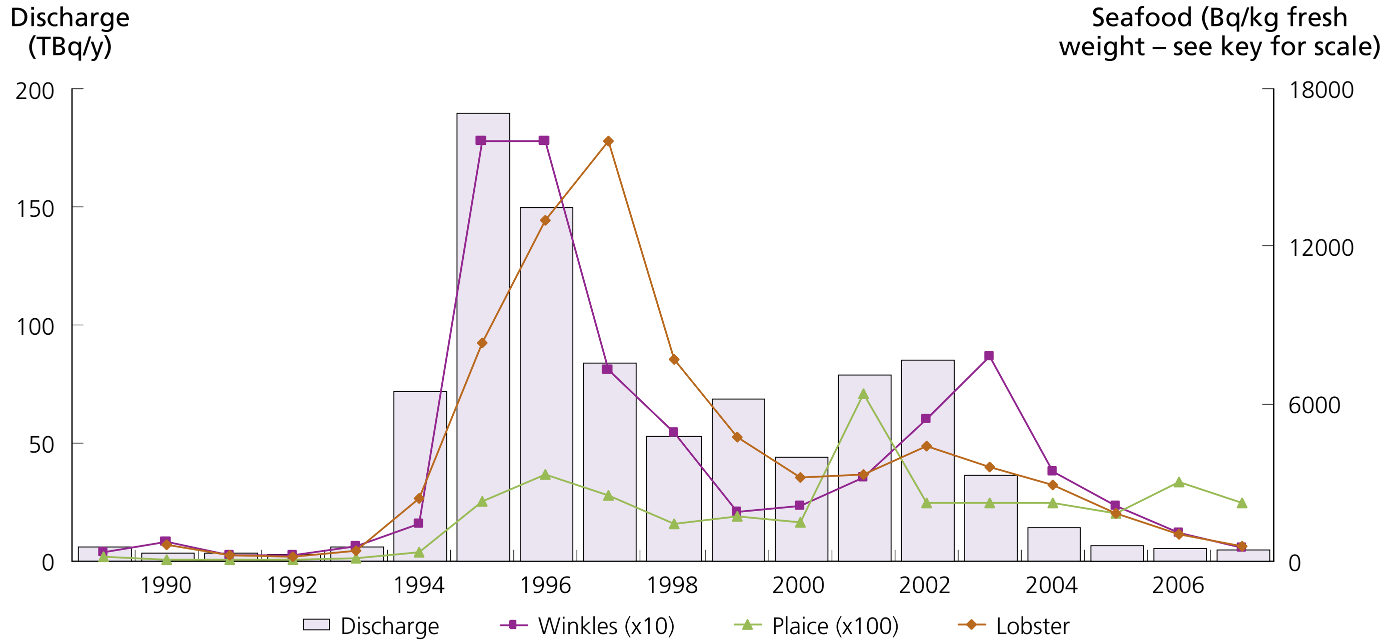
non-nuclear sectors. The Strategy reports on the progress that has been made on reducing discharges and concentrations to the marine environment since 2002 on a sectoral basis and sets projections and expected outcomes for radioactive discharges up to 2030, based on a set of environmental principles. Forecasts indicate the UK's consistent progress with meeting the OSPAR commitments.

This strategy is having a noticeable effect, and inputs have fallen further since *Charting Progress*. The annual reports in the Radioactivity in Food and the Environment (RIFE) series confirm that radioactivity levels in UK waters currently pose no risk of harm to humans or wildlife.

With regard to specific radionuclides:

- Since 2005, technetium-99 (^{99}Tc) discharges from processes at Sellafield have fallen below 10 TBq per annum, and have met the end of 2006 target set in the UK Strategy for radioactive discharges (2002). Environmental concentrations of this radionuclide have also decreased significantly overall since 1995 (see Figure 4.12 for biota). Figure 4.13 shows the current distribution of ^{99}Tc in subtidal sediments of the Irish Sea. Note that the highest concentrations are in a patch of muddy sediments off Sellafield.
- Remobilisation of radionuclides from deeper sediment layers into surface sediments and overlying waters is now the principal source of caesium-137 (^{137}Cs) and plutonium in the Irish Sea. Increased concentrations of plutonium-239/240 (^{239,240}Pu) in certain areas of the Irish Sea and Solway Firth suggest redistribution of historically contaminated sediments is an emerging factor for ^{239,240}Pu.
- Polonium-210 (^{210}Po) was historically discharged by a phosphate processing plant near Whitehaven. The levels of ^{210}Po in seafood around Whitehaven have fallen to

Figure 4.12 Annual ^{99}Tc liquid discharge from Sellafield and concentrations in winkles, plaice and lobster collected near Sellafield.

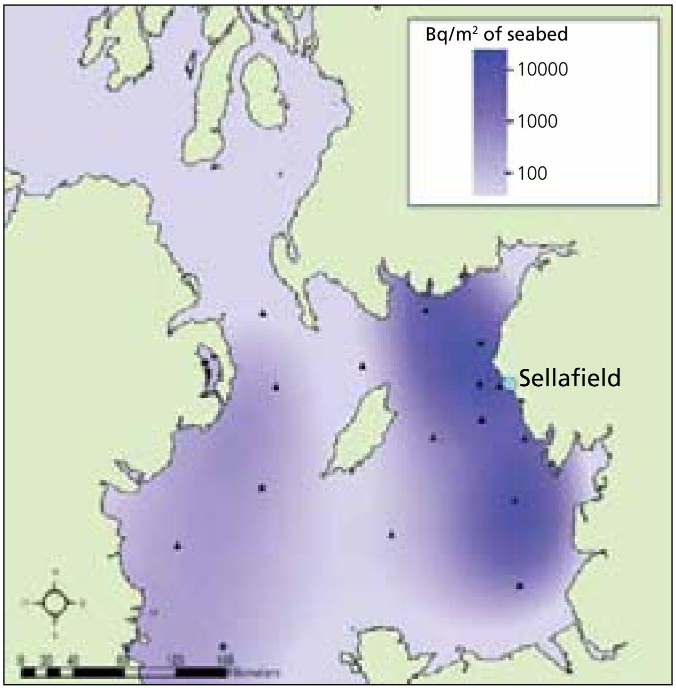


within the range of natural variability. ^{210}Po is responsible for ~50% of the radiation dose to seafood consumers around Sellafield, which remains well within the UK and EU annual dose limit of 1 mSv set to protect human health. Most of this dose is due to the legacy of earlier discharges. Current discharges from Sellafield are very low relative to their 1970s peak and continue to fall.

- Concentrations of tritium (^{3}H) and carbon-14 (^{14}C) in fish and molluscs near the radiopharmaceutical plant in Cardiff are decreasing, although tritium levels remain higher than elsewhere in coastal waters.
- The offshore oil and gas industry is responsible for a large proportion of the total alpha-emitting radioactivity entering UK waters, as a result of discharges of the ‘produced water’, which contains elevated levels of the naturally occurring radionuclides radium-226 (^{226}Ra), radium-228 (^{228}Ra) and lead-210 (^{210}Pb). However, discharges fell by about 25% between 2000 and 2006, and will continue to reduce in line with declining production of oil and gas.

There is evidence of radioactive particles on beaches around Sellafield and Dounreay. However, the beaches remain open at both locations as there is no risk to users of these beaches. For the protection of consumers, the harvesting of seafood in the vicinity of Dounreay was banned under FEPA in 1997. Monitoring programmes are in place at both Sellafield and Dounreay to locate and retrieve contaminated particles from the foreshores. At Dounreay, an offshore programme of particle recovery is also underway.

Figure 4.13 Distribution of ^{99}Tc in Irish Sea subtidal sediments based on 2005 and 2006 survey data (small black triangles denote sampling locations).



In a screening assessment, modelled dose rates in aquatic systems were below the threshold of 40 µGy/hr in all cases except near the Springfields nuclear fuel manufacturing site in Lancashire, where new discharge limits should ensure that, in the future, the dose rates do not exceed the threshold.

40 µGy/hr threshold

The 40 µGy/hr guideline is the dose rate below which there will be no harm to the species at the population level (Radioactive Substances Regulation – Environmental Principles, Environment Agency, 2009).

Eutrophication

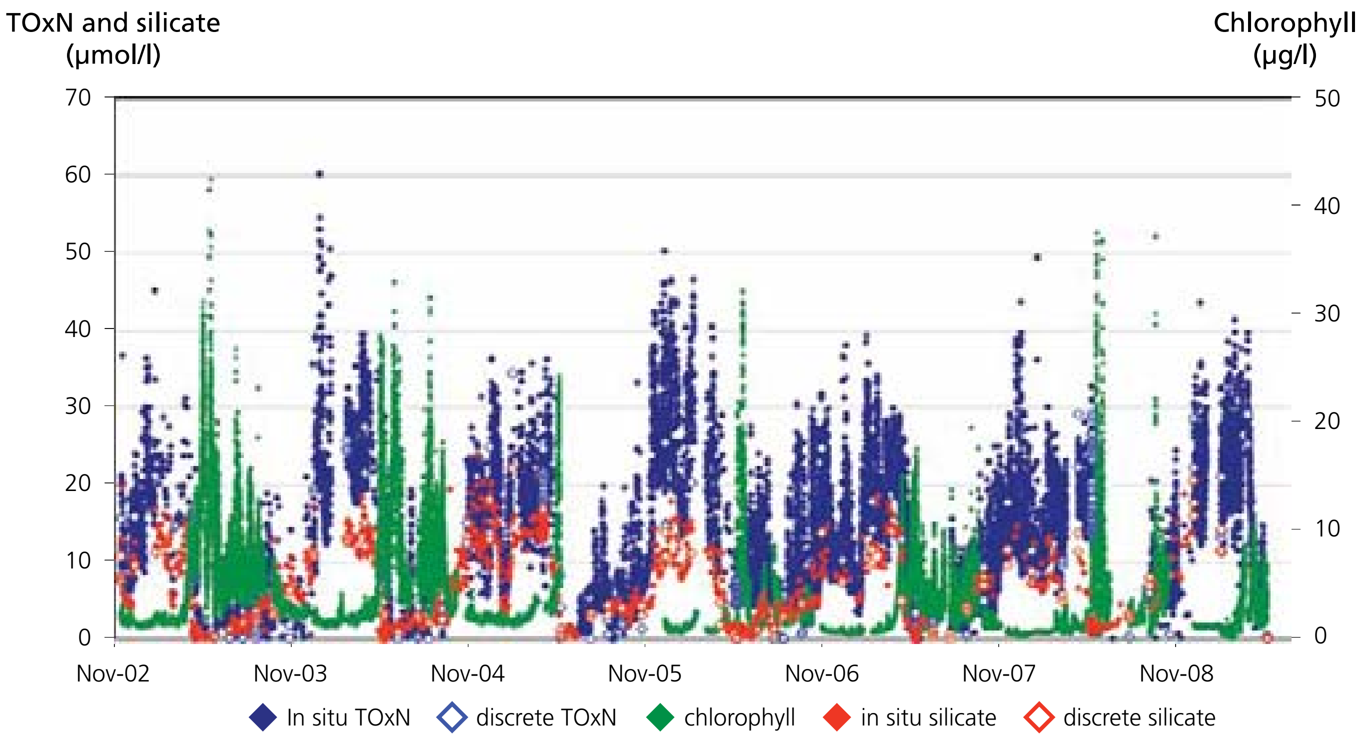
Eutrophication is one of the major threats to the health of estuarine, coastal and shelf sea ecosystems around the world. It occurs when the enrichment of water by nutrients (often from fertilizer run-off from agricultural land or sewage discharges) causes an accelerated growth of algae and higher forms of plant life. This in turn leads to an undesirable disturbance to the balance of organisms present in the water and to the quality of water concerned. (This definition is based on the Urban Waste Water Treatment Directive, UWWTD; 91/271/EEC.) For this assessment, undertaken in 2007, we focused on the risk posed by nutrient enrichment in the period 2001 to 2005 and in the near future, and the extent of eutrophication problems in UK waters.

We used OSPAR's Comprehensive Procedure for identifying the eutrophication status of coastal and offshore waters. This uses a 'weight of evidence' approach to identify 'non-problem areas', 'potential problem areas' at risk of eutrophication, and 'problem areas' that are already experiencing undesirable disturbance to the balance of organisms. For estuarine water we used the results of similar assessments carried out in support of the EU UWWTD and Nitrates Directive. We assessed field measurements against a checklist of parameters including concentrations of nutrients, chlorophyll and dissolved oxygen, phytoplankton indicator species, macrophytes and toxin-producing algae. Figure 4.14 shows data collected using a SmartBuoy. Higher concentrations of nitrogen and silicate are seen during the winter and of chlorophyll in the spring and summer, in response to blooms of algae which consume nutrients and photosynthesise. Each dot represents a single, automatic, measurement. Traditionally, nutrients levels and trends were monitored using a relatively small number of discrete samples analysed on-board ship or in the laboratory. Newer developments allow the gathering of much more frequent data (as shown in Figure 4.14).

Deployment of a SmartBuoy to provide detection of environmental change in UK waters

We found that UK coastal and offshore waters in each of the eight regions are currently non-problem areas with respect to eutrophication. The coastal waters include five areas that had caused concern in an earlier assessment undertaken in 2002 and reported in *Charting Progress* – these were East England, East Anglia, Liverpool Bay, the Solent and the Firth of Clyde. Although these areas are still nutrient enriched, and some showed evidence of accelerated growth of algae, there was no evidence for undesirable disturbance, and the risk is not increasing.

*Figure 4.14 A time series of nitrate + nitrite (TOxN), silicate and chlorophyll concentrations (*in situ *data) from the Cefas SmartBuoy in Liverpool Bay, together with the results from periodic ship-based surveys (discrete).*



Opportunistic green algae growing in an estuary

However, in 2007 we identified 17 small estuaries and harbours as problem areas and 5 as potential problem areas. These water bodies are also designated as Sensitive Areas under the UWWTD and as Nitrate Polluted Waters (eutrophic) under the Nitrates Directive, and hence are already subject to nutrient reduction programmes. But there is such a large reservoir of nutrients in soils and sediments that the environmental response to the reduction in nutrient inputs is likely to be slow. Moreover, it is not clear to what extent these protective measures will lead to ecological recovery, because the eutrophication process is complex and may not be easily reversible.

The biggest pressures on eutrophication status occur in the east, south and north-west of England where nutrients of human origin (notably nitrate and phosphate from agriculture and urban waste water sources) have enriched

coastal waters. We found no changes in eutrophication status over the period 1996 to 2005, and re-assessment of the five areas cited above with additional data confirmed them to be non-problem areas. The designation of Nitrate Vulnerable Zones covering 69% of the land in England, 14% of Scotland, 4% of Wales and the whole of Northern Ireland is likely to lead to a reduction in nutrient inputs from agriculture, as is the effective implementation of the UWWTD which will reduce nutrient inputs from waste water. Since 1998, total inputs of phosphate have declined by around 6% to 9% per year in all regions, while total inputs of dissolved inorganic nitrogen have decreased by 2% per year in the North Sea (Region 1) and the Irish Sea (Region 5).

We have high confidence in the assessments of eutrophication in most areas due to the availability of extensive datasets, and enhanced monitoring which was put in place in areas that were previously reported to be vulnerable.

In conclusion, we have reached a situation where eutrophication problems are apparent in some small estuaries, which occupy only a small percentage of our seas (< 0.2% of the area in each region, and < 0.03% overall). However, we should continue to reduce nutrient pressures through appropriate actions under EU Directives to address areas where there are still problems, even though recovery may take many years. A further application of the OSPAR Comprehensive Procedure to assess the current eutrophication status will begin shortly.

Oil and chemical spills

Although oil and chemical spills are generally short-term and localised, their effects can be significant. We could not assess the regional impact of accidental spillages of oil and chemicals, because in general they are logged as the number of incidents reported rather than as volumes lost. Most happen in major shipping lanes or where the offshore oil and gas industry operates. We have high confidence in the estimates of oil lost from offshore platforms as the UK Government has a mandatory reporting requirement, but our confidence is lower in relation to spills from ships, because these are usually detected using aerial surveillance and satellite data rather than being reported by those responsible.

In 2007, the most recent year for which data are available, there were 654 accidental discharges of oil from ships and offshore platforms into UK waters, an increase of 29% in discharges from ships and 13% in discharges from platforms compared to 2006. However, most were small, with only 47 incidents involving the loss of oil or chemicals in excess of 2 tonnes. We could not assess compliance with the OSPAR Ecological Quality Objective (EcoQO) for the proportion of oiled common guillemots found on beaches around the North Sea due to a lack of monitoring data; however, in Orkney and Shetland, the EcoQO has been met and the proportion of oiled guillemots is decreasing. The only incident of note since *Charting Progress* involved the container ship MSC *Napoli* which was beached in January 2007, spilling a total of 302 tonnes of oil, of which 150 tonnes affected Lyme Bay on the Devon/Dorset coast. The incident was effectively dealt with by the Secretary of State's Representative for Maritime Salvage and Intervention and the Maritime and Coastguard Agency, and only had a small local impact on seabirds.

The growing traffic in heavy fuel oils from the former Soviet Union past UK coasts is raising the risk of accidental spillages of oil and chemicals, as is the increasing size of container vessels.

MSC Napoli *grounded in Lyme Bay in January 2007*

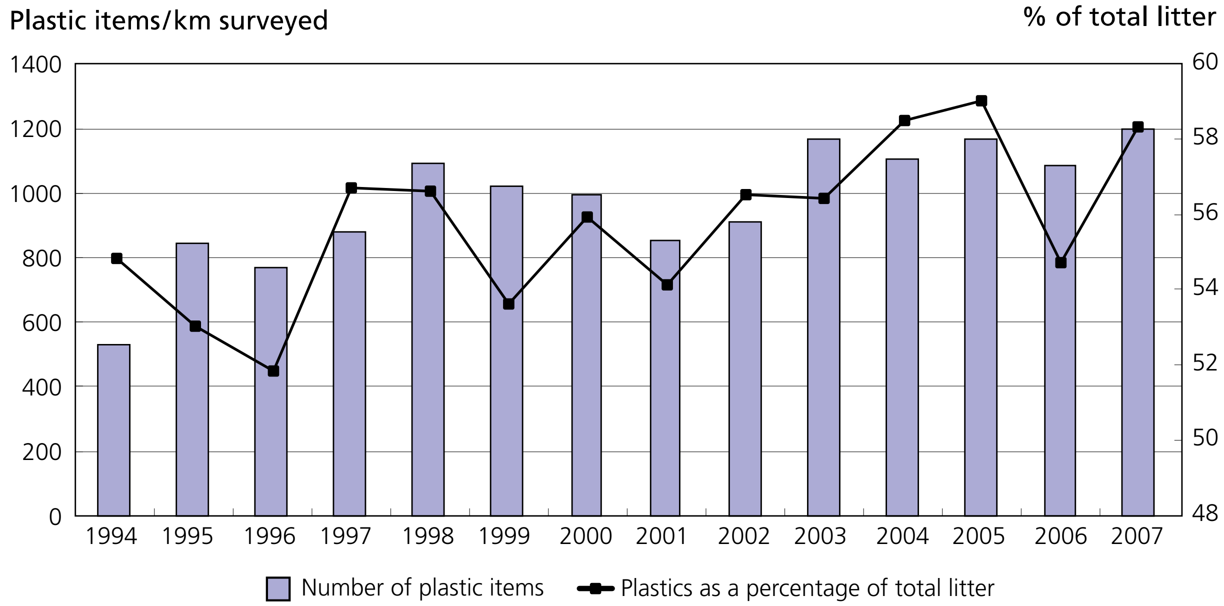
Prevention is better than cure. The best hope of reducing incidents comes from international efforts to ensure that the best modern ships and well-trained and efficient crews are passing through our waters. Other mitigation measures, such as traffic separation schemes and the provision of emergency towing vessels, are in place. The UK also has a good response capability, under the umbrella of the National Contingency Plan for Dealing with Pollution from Ships and Offshore Installations.

In the absence of a major spill, oil and chemical spills are generally of relatively minor significance in preventing progress towards the UK vision of clean and safe seas.

Litter

Significant amounts of litter appear in our seas and on our beaches. It is unsightly and can cause harm to marine wildlife through entanglement and ingestion, and through smothering of the seabed. Litter has both environmental and economic effects through harm to wildlife, costs to local communities in terms of clean-up costs and lost tourism, and costs to fishermen through lost catch and snagged nets. It can also pose a hazard to seafarers through fouling of ship propellers. Plastics are the main type of litter found both on beaches (Figure 4.15) and offshore, including increasing quantities of microscopic pieces of plastics resulting from degradation of larger plastic products in the sea. These may act as a vector for transferring

Figure 4.15 Plastic litter items per kilometre of UK beaches surveyed and as a percentage of total beach litter.



Beachwatch litter survey

toxic chemicals to the food chain. Plastic litter can take hundreds if not thousands of years to break down, and it may never truly biodegrade. International and UK legislation prohibits the disposal of all plastics into the sea.

To assess beach litter, we used the annual series of surveys undertaken by volunteers for the Marine Conservation Society over one weekend each year. Offshore litter data come from CSEMP and other research cruises. Seabed litter has been surveyed at only a few sites and data are sparse, making assessment difficult. The KIMO 'Fishing for Litter' initiative enables litter trawled up from the seabed by fishing boats to be landed ashore and disposed of responsibly. The quantities of litter landed by region are reported, but the source locations are not logged.

Beach litter

Among the beach litter that can be identified, the main sources are the general public, fishing, sewage discharges and shipping. In general, there has been no appreciable fall in the

quantities of litter on UK beaches since *Charting Progress*. In fact, if we consider data collected since the start of monitoring, there has been a considerable increase. In 1994, an average of around 1000 items per kilometre was recorded but, by 2007, this had almost doubled. The majority of this increase occurred between 1994 and 2003; since then litter levels have been relatively steady although still high (Figure 4.16).

The methodology presently used by the Marine Conservation Society is comparable to that used by OSPAR and with the recently published UNEP/IOC guidelines on survey and monitoring of marine litter. But, more frequent sampling would increase confidence in the assessment of trends.

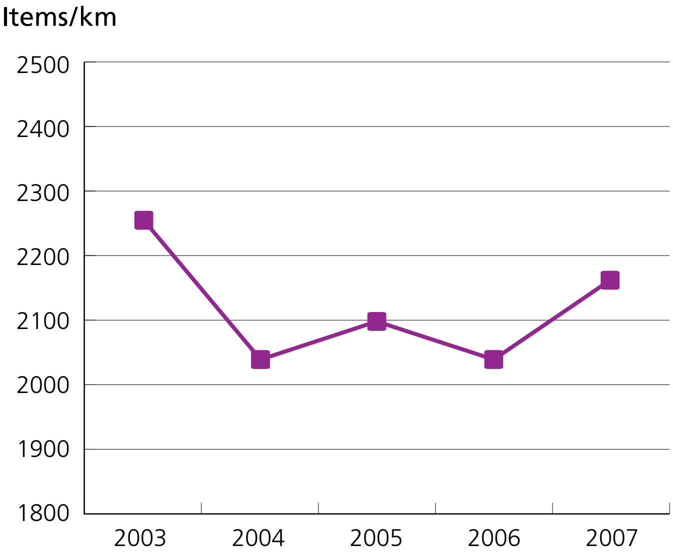
Some beaches are not surveyed every year making a comparison of these sites more difficult and some areas have sparse data sets. Up to 40% of litter items remain unassigned each year, either because they are too small or too weathered to identify a source, or because they could have come from a number of sources. Although it was assigned a 'red' status (unacceptable) in some areas in *Charting Progress*, the overall 'traffic light' status assigned to beach litter is orange (some problems) in Regions 1 to 5. However, with the exception of Region 3 which has improved, the status has not changed significantly since *Charting Progress*.

Offshore litter

We found a wide variability in offshore litter between sites and sometimes in successive years for locations sampled. There is generally not much litter on the seabed, but seabed smothering could be an issue in particular locations.

The presence of significantly higher densities of litter at Carmarthen Bay, North Cardigan Bay, in the Celtic Deep and in Rye Bay suggests that these are areas of accumulation, where litter

Figure 4.16 Beach litter items (all types) per kilometre surveyed in all UK regions, 2003–2007.



gathers because of the effects of winds and currents. The frequency of litter ranged from 0 to 17 items per hectare. Rope, polypropylene twine and hard plastics are the most common forms of offshore litter. However, data are too sparse to allow a meaningful assessment of changes in quantities of litter either regionally or over time, and we also know too little about the impacts of litter in the sea to draw any reliable conclusions about the effects.

Drivers for change include the Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations, and for Port Waste Reception Facilities, and the Updated Code of Practice on Litter and Refuse. Increased participation in recycling schemes by the general public and implementation of relatively new legislation may take time to show effect.

At present, responsibility for marine litter is spread across a number of UK agencies. Further co-operation between all organisations responsible for litter will help coordinate efforts to control marine litter.

While marine litter would appear to be largely preventable, the wide range of sources of litter, the number of pathways by which it enters the marine environment, and the fact that litter can be easily transported by winds and currents, all make managing the problem highly complex.

Litter is one of the 11 qualitative descriptors that will be used for assessment of Good Environmental Status under the EU Marine Strategy Framework Directive, so gathering data to allow a robust assessment will be essential. The UK Marine Monitoring and Assessment Strategy Assessment (UKMMAS) community will need to develop a more comprehensive programme to do this.

Marine litter has economic, environmental and aesthetic impacts. What is not yet clear is the full extent of these impacts in the UK.

Noise

For most marine mammals, many marine fish, and possibly some shellfish, sound is important for communication, locating mates, searching for prey, avoiding predators and hazards, and for short- and long-range navigation. Noise at inappropriate volume and frequency can mask biologically relevant signals; it can lead to a variety of behavioural reactions; hearing organs can be adversely affected, and at very high levels, sound can injure or even kill marine life. Man-made sound sources of primary concern are explosions, shipping, seismic surveys, offshore construction and offshore industrial activities and sonars of various types, including military sonar, which has previously been implicated in deaths of beaked whales.

There is currently not enough evidence to provide a quantitative assessment of underwater noise in UK waters, but increasing activity in constructing, for example, offshore wind farms, is likely to have raised local noise levels while the developments were underway. Further large-scale developments of offshore wind farms are likely in the future. The management of subsurface noise emitted from shipping is currently the subject of international debate within the International Maritime Organization and we expect further guidance on this issue in the future.

Meanwhile, this area requires considerably more research. Future studies should focus on mapping and modelling ambient noise, observational and experimental studies, and developing frameworks for assessing noise related risks. The UK Marine Monitoring and Assessment Strategy (UKMMAS) community will eventually need to develop a monitoring programme regarding underwater noise to meet the requirements of the EU Marine Strategy Framework Directive.

Offshore construction

Safe Seas

Microbiological contamination

Microbiological monitoring of the marine environment is currently focussed on identifying faecal pollution of bathing waters and shellfish harvesting areas. There are three national programmes covering bathing waters, shellfish waters and shellfish hygiene. Management regimes are in place to protect public health in relation to shellfish, ensuring that contaminated shellfish does not reach the market.

We have assessed microbiological data against standards set within the EU Bathing Waters Directive, the Shellfish Waters Directive and the Shellfish Hygiene Standards within the EU Food Hygiene Regulations. Current standards assess bacterial contamination as indicative of levels of faecal pollution. This serves as a proxy for other agents such as viruses. Limited ability to measure viral loads in the environment and a lack of understanding of the dose-response relationship in humans means that viral standards have yet to be established. Such issues continue to be investigated with a view to developing a viable approach to the management of viruses.

Bathing Waters: In 2007, 96% of bathing waters met at least the 'imperative' (compulsory) standard and 76% met the 'guideline' (desirable) standard under the EU Bathing Waters Directive. This is similar to the findings in *Charting Progress*. The 2003 assessment showed that 98% of designated bathing waters met the imperative standard and 74% met the guideline standard. See Figure 4.17 for a regional summary of compliance with the imperative bathing waters standard.

Bathers on a Cornish beach

Figure 4.17 Location of UK identified bathing waters in 2007 (●) and regional compliance with the imperative bathing waters standard in UK bathing waters, 1998–2007. Sampling areas include a small number of inland bathing waters.

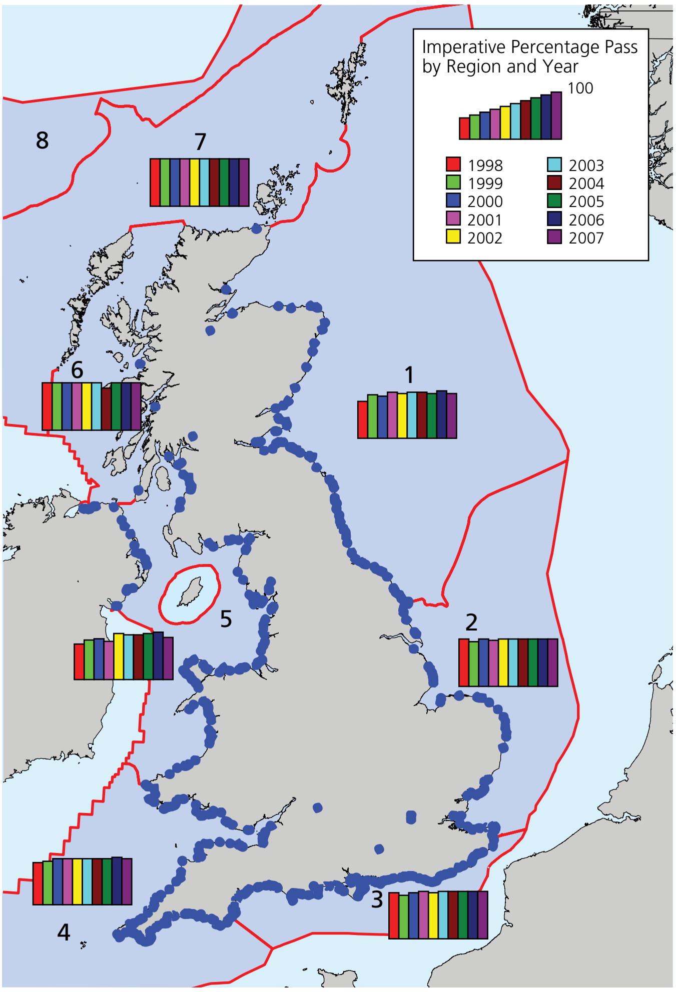
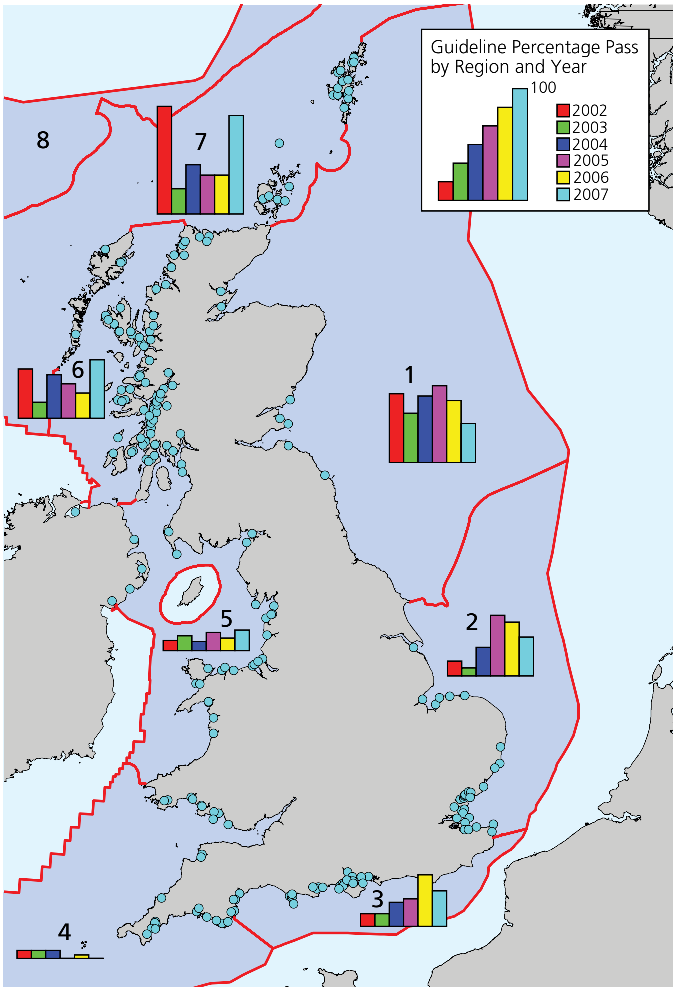


Figure 4.18 Location of UK designated shellfish waters in 2007 (⊙) and regional compliance with the guideline shellfish waters value, 2002–2007. There is year-to-year fluctuation; overall, the percentage compliance was greatest in Regions 6 and 7 and least in Region 4.



All bacteria concentrations per 100 ml of seawater; Bathing Waters Directive: Imperative standard 10 000 total coliforms, 2000 faecal coliforms in 95% of samples; guideline standard 500 total coliforms and 100 faecal coliforms, in 80% of the samples.

Shellfish Waters: In 2007, 40% of sampled shellfish waters met the guideline value under the EU Shellfish Waters Directive (see Figure 4.18 for locations and time series). This value is significantly more stringent than the guideline standard in the Bathing Waters Directive. (Shellfish taken from the more contaminated waters are cleansed prior to sale for human consumption, to reduce bacterial contamination to a safe level.) *Charting Progress* undertook only a limited assessment so we cannot determine whether any significant change has taken place since then.

Shellfish Hygiene: In 2007, shellfish from 21% of areas could be consumed without treatment, while 78% required some treatment. Less than 1% was prohibited from harvest on the grounds of microbiological contamination. Comparable figures in *Charting Progress* were 17%, 82% and 1%, respectively.

The levels of compliance reflect significant investment in sewage treatment and infrastructure driven by the Bathing Waters and Shellfish Waters Directives. Water companies plan to spend over £300 million on additional improvements under these Directives over the next five years. Further improvements in microbiological quality will also require measures to reduce the impact of land run-off. This includes reducing misconnections in piping, sustainable drainage systems, and in changes to land management, such as establishing buffer zones excluding grazing animals from the vicinity of water courses. Viruses are also of concern and further work is needed to measure them and establish suitable standards.

Algal toxins

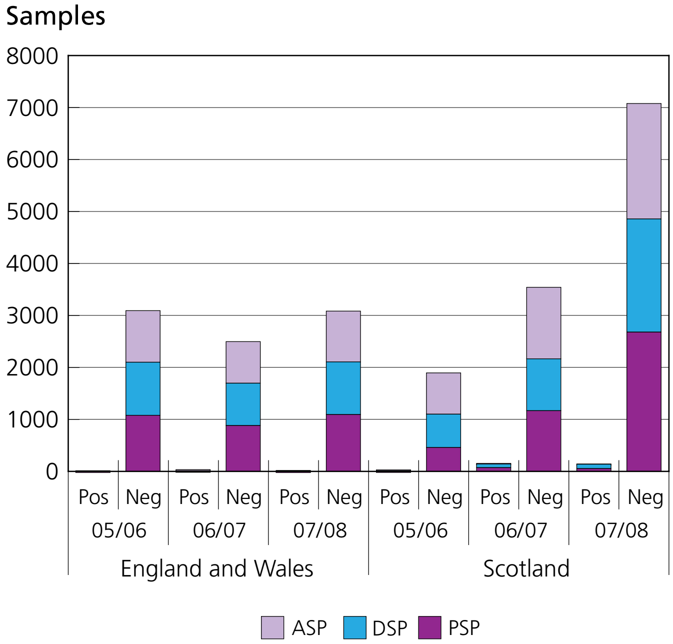
Algal toxins (also known as biotoxins) are natural compounds produced by certain species of marine algae. They are of concern because shellfish such as mussels, cockles and oysters can accumulate them when they feed, and this has the potential to affect human consumers. However, when toxins are detected in shellfish by the statutory monitoring programme (Figure 4.19), appropriate management measures are taken to protect shellfish consumers. Despite some concern that high levels of nutrients could increase the occurrence of harmful algal blooms in which the toxins are produced, a recent study concluded that the abundance of the harmful algal bloom species in UK and Irish coastal waters is not related to nutrient enrichment from human sources. Essentially, harmful algal blooms are a natural phenomenon beyond our control and, as such, will occur. However, we will need to continue with monitoring programmes to protect public health and shellfish production, particularly as climate change may alter the frequency of toxic blooms.

Figure 4.19 The occurrence of positive samples for diarrhetic shellfish poisoning (DSP) between April 2005 and March 2006. Exceedance of the limit value results in temporary closure of the fishery until levels fall.

For this assessment we used data from comprehensive biotoxin monitoring programmes covering the period 2005 to 2008. These include monitoring for relevant phytoplankton species in all regions of the UK to comply with EU legislation. (The testing methods employed by all official monitoring laboratories on behalf of the competent authority follow United Kingdom National Reference Laboratory [UKNRL] protocols [where these exist] and are accredited to ISO17025 standards where possible.) We did not include data from additional studies outside this three-season programme.

We did not include historical data in this assessment, so have not reported trends in toxicity observed in shellfish. We found that marine biotoxins and toxic algae were present in samples from all monitored areas in England and Wales, Northern Ireland and Scotland during the three years of study, but they did not increase either temporally or spatially. However, the number of samples in which toxins were detected was small, generally fewer than 5% and less than 1% in some years. There were no incidents of human toxicity and thus we conclude that the current monitoring regime within the UK (which monitors the three classes of shellfish toxins responsible for amnesic shellfish poisoning, ASP; diarrhetic shellfish poisoning, DSP; and paralytic shellfish poisoning, PSP – see Figure 4.20) provides sufficient protection for human consumers of shellfish in respect of ASP, DSP and PSP toxins. Other algae occur in UK waters which generate additional toxins; notably the azaspiracids and spirolides

Figure 4.20 Numbers of samples testing positive or negative for the presence of ASP, DSP and PSP toxins in samples from England, Wales and Scotland 2005-2008. Note low frequency of samples testing positive.



Farmed mussels

© Muckairn Mussels

and the toxins responsible for neurotoxic shellfish poisoning. Current monitoring arrangements do not include these, so we need further research to assess the risk they pose and whether they should be monitored in the future.

Future work

The information presented in this report and the more extensive descriptions detailed in the associated Feeder Report prepared by the Clean and Safe Seas Evidence Group, lead us to conclude that where regulation has been introduced it has generally had a beneficial impact. Reductions in emissions, losses and discharges of hazardous substances have resulted in some reductions in contaminant concentrations in sediment and biota. However, concentrations of some persistent chemicals resident in sediments are declining only very slowly. The timescale for observation of these trends is generally greater than that of the period between *Charting Progress* and the present assessment. The gathering of additional data, extending time series, is resulting in some downwards trends becoming significant.

There are problem areas in UK waters with respect to eutrophication, but these represent a very small total area.

In terms of safe seas, this report has focussed on microbiological contamination and algal toxins. Both issues are regulated and current programmes provide a significant degree of public protection. Thus, in the UK, we continue to move towards a vision of clean and safe seas.

Some of the 'new' issues, such as underwater noise and litter, are going to require greater scrutiny in the future given their incorporation as descriptors of Good Environmental Status under the Marine Strategy Framework Directive. Current monitoring will need to be extended in order to gather evidence in relation to their significance and impacts.

Assessment summary

The summary table presents our expert opinion on a single comparable assessment of status and trend across all components assessed for clean and safe seas. We have done this by assigning a single colour for status where: green indicates few or no problems, amber indicates some problems and red indicates many problems. Trend arrows are also provided based on the evidence available, showing whether the state or condition of the component is improving (⬆) or deteriorating (⬇), or where there is no overall trend discernable (⬌). The confidence rating of each assessment is also estimated in the associated Feeder Report, based on the criteria developed by the UK Marine Climate Change Impacts Partnership (MCCIP). Assessments which have been made with low confidence are indicated in the summary table.

A more detailed discussion of the rationale for this approach, 'traffic-light' status, and the confidence assessment is given in Chapter 1.

The 'traffic light' status assigned originates from the detailed assessments made for each component in the Feeder Report. Each component assessment section in the Feeder Report was accompanied by a table which summarised the findings if sufficient evidence was available.

The Feeder Report assessments provide valuable additional information that can be used to give context to the summary assessments in the summary table and provide a broader understanding of each component, its status and the pressures to which it is subject.

Clean and Safe Seas – Summary Table

Components currently assessed	***Region***							
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***
	Clean Seas							
Hazardous substances	↔	↔	↔	↔	↔	↔	↔	*
	Main sources are inputs from rivers, the atmosphere, various industries and agriculture. These sources are subject to controls. In some limited areas marine biota are at risk, particularly near to the main sources in industrialised estuaries. Reservoirs in sediments due to historical contamination will take many years to dissipate to background concentrations due to persistency of the substances.							
Radio-activity	↔	↔	↔	↑	↑	↔	↔	↔
	Main sources are discharges from the nuclear sector and hospitals and the offshore oil and gas industry which discharges naturally occurring radionuclides. Received doses of radioactivity to both humans and wildlife continue to be well within regulatory limits.							
Eutro-phication	↑	↔	↑	↑	↑	↑	↑	*
	Main sources are inputs of nitrogen (N) and phosphorus (P) from sewage works and agriculture. Ecosystems are at risk if eutrophication occurs. A few very small coastal harbours and embayments with limited water circulation experience eutrophication problems. Nitrogen and phosphorus inputs to these are controlled.							
Oil/ chemical spills								
	Main sources are accidental spills from ships and the offshore oil and gas industry. Ecosystems, habitats and species may be at risk if loads are significant. Where significant tonnages are spilt, regional monitoring programmes are implemented to assess risk. Assessment of cumulative impact is problematic.							
Beach litter	↔	↔	↑	↔	↔			
	Main sources are the general public, fishing, sewage discharges and shipping. Aesthetic, economic and environmental impacts may occur if levels are high. Only limited data available for Regions 6, 7 and 8.							
Offshore litter								
	Main sources are from fishing/shipping and plastics discarded on land and at sea. There is insufficient evidence or criteria to assess impacts and state on a regional basis, but several surveys indicate that marine litter accumulates in certain locations due to sea currents.							
Noise								
	Main anthropogenic sources are explosions used in construction and demolition, shipping, seismic surveys, offshore construction and industrial activities and sonar of various types. There is insufficient evidence or criteria to assess impacts and state on a regional basis, but research indicates that cetaceans and fish may be affected by specific noises.							

Components currently assessed	*Region*							
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Safe Seas								
Micro-biological quality of bathing waters	↔ (green)	↔ (green)	↔ (green)	↔ (green)	↔ (amber)	↔ (green)	↔ (green)	**NA**
	The main source is bacteria and viruses originating from sewage treatment works. In 2007 96% of bathing waters met the imperative standard of the EC Bathing Waters Directive, which indicates that water quality is acceptable, and should present a minimal risk to human health. However, the standards are being tightened under the new Bathing Waters Directive to give a higher level of protection.							
Micro-biological quality of shellfish growing waters	↔ (amber)	↔ (green)	↔ (amber)	↔ (amber)	↔ (amber)	↔ (green)	↔ (green)	**NA**
	The main source is bacteria and viruses from sewage treatment works. Concentrations of indicator bacteria in shellfish have not consistently met the most stringent standards. In such cases, the shellfish have to be removed for depuration before placing on the market in order to protect public health or in a small number of cases cannot be harvested.							
Algal toxins	* (green)	* (green)	* (green)	* (green)	* (green)	* (green)	* (green)	**NA**
	Algal toxins from phytoplankton can contaminate seafood. The phytoplankton which are the source of the toxins occur naturally in UK waters. Controls are in place, including occasional closures, to protect public health. No shellfish harvesting in Region 8. Algal toxins were not addressed in CP1.							

- (green) Few or no problems
- (amber) Some problems
- (red) Many problems
- (grey checked) Lack of evidence and/or robust assessment criteria
- **NA** No significant activity in the region
- ↔ No overall trend discernable
- ↑ State improving
- ↓ State deteriorating
- * No trend information available
- ☰ Low confidence in assessment

CHAPTER 5
PRODUCTIVE SEAS

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Introduction

This is the first time that a dedicated chapter on the productive use of UK seas has been compiled as part of the evidence base for *Charting Progress*. The evidence for this chapter has been prepared by the Productive Seas Evidence Group and is provided in a separate Feeder Report. For this assessment, we have defined 'Productive Seas' as consisting of socio-economic activities that use the marine environment's natural goods and services to produce outputs of other goods and services that are owned and can be exchanged for payment.

We have categorised activities in the marine environment into principal, secondary and ancillary activities. Principal activities use marine ecosystem goods and services directly to provide a marketable good or service, such as food, energy or transport. Ancillary activities are those that enable the primary activity to function, such as construction of wind farms or the manufacture of fishing nets, while secondary activities are those that arise as a result of the outputs from the primary activity, for example, fish processing, and manufacturing of petrochemicals from oil and gas.

Summary assessments

This chapter summarises the principal activities occurring in the marine environment (for more information refer to the full assessments in the Feeder Report prepared by the Productive Seas Evidence Group, see also the summary table at the end of this chapter). Each full assessment provides the following information:

- How the activity is defined
- How it is managed, by whom and under what legislation
- The economic 'value' of the principal activity and any secondary or ancillary activities
- How this activity (and value) is distributed around the UK and how it has changed over time
- Additional socio-economic pressures from the activity (e.g. employment, HM Treasury revenue through taxes, impacts on other activities)
- Environmental pressures, consequent impacts and management measures (with relevant links to other Feeder Reports)
- The relationship between the activity and climate change
- Industry stability and sustainability
- The future outlook (including key research issues).

Different data that can measure economic 'value' are available for the different sectors assessed in this report. Economic value is fully described as 'Total Economic Value' which has three main components: use values, option values and non-use values. This assessment is primarily concerned with use values, as reflected in market activity. Market prices are used to measure this activity, but this still gives rise to a number of different measures of economic activity. These have been used as follows:

- Turnover is the total market value of goods or services sold – it measures output.
- Investment is the spending on assets that will produce goods or services in the future (e.g. investment in research and development secures the benefits from such information in the future). It is a minimum measure of expected future benefits, because if this benefit was less than the investment, it would not be a rational choice.

- Expenditure is the total market value of goods and services purchased. It is a proxy for turnover, because if it was greater than turnover, an activity would not be economically viable.
- Gross value added (GVA) is the added value of outputs of goods and services from an activity compared to inputs. For example, the GVA of fish fingers is their sale value, minus the value of the raw fish, labour, and machinery etc needed as inputs to their manufacture – it therefore reflects the extra value created from the combination of these inputs into the final product. GVA data are available for some activities, or can be estimated as a proportion of Turnover based on sector-specific, or generic, ratios. Being net of the value of inputs means that GVA can be summed from different sectors without risk of double counting and is used to represent the contribution to Gross Domestic Product (GDP).

Aquaculture

Aquaculture is the farming or culturing of aquatic organisms (fish, molluscs, crustaceans, plants). More than 99% of economic aquaculture activity in the UK is related to fish and shellfish although there is increasing culture of seaweed and marine worms for bait.

The majority (99%) of existing marine-based fin-fish aquaculture activity is located in Scotland although it is increasing in areas of Wales and England. Shellfish production is more evenly spread throughout the UK (Table 5.1). In 2007, the turnover from aquaculture was £350 million providing a GVA of £193 million. In addition, processing of fish from aquaculture provided an estimated £105 million GVA in 2007. Aquaculture revenue within the UK increased by 132% between 2000 and 2006. Development of the industry is closely tied in with changes in wild fisheries, the availability of investment, site availability and environmental carrying capacity.

Table 5.1 Production and total value of cultured shellfish species in the UK in 2007.

Species	*Scotland*	*England*	*Wales*	*N Ireland*	*Total*
Pacific oyster	208	576	10.5	374	1169
Native oyster	22	55	0	0	77
Scallop	2	0	–	2	4
Queen scallop	15	–	–	–	15
Mussel	4806	3252	10 016	8039	26 113
Clams	–	12	–	10	22
Cockles	–	10	–	–	10
Total (tonnes)	**5053**	**3905**	**10 027**	**8425**	**27 410**
Total value (£million)	**5.1**	**4.5**	**7.5**	**5.8**	**22.9**
Percentage of the total	**22**	**20**	**33**	**25**	**100**

Fish farm

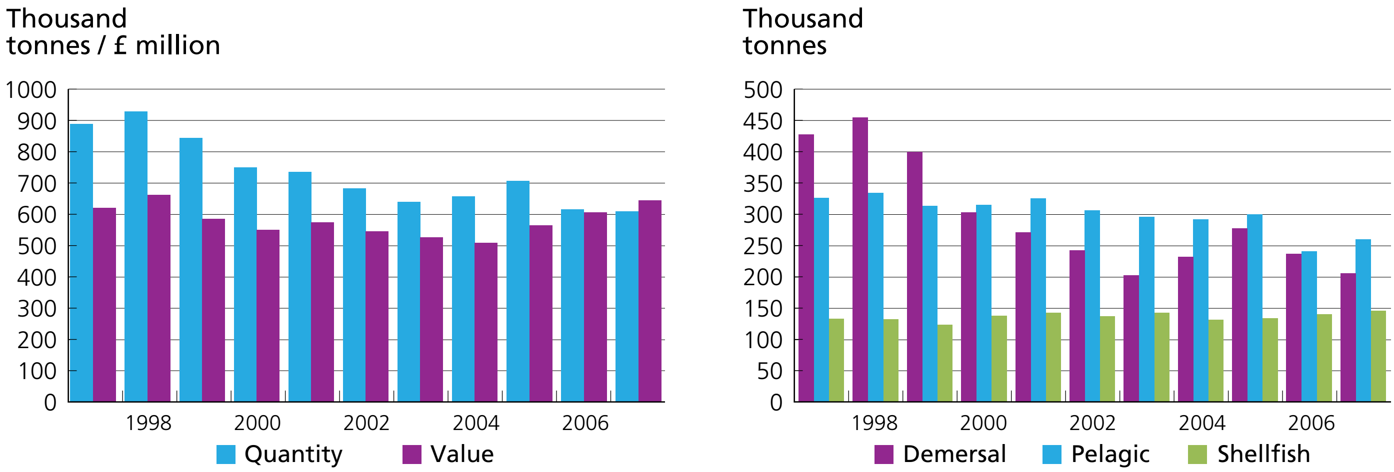
The main environmental issues relate to: the sustainability of fish feed; the presence of structures that affect habitats and hydrodynamics; operations that disturb the seabed such as harvesting; and outputs such as discharges, escapees from farms and diseases/ parasites. These issues are managed by the relevant regulatory bodies (including Devolved Administrations, environment agencies and local authorities) through the consenting system and are also dealt with through voluntary best practice undertaken within the industry. The licensing system is extremely complex although there are plans to streamline it through the Marine and Coastal Access Act 2009, the Marine (Scotland) Act 2010 and proposals for similar marine legislation in Northern Ireland. A number of new strategies support sustainable development by setting out goals for balancing economic growth with careful management of environmental impacts and support for social development. The overall aim of the 2009 EU Strategy for the Sustainable Growth of European Aquaculture is to encourage growth in the industry while building on the high environmental and quality standards that have been achieved so far.

While we have good information on the location of fish farms there are some uncertainties over the distribution of pressures associated with aquaculture activities, for example the dispersal of waste products and inputs of nitrogen and phosphorus. This is due to the way that information is collected: details are typically specific to individual sites and projects and are described in individual licence applications and are not centrally collated or freely and readily available. It is recommended that this information is collated centrally, for example by the UK Government and Devolved Administrations or their respective environment agencies.

Fisheries

The UK marine fisheries sector comprises all socio-economic activities related to the capture of wild marine fish and shellfish, and the subsequent handling and processing of catches. In 2007, the UK commercial marine fishery landed 611 thousand tonnes of fish and shellfish into the UK and abroad, worth almost £650 million at first sale (Figure 5.1). Of this, £510 million of catch was from the eight UK regions providing a GVA of £204 million. Shellfish and demersal fish species currently contribute around

Figure 5.1 Trends in landings and first-sale value of shellfish, pelagic and demersal species landed by UK vessels into the UK and abroad.



40% each to the total market value of the catch, with the remaining 20% comprising pelagic species such as mackerel and herring. Secondary activities can be equally important with fish processing from sea fisheries contributing £385 million GVA in 2007.

The North-East Atlantic mackerel stock currently supports the most valuable fin-fish fishery in UK waters, operating mainly from Scotland. In Northern Ireland, Wales and the Channel Islands, the most valuable fisheries are for shellfish, reflecting the relatively higher incidence of inshore fishing for crabs, lobsters and other shellfish such as cockles in these areas. The demersal fisheries in the North Sea, west of Scotland and in the Irish Sea have shifted away from offshore fishing for fin-fish species and towards inshore waters for the very valuable Norway lobster (*Nephrops norvegicus*) and other shellfish and mixed demersal species. This shift has resulted partly from long-term declines in many stocks and associated fishing restrictions, particularly those aimed at cod recovery, as well as the perceived economic opportunities in other fisheries. The composition of catch within each administrative area is summarised in Table 5.2.

Seven of the top ten most profitable fleet segments operate in the North Sea and off the west of Scotland. The total profit earned by the UK fleet was around £95 million in 2006 (before interest payments and depreciation). This represented a 24% decline from 2005 despite increased earnings, although 12 out of 27 fleet segments showed increasing profits over this period. Profitability has varied widely in the UK catching sector during the 2000s because of a reduction in catch per unit effort, escalating fuel prices, an increase in quota trading, and increases in first-sale prices following the introduction of Buyers and Sellers regulations in 2006.

Commercial fishing is a particularly important socio-economic activity in remote coastal regions in Scotland, and in coastal regions in Wales, Northern Ireland and the south-west, although it makes a relatively low contribution to overall GDP. It can provide the economic heart in such regions, where the inshore fishery is dominated by small boat activity. The UK catching sector employed almost 13 000 people in 2007, while the processing sector employed over 18 000 people in 2005 (although some of this processing employment is derived from

Table 5.2 Percentage composition of total value of catch taken by vessels registered in different parts of the UK in 2007.

	England	*Scotland*	*N Ireland*	*Wales*	*Total UK*
Demersal	45	35	11	21	37
Pelagic	16	23	23	2	20
Shellfish	39	42	66	77	43

Norway lobster

Plaice

aquaculture products). The dependency of jobs on fishing can be as high as 20% or more in some coastal communities.

Over the past eight years, total fishing effort in the international demersal fisheries has fallen by around 30% or more in the North Sea, west of Scotland and in the Irish Sea. During the same period, North Sea haddock and cod, and northern-shelf saithe have shown significant declines in fishing mortality (the term 'fishing mortality' defines the rate at which fish are removed from the stock by fishing). These trends are likely to be due to a combination of EU controls on total allowable catches (TACs) and effort, and the decommissioning of vessels in the UK and some other countries. The UK demersal trawl fleet was decommissioned by 15% between 1997 and 2007, with a particularly large impact on the Scottish fleet. Fleet capacity is currently (2007) estimated at 213 000 tonnes; 6763 commercial fishing vessels.

The main pressures of fishing on ecosystem services are on productivity and biodiversity. Although there is evidence in a range of ecosystems that fishing can cause a reduction in biodiversity, the evidence is less clearly established than for productivity of individual fish stocks. The direct impact of fishing gears on components of the wider marine ecosystem and habitats may ultimately also impact on the marine resources

available to the fishing sector. Generally, there is good information on the distribution and intensity of the use of different gear types.

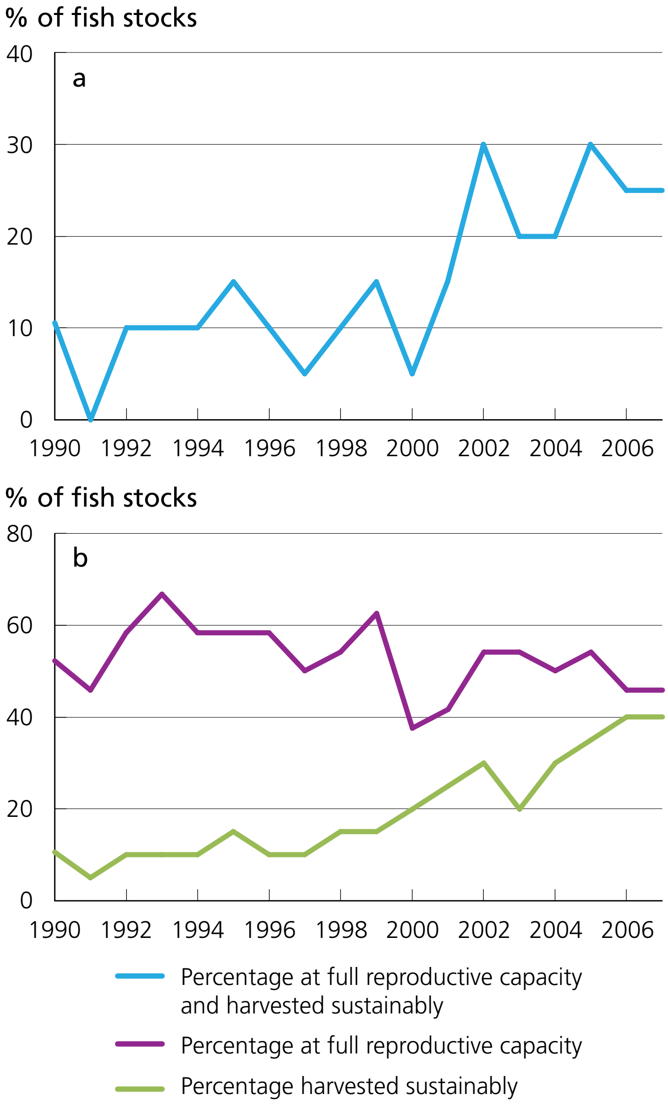
The International Council for the Exploration of the Sea (ICES) provides scientific assessments on the sustainability of European fish stocks. In addition, various government agencies throughout the UK publish annual statistics on the UK fishing and processing industry. Further data on fish stock abundance and distribution, and on aspects of fishing gear design, come from the Fisheries Science Partnership and the Scottish Industry/Science Partnership both of which have developed increasing time-series of data on fish stocks since *Charting Progress*.

Out of 20 indicator fin-fish stocks in UK waters, the proportion of stocks at full reproductive capacity and being harvested sustainably has risen from around 10% in the early 1990s to 25% in 2007 (Figure 5.2a), while the proportion of stocks with full reproductive capacity has changed little since 1990. The proportion of these 20 indicator fin-fish stocks being harvested sustainably has risen from 10% to around 40% over the same time period (Figure 5.2b). The lack of a concomitant increase in reproductive capacity following reductions in fishing mortality may be due to time lags in the recovery of stock biomass, or environmental factors affecting recruitment. Data for 2008 have become available since the Feeder Report was prepared by the Productive Seas Evidence Group and begin to show improvements in spawning stock biomass associated with the progressive reduction in fishing mortality (see data available[1]).

Overall, the large majority of scientifically assessed stocks continue to be fished at rates well above the levels expected to provide the highest

[1] http://www.cefas.co.uk/media/139292/website%20psa%20sustainability%20indicator%20v2.pdf

Figure 5.2 Change in exploitation status of 20 indicator fin-fish stocks around the UK. (a) Percentage of stocks at full reproductive capacity and being harvested sustainably; (b) percentage of stocks where one of the conditions holds each year.



long-term yield. The European Commission is developing multi-annual management plans to recover depleted stocks, and to manage stocks sustainably. They seek to restrict fishing mortality rates to the maximum sustainable yield (MSY) by 2015, as required by the World Summit on Sustainable Development in Johannesburg in 2002. Such management plans were initially focused on cod recovery, but have now been extended to a range of other species.

Fishmonger

Since *Charting Progress*, the UK Government and Devolved Administrations have made considerable progress in establishing long-term visions and strategies for sustainable development of the fishing industry and associated activities. This has included further strengthening of the role of the fishing industry in management decisions and collection of data, for example through consultation exercises and fishery science partnerships. The identification of target fishing mortality rates and indicators to monitor progress towards achieving MSY will continue development while revisions to the EU Common Fisheries Policy and implementation of the EU Marine Strategy Framework Directive will increase the focus on management of fisheries within a broader ecosystem framework.

Leisure and recreation

Many different leisure and recreation activities in the UK make use of the marine environment. It is difficult to capture the principal market value obtained from recreational and leisure activities because some activities, such as swimming, do not result in a marketable good or paid-for service. Although this sector is likely to have a high value of economic activity, uncovering the economic contribution is hampered by the number of activities, their wide distribution and the lack of centrally available statistics. Such issues also make it difficult to fully assess spatial pressures.

Some indications of the market value of ancillary activities include a turnover of £1.84 billion for the small commercial marine industry in 2006/07; surfing industry turnover of £200 million in 2001; and total expenditure from recreational fishing of £538 million for England and Wales in 2003 and £141 million for Scotland in 2008. These sources provide a total turnover of £2.74 billion and £1.29 billion GVA. Expenditure on secondary activities such as coastal tourism, accommodation and food can also be significant with an estimated market value for coastal towns of £4.8 billion in 2005 (GVA £2.26 billion). Other benefits that are potentially substantial include employment and cultural values. A good indication of social value can be provided by the levels of participation: in 2007, 5.4 million people participated in watersports and 0.8 million in sea angling.

Overall, the participation in most marine leisure and recreation activities has stayed relatively stable or increased in recent years. The growth and stability of the marine leisure and recreation market is heavily dependent on the general health of the UK economy, which determines whether people have time and money for leisure

Surfer

pursuits. In addition, trends in sea angling are particularly dependent on advances in fishing technology and catch rates of fish while many watersports are supported by improvements in exposure suits and wet suits.

Environmental pressures as a result of recreational use of the seas may include the removal of marine fauna and flora, physical or visual disturbance of wildlife, pollution from wastewater and litter and alteration of coastlines to facilitate access. They are generally managed through a number of local planning policies and best practice guidance published by organisations such as the Royal Yachting Association.

Mineral extraction

Dredging for marine aggregates is by far the largest activity within this sector, which also includes the extraction of salt.

Eleven companies are generally involved in the production of marine aggregates in the UK. In 2008, these companies landed 19.3 million tonnes of primary aggregate for construction in the UK and abroad representing an estimated landed value (turnover) (before processing and on land sorting) of £116 million and a GVA of £54 million. A further 2 million tonnes were extracted for beach replenishment. Those secondary market values for the marine aggregate dredging industry that could be identified included £80 million GVA from processing and £303 million GVA from sales of concrete products in 2005. Ancillary market values from exploration and transport were more difficult to define in total but indicators include a dredging fleet replacement value of £1 billion.

Marine aggregates mainly come from the eastern and southern coasts of England (Regions 2 and 3) with smaller amounts off Wales and north-west England (Regions 4 and 5). There is currently no dredging within Northern Ireland and Scottish waters due to an adequate land supply of aggregates and lack of suitable and easily accessible resources on the seabed. The maximum depth that dredgers can practically operate in is around 50 m and is limited by available technology and vessel size.

The marine aggregate dredging industry employs about 640 staff, 500 of which are ship crew and the rest provide shore support and administration. A further 600 staff are employed on the wharves that receive UK marine aggregates and about 500 related to the primary delivery of sand/gravel (i.e. from wharves to the point of initial use).

Aggregate dredging

Activity within the sector is driven by the demand for construction material and the availability of land-based aggregates in comparison with marine aggregates. In 2005, marine sand and gravel accounted for 19% of total sand and gravel sales in England and 46% in Wales. Estimates of proven reserves suggest that there is still a large amount of marine resource available, sufficient for at least 50 years production at current rates of extraction.

A well supported research fund (the Aggregate Levy Sustainability Fund), well developed onboard monitoring systems and regional environmental assessments, mean that there is good understanding of the environmental impacts from marine aggregate extraction and the characterisation of regional aggregate resources and palaeo-landscapes. Pressures from marine aggregate dredging include removal of sand and gravel, damage or disturbance of benthic habitats, and smothering from extraction operations and sorting of sediments. However, the proportion of seabed directly impacted by removal is just 0.007% of the UK continental shelf (UKCS) and impacts are managed through licence-specific environmental impact assessments.

In 2008, the sea salt extraction industry had a combined turnover of about £4 million from the three companies in operation in Cornwall, Anglesey and Essex. Extraction of sea salt is limited by the availability of high quality marine resources and is driven by markets at home and abroad.

Oil and gas

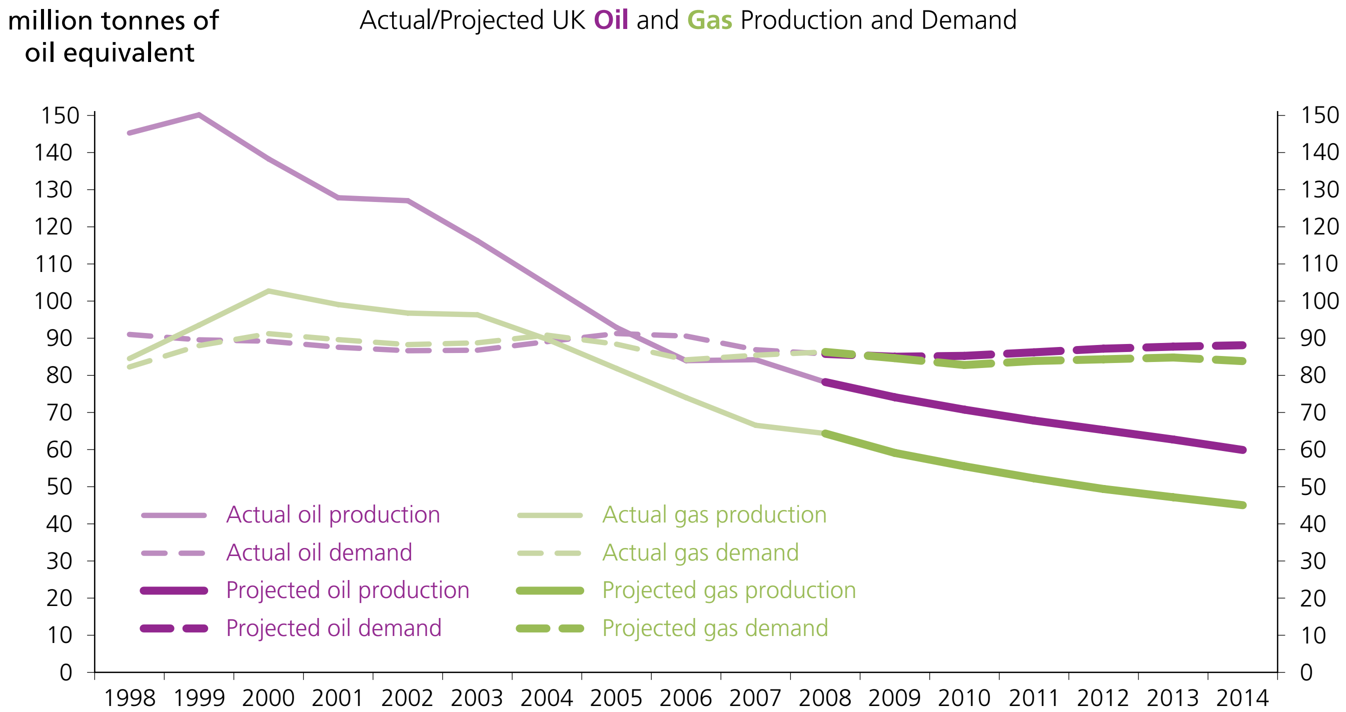
This section summarises all activities associated with oil and gas extraction, transport and storage in the seas around the UK, together with gas storage and storage of carbon dioxide (CO_2) captured from industrial activities.

Oil and gas remain the UK's principal sources of fuel and power, meeting more than 75% of demand in 2008. One billion barrels of oil equivalent were extracted from the UKCS in 2008, comprising: 72 million tonnes of oil and natural gas liquids and 68 billion cubic metres of gas. Total UK oil and gas production peaked in 1999 and has been declining since due to decreasing reserves (Figure 5.3). Domestic resources satisfied about two-thirds of UK primary energy demand in 2008 (94% of oil demand and 74% of gas demand) and are projected to satisfy about half of the UK's oil and gas demand in 2020.

The domestic oil and gas extraction industry accounted for £37 billion GVA in 2008 and is one of the largest contributors to GDP. The value of oil and gas is driven by the sale price of oil and gas and the level of production. For example, price per barrel of oil is strongly influenced by volatile energy markets owing to a complicated range of supply and demand factors.

Oil platform

Figure 5.3 Actual and projected UK oil and gas production and demand (as at February 2009).



The recovery of remaining oil and gas reserves will require additional investment, both in money and expertise. The distribution of resources is fairly well understood although exploration activities continue in all areas with suitable geology. Around 500 individual structures (including production platforms and tie backs) will be decommissioned over the next three decades.

In 2008, the upstream oil and gas industry invested £4.8 billion in developments, £1.4 billion in exploration and appraisal, and spent £6.8 billion on operations. The extraction of oil and gas is supported by highly specialised 'supply chain' activities and also supports a large downstream manufacturing sector (oil refining: net trade surplus £1 billion; petrochemicals: turnover £50 billion; trade surplus £5 billion), although these use a mix of UK and imported production. In 2008 there were 107 oil platforms, 181 gas platforms, 14 000 km of pipelines, plus 9 crude oil refineries and 3 specialist onshore refineries.

Additional socio-economic benefits from the oil and gas sector include employment, taxes paid to HM Treasury, export business and energy security. The majority of oil and gas fields on the UKCS are located in the North Sea (Regions 1 and 2) and as a consequence Scotland is the largest region of related employment in the UK. The extraction industry employs 34 000 people; 230 000 in supply chain companies and 214 000 in secondary petrochemical industries.

There are a number of environmental issues associated with oil and gas extraction, the most notable being the risk of oil spills, noise from exploration and production, historical oil-based cuttings piles, and inputs of production chemicals. Oil discharges in produced water have fallen and most oil spills are of less than 1 tonne. Impacts from pipeline installation on habitats are spatially minor with short-term noise and disturbance impacts. The extraction, processing and burning of oil and gas to provide energy is very energy intensive and produces high levels of associated CO_2 emissions causing concern over climate change (see Chapter 6).

As a result of increasing dependence on imported fuels the UK will have a growing need for gas storage. The use of geological structures in the sub-sea marine environment for the storage of gas is therefore receiving increasing focus. Structures can include depleted oil and gas fields or artificially created salt caverns and they have been used to store natural gas in Europe and the UK for over 30 years, although there is only one offshore gas storage facility currently in operation in the UK: the *Rough 47/8 Alpha* facility.

As an indicator of economic potential, the Department for Trade and Industry – now the Department of Energy and Climate Change – estimated in 2007 that £10 billion of investment in new gas storage and import facilities was in place or planned over the next few years. Use of existing storage features and infrastructure is likely to have negligible environmental impacts although the release of hypersaline water in the production of salt caverns may have some localised effects.

There have also been proposals to store CO_2 released from power generation and industrial processes, a process known as Carbon Capture and Storage (CCS). CO_2 can be stored in depleted hydrocarbon fields or aquifers. Given that CCS is a fledgling industry, there is considerable uncertainty surrounding future rates of development, specific location of developments, investment, cost-efficiency of construction, financial incentives and total economic contribution of the industry.

Wind farm maintenance

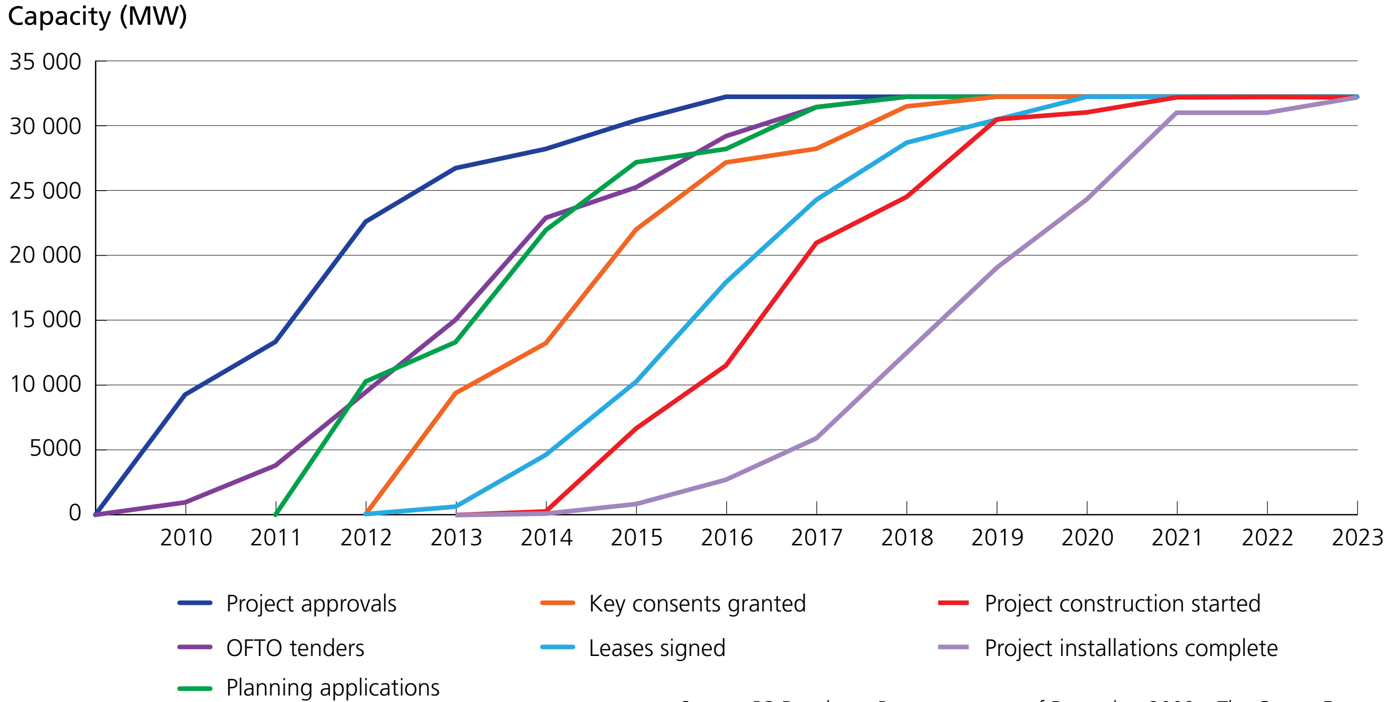
Renewable energy

The UK has among the highest density of exploitable renewable energy resources in the world, and has the potential to become a global leader in both engineering development and energy production. The resources include wind (on both coasts); wave (mostly on the west coast); tidal stream (focussed inshore around headlands and in sounds such as Pentland Firth) and tidal range (particularly in the Severn and Mersey estuaries).

The estimated direct turnover for the industry from current generating capacity is £165 million and GVA is £50 million with additional indirect turnover from manufacturing and installation. Although the location of wind, wave and tidal resources is well understood, the location of economically viable renewable energy projects is constrained by a number of other technical factors, such as the capacity of national grid networks, sea conditions and other existing sea users like fisheries and shipping.

Wave and tidal power in particular are fledgling industries with enormous potential and strong government support, aimed at helping prove these technologies and overcoming uncertainty around limited long-term investments in the current economic climate. They are being supported by test facilities such as the European Marine Energy Centre in Orkney and the New and Renewable Energy Centre in north-eastern England. There is also some uncertainty around environmental pressures such as hydrodynamic changes, construction noise, and collisions by birds or marine mammals with devices that tend to be device and site-specific. However, these are being addressed by detailed monitoring programmes and coordinated research initiatives.

Figure 5.4 Projected delivery dates and capacity from Round 3 wind farm projects.



Source: R3 Developer Programmes, as of December 2009 – The Crown Estate.

The rapid growth of this sector has been aided by governmental support for energy generation from renewables, involving financial investment and planning and policy initiatives that help to encourage much-needed private investment. The main driver is the EU 2008 integrated energy and climate change policy, according to which the UK must obtain at least 15% of its total energy needs from renewable energy sources by 2020. Targets are much higher than this in some parts of the UK, with Scotland aiming for 20% by 2020 and Northern Ireland 40% by 2025. The Welsh Assembly Government's energy policy statement details the potential to produce more than twice as much renewable electricity as Wales consumes as a nation today by 2025. The extraction of energy from renewable sources lessens UK dependence on fossil fuel energy, which has much higher associated CO_2 emissions, and improves energy security by increasing the diversity of electricity supply.

By December 2009, there were ten offshore wind farms operating 228 turbines with a total installed capacity of 0.7 GW of electricity (two are small demonstrator projects). A further 1.7 GW of capacity was under construction; 4.9 GW had been consented, and about 9.9 GW was in planning and pre-planning processes across the UK. The total installed capacity from all these wind farms will be over 14 GW. This does not include Round 3 wind farms which may add more than 30 GW additional generating capacity (see Figure 5.4). There are strong targets to increase total capacity to 33 GW by 2020. Financial incentives such as the Renewables Obligation Certificates, the Scottish Government's Saltire Prize and the Marine Renewables Deployment and Proving Funds will continue to provide support for the industry over this period.

Telecom and power cables

This sector involves the transfer of telecommunications (telecom) and power between the UK and other countries and among the islands of the UK through subsea cables.

There are some 18 000 km of telecommunication cable and 2368 km of power cable on the UKCS. The overwhelming majority of international communication transmissions are through fibre optic submarine cables with the highest proportion (43%) passing through Region 4 (Western Channel and Celtic Sea). The only international power cable link is currently with France. Remaining cables provide links among the islands of the UK, for example, mainland UK with the Isle of Man and the Scottish Isles.

An indicative GVA of £2.7 billion was estimated for telecom cables based on the number of international phone calls. However, this figure does not include the value of internet and data capacity which are now the primary commodity and which are increasing. The true value of telecommunication cables should incorporate both the value of the traffic which is carried and the significance held by the UK as a key strategic location for international systems looking to reach markets in America, Europe, Africa and Asia. These are difficult to capture in market value terms but are significant. The capacity from the main interconnecting power cables, which is currently 2540 MW from 212 km of cable, may be used as an indicator of the scale of the activity.

Impacts from cable installation on the seabed are short term and spatially minor. Although there is potential for the electromagnetic fields associated with high voltage power cables to impact on animals that are sensitive to such fields, considerable research suggests that the spatial extent is small and, if the cables are buried to more than 1 m, the impact will not be significant.

The deployment of power cables has been steadily increasing due to increasing demand within the UK and demand for improved security and stability in electricity supply. Deployment of power cables is likely to increase as we develop more offshore renewable energy installations.

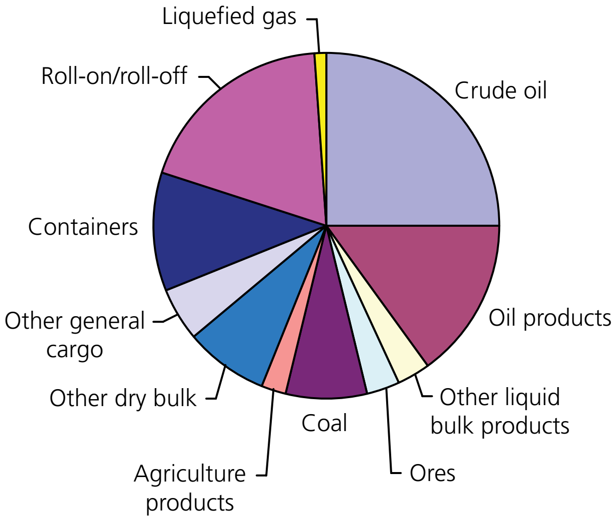
The UK telecommunications sector went through a period of correction from 2002 to 2006 following the growth and downturn associated with the Dotcom bubble, but major domestic and international systems are now being installed. Future developments in this sector are focused on extending the global reach of the sub-marine networks, investing in higher capacity circuits and increasing resilience by operating networks over a number of different cables.

Maritime transport

This section encompasses the transport of both freight and passengers by sea. Maritime transport is supported by a diverse range of ancillary activities including shipbuilding, the construction of ports and marinas and activities associated with navigation including dredging and the production of charts.

In 2007, the turnover of UK shipping (freight, passenger and charter services) was £9.5 billion with a direct contribution to GDP of £4.7 billion GVA. In 2007, there were 24.8 million passengers making international sea journeys and 424.42 million domestic sea passengers. UK ports handled 582 million tonnes of freight traffic, although the number of freight passages is unknown due to the commercial sensitivity of shipping data. The type of freight transported is shown in Figure 5.5.

Figure 5.5 UK major port traffic by cargo type in 2007.



A total GVA of £7.8 billion was calculated for those ancillary activities for which such information was available (e.g. port activities, shipbuilding and navigation activities). However, the value to the economy from other service activities such as construction of ports is less certain, so this is likely to be an underestimate.

In total there are more than 650 ports in the UK for which statutory harbour authorities have been established; of these 120 are commercially active. Values to the economy were assigned to reporting regions based on the proportion of freight tonnage handled by major coastal ports in each region. The majority of value to the economy (> £1 billion each) is located in Region 2 (Southern North Sea; which includes major ports in the Thames connecting with London), Region 1 (Northern North Sea; linking with the northern European mainland), Region 5 (Irish Sea; linking Scotland, the Republic of Ireland, Northern Ireland, England and Wales), and Region 3 (Eastern Channel; with key routes to Europe and North Africa). This pattern is also likely to be a fair reflection on the distribution of pressures from shipping among the regions.

Key pressures relate to pollution (from oil spills, loss of cargo and leaching of antifoulants), introduction and spread of non-native species (through ships' hulls and ballast water), noise impacts from ship movement and habitat damage (for example from port development, maintenance dredging and disposal of dredge material). While shipping is generally a very carbon efficient form of transport, continued growth in the sector will increase global emissions which currently account for around 3.3% of global CO_2 emissions. Most of the shipping impacts are managed through the International Maritime Organization. Impacts from local development are managed through local planning policies and conservation objectives where they apply. While records are kept of vessel movements and shipping densities, this information is currently not easily and freely accessible, hampering an assessment of pressures. To be useful for assessments, collated information should include the size of ships and temporal data such as when and how often they sail.

The long-term trend is for sustained growth of 3% to 4% on average per year in the container and roll-on/roll-off sectors. The Ports Policy review in 2007 proposed no substantive change to the regulatory framework although the recommendation for Master Plans by major ports may help to refine the operating framework for ports.

Defence – military

UK military defence spending is the third largest area of public government expenditure. For 2007/08 the total expenditure was £1.8 billion for the principal activity with a GVA of £468 million, and £1 billion for ancillary activities. A large amount of public expenditure has recently

been directed towards building of new warships with £1150 million spent on shipbuilding and repair in 2006/07. Activities and hence the location of the value to the economy are mainly related to the location of the naval bases and exercise areas. The Navy employs 38 600 people and 5200 civilians and local economies also benefit from activities associated with the naval bases.

Military defence activities in the marine environment largely involve training, surveillance and monitoring, and transport. Designated exercise areas can be very large, and given the need for a certain amount of security there are uncertainties on the exact location and frequency of training activities within these areas. This hampers a spatial and temporal assessment of environmental pressures within the sector. Key pressures are likely to include noise from sonar and underwater explosions, habitat damage and introduction of marine litter and contaminants.

A sustainable development strategy was published by the Ministry of Defence in 2008 and provides a number of objectives, measures and targets for changing the way that activities are carried out in order to reduce pressure on the marine environment, climate and communities.

Waste disposal

Disposal of waste material into the marine environment includes the regulated discharge of wastewater and the disposal of hazardous and non-hazardous waste. Solid wastes include disposal of dredged material from capital and maintenance dredging.

The environment agencies throughout the UK impose strict regulations and controls on discharges to the sea. Although there are around 215 marine disposal sites for dredged material in the UK, only about 100 are in use at any one time. The amount of material disposed of (as wet weight tonnages) has remained relatively constant in England, Scotland, Wales and Northern Ireland over time. Environmental pressures are well documented and monitored by the relevant agencies and can include organic enrichment and the introduction of contaminants and smothering from waste disposal.

Waste disposal is dependent on the sea's ability to assimilate wastes. We used the income generated through licensing of discharges and disposal as an indicator of investment and therefore economic value: income from licensing includes about £0.3 million for waste disposal (2007 data) and £9.1 million for water discharges (2007/08 data).

The disposal of waste also has a positive economic benefit to communities where it allows industries to function. The maritime transport sector, for example, is reliant on shipping access to the coastline and without dredging of navigational channels (supported by disposal) this sector would either be limited or face costly alternative means of disposal. In 2007/08, employment in the licensing of water discharges provided an estimated £6.0 million GVA in the UK, reflecting additional social benefits from the activity.

It is unlikely that demand for disposal will decrease. However, there is increasing pressure from the various environment agencies to minimise disposal into the marine environment. An Environment Agency Technical Advisory Group is attempting to produce a protocol to

Power stations abstract water for cooling

allow beneficial uses of dredged material, such as use in contract fill and for constructing soft and hard flood defences, rather than classifying all material as waste.

Water abstraction

The majority of water abstractions in the UK are from surface freshwaters and groundwater for use in public water supply, with relatively few from estuarine and coastal waters.

The major saline abstractions provide cooling water for power stations. A large power station may abstract up to 40 cubic metres per second or more during peak load. Other types of saline abstraction include fish farms and fish processing factories, passive and pumped navigation abstractions (to maintain water levels in impounded docks), ballast water abstractions and abstractions associated with certain dredging activities, such as hydraulic dredging.

The various environment agencies throughout the UK license abstractions from inland waters and groundwater. This includes some saline abstractions as inland waters include estuaries, embayments and arms of the sea. Historically, navigation abstractions and abstractions associated with dredging activities in saline waters have been exempt from licensing. Some modifications to these exemptions are being proposed as part of the implementation of the abstraction provisions of the Water Act 2003 but such activities will remain largely exempt.

Environmental concerns relate to the impingement of fish, invertebrates and algae. Risk assessments made under the EU Water Framework Directive indicate that no water bodies are considered to be 'at risk' of failing the Directive in this respect, although nine sites are 'probably at risk'.

Managed realignment of the coastline at Chowder Ness

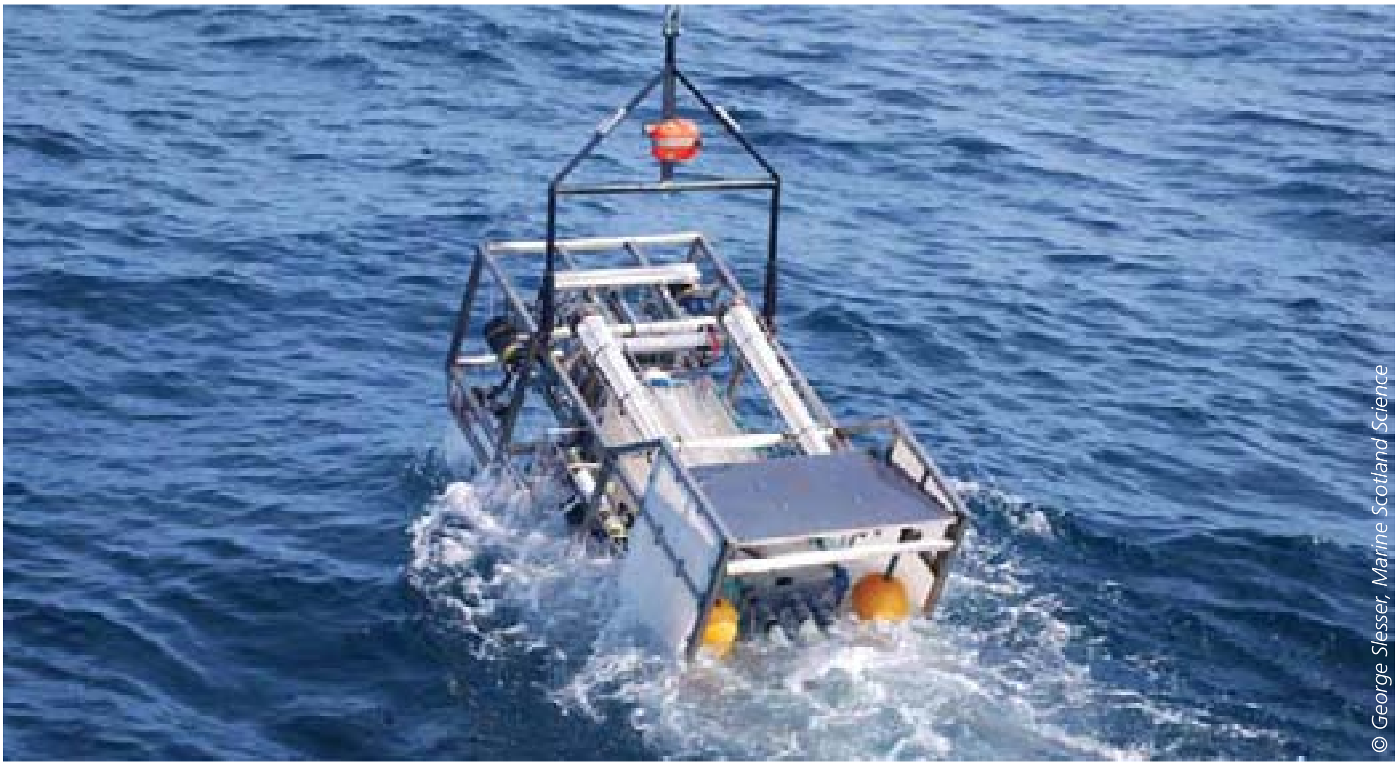
It is difficult to calculate the contribution to the economy associated with saline abstractions, although it is clear that they are fundamental to sustaining several major economic activities. The annual market value of electricity sales from coastal power stations is in the region of £5 billion to £10 billion. Coastal power stations with 'once through' cooling water systems have an energy efficiency advantage over air-cooled power stations, of the order of 2%. On this basis it could be argued that the specific value to the economy of coastal power generation was of the order of £100 million to £200 million per annum. No indicative values were identified for ancillary or secondary activities.

The amount of water abstracted for industrial purposes has remained relatively constant over time and it is likely that the requirement for coastal water abstraction will continue at the same levels. While many coastal power stations are due to be decommissioned over the next two decades, a series of new coastal nuclear power stations may be developed.

Coastal defence

This sector includes coastal defence measures used to prevent or reduce flood risk and coastal erosion. Defences may involve hard structures such as concrete seawalls, and soft engineering such as beach replenishment and managed realignment. Around 44% of the England and Wales coastline is defended and 6% of Scotland's coastline. The investment in coastal defence and flood protection in 2007 was £358 million. The investment in beach replenishment in England and Wales in 2007/08 was £11 million. Ancillary market values include £60 million (2007/08) for construction of defences in England and Wales. Data for

The OCEAN Sampler collects plankton samples



Scotland and Northern Ireland are difficult to source as responsibility lies with several different departments and agencies.

The investment and hence activity within this sector in England and Wales has doubled over the past ten years due to the vulnerability of the coast to potential flooding and coastal erosion associated with climate change. However, investment and employment figures alone do not capture the entire value to the economy of coastal defences, as there are significant indirect social and economic benefits that are difficult to quantify.

Flood and coastal erosion risk management projects often have substantial impacts on the coastal environment, for example from construction, physical footprint, changes in geomorphology and coastal squeeze, as well as other forms of habitat degradation and loss. All schemes are therefore subject to appraisal by the relevant regulatory authorities and agencies which take account of the social, economic and environmental impacts as part of the consenting and funding processes.

Projections are that current spending on coastal defences will need to double by 2080. The use of managed realignment (a measure often undertaken as a compensatory measure for coastal works, that may provide additional 'soft' flood and coastal defence benefits) and other forms of soft coastal defence measures are likely to increase.

Other activities

Other activities occurring on the UKCS that may contribute economic productivity and/or support existing activities include research and development (R&D), education and general management and regulation.

Fisheries Research Vessel: Alba na Mara

Internationally, the UK is a leading provider for marine tertiary education, which directly contributes to productivity through the use of the marine environment for field studies. Education in turn underpins a number of other principal activities, such as providing support for leisure, maritime transport, and R&D activities. Likewise, R&D activities may provide support for other marine industries. General management and regulation, rather than producing a marketable product, is an ancillary activity that provides support for all activities occurring on the UKCS.

The values of these three sectors are difficult to identify due to the range of institutions involved, the wide distribution of activities and the lack of centrally available statistics that are specifically marine in focus. Funding levels may provide an indicator of the ancillary value of R&D and associated knowledge. The Research Council's spending on marine science in 2006/07 was £67 million. All of the research institutes combined had an average annual income of £76 million (GVA) from 2006 to 2008. The turnover related to education is estimated to be £132 million with a GVA of £95 million. The downstream value to be gained from R&D and education is likely to be significant. The turnover of general management and regulation activities includes income of £109.39 million from public administration, £3.06 billion from business services and £102 million from licence and rental (£42 million from the Crown Estate and £60 million from oil and gas licensing).

Environmental impacts from education and R&D are likely to be minimal due to the benign nature of most activities, however key pressures may include wildlife disturbance, physical disturbance and removal, noise and loss of habitat from construction of coastal facilities.

Students taking part in Discover Oceanography onboard the University of Southampton RV Callista

Trends in this group of activities are driven by high level policy developments and changes in economic activities related to a number of factors including market demand, investment, and technological progress. These in turn indirectly drive cognitive development in the marine environment, funding for R&D and education and the need for regulation and management of activities in the marine environment.

Industry investment in R&D may decrease in the short term due to the current economic situation. The Marine Science Strategy will help us to identify priority areas for future research. Due to an increased focus on the marine environment (within various new marine policies and marine planning initiatives) demand for related marine education programmes and the need for general management and regulation activities is likely to increase.

Forward look

There are a number of developing policies (international and national) aimed at both marine economic activity and the management of the impacts of those activities that will help to shape the future of economic activity and monitoring on the UKCS. These include Sustainable Development policies; the Marine and Coastal Access Act 2009, the Marine (Scotland) Act 2010 and similar marine legislation in Northern Ireland; sectoral policies such as the EU Common Fisheries Policy and various EU Directives (such as the Marine Strategy Framework Directive, the Water Framework Directive and the Habitats and Birds Directive).

The increasing use of impact assessment as part of policy development across Government is improving the information base on the economic and social values generated by human activity as

well as their environmental costs and benefits. The adoption of an ecosystem goods and services approach to valuation is developing through initiatives such as the National Ecosystem Assessment. Such information is likely to be increasingly influential in informing policy choices and can make a substantial contribution to sustainable development.

Finally, the new Marine Management Organisation (under the Marine and Coastal Access Act), Marine Scotland and marine planning throughout the UK will be important vehicles for coordinating research and collating information to enable a better understanding of the extent of pressures. For example, studies are currently being conducted on the distribution of current and potential economic value in relation to aquaculture, renewable energy and inshore fisheries to help inform planning for the development of Marine Protected Areas.

These policy developments will require a better understanding of market value and the direct causal relationship between impacts, pressures and the environment along with better access to such information. Key future research areas are as follows.

- Greater understanding is required in some areas to support the assessment of Good Environmental Status for the EU Marine Strategy Framework Directive. For example, knowledge of the distribution and status of seabed features and the spatial and temporal distribution of noise sources, litter and invasive species in the marine environment and their significance to marine ecosystem functioning.
- Summary assessments of pressures related to each activity are based on expert judgement and a range of pressure indicators. In order to improve these assessments we need to better understand cumulative pressures.
- We need better centralised collation of data on the distribution of pressures associated with activities such as aquaculture, leisure and recreation, and shipping.
- We need to agree a methodology on how to spatially allocate socio-economic data to support regional analyses although the assumptions made here have been broadly agreed by industry in reviewing this report.
- Primary research on the economic value of some ecosystem goods and services and on understanding the non-use and option values of the marine environment would also be valuable.
- Greater discussion is needed regarding the market value of some activities that to date are poorly quantified, for example, leisure and recreation, waste disposal, telecommunications and power transmission.
- Certain activities and uses of the marine environment have benefits that are hard to quantify. For example, we need a better understanding of the contribution that marine activities make to social values, such as upholding cultural traditions in local fishing communities. Evidence on the cultural and historic values of the marine environment is patchy and to some extent dependent on information from extractive industries.

Assessment summary

The summary table provides a summary of the state (economic productivity) and pressures for UK seas focussing on the main economic activities where monetary values were possible to determine. Pressures for each activity have been assessed based on an expert judgement of their spatial and temporal aspects ensuring that we captured issues such as intensity, size of footprint and distribution.

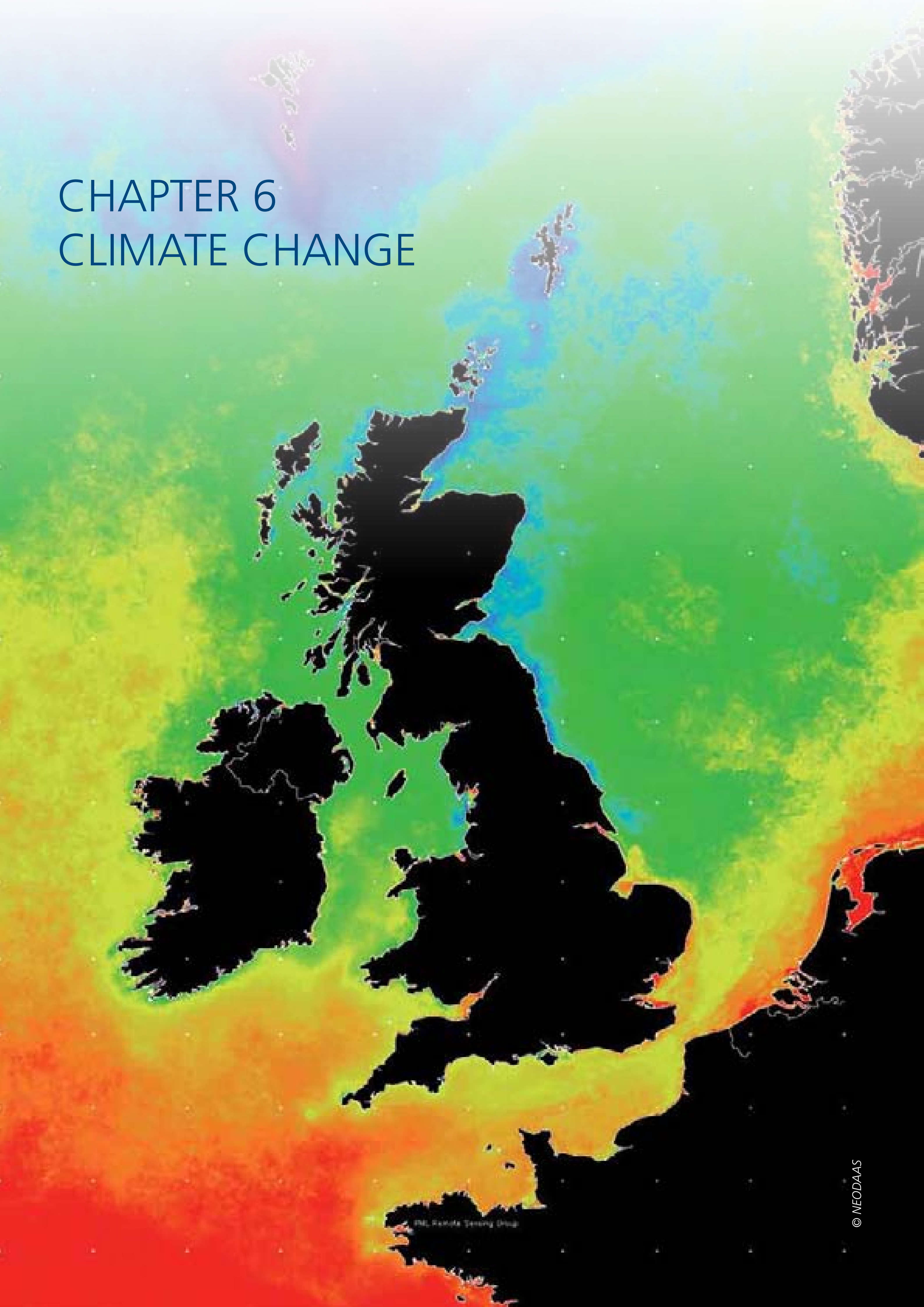
Summary of state (economic productivity) and pressures for UK seas

Activity	*Productivity*			*Pressures*[1]
	£ million[2]	*Trend*[3]	*Output*	*Trend*[3]
Oil and Gas	37 000	↑	↓	↔
	Value increased despite decline in production. No change in most activities, recent increase in appraisal drilling. Small localised footprint from structures. Operational long term and year round			
Maritime Transport	4700	↔	↔	↔
	Overall little change in imports and exports. Widespread pressure footprint. Occurs long term and year round			
Telecom Cables	2700	↑	↑	↑
	Capacity has increased, several international projects. Small localised footprint from cables that are present long term and operational year round			
Leisure and Recreation	1289	↑	↑	↑
	Increased participation rates likely in some activities. Widespread pressure footprint. Pressures are seasonal but present long term			
Defence – Military	468	↔	?	↔
	Large zone of potential activity that is likely to be localised. Unknown temporal nature. Expenditure is stable so assume that extent of activity is as well			
Fisheries	204	↔	↔	→
	Large and widespread extent of disturbance. Long term pressures mostly occurring year round			
Aquaculture	193	↑	↔	↑
	Increases in some stocks since 2003. Localised spatial pressures, farms present long-term but seasonal in operation. Few data on spatial extent of pressures			
Water Abstraction	150	↔	↔	↔
	Little change in the amount abstracted. Small localised footprint of disturbance. Operational long term and year round			
Mineral Extraction	54	↔	↔	↔
	No change in production overall although tonnage has fluctuated. Small localised footprint of disturbance. Seasonal and medium term in time			

Activity	*Productivity*			*Pressures*[1]
	£ million[2]	*Trend*[3]	*Output*	*Trend*[3]
Renewable Energy	50	⬆	⬆	⬆
	Large increases in investment and consequent production of energy. Small localised footprint from structures. Operational long term and year round			
Coastal Defence	358[Inv]	⬆	⬆	⬆
	Investment has doubled over the past 10 years in east of England. Large and widespread extent of disturbance. Structures are more or less permanent			
Waste Disposal	9.3[Inv]	⬌	⬌	⬌
	The amount of material disposed of relatively constant. Small localised footprint of disturbance. Wastewater disposal is operational long term and year round			
Education	95	⬌	⬌	⬌
	Value calculated from a range of years therefore low confidence in estimate. Participation varies among subject areas but likely to be no overall change			
R & D	3624[Inv]	⬌	⬌	⬌
	Centralised investment. R&D likely to have increased in the offshore region			
Power Transmission	?	⬌	⬌	⬌
	Not possible to establish monetary value. No temporal data, deployment rates likely to have been stable			
Storage of Gases	?	⬌	⬌	⬌
	Not possible to establish current monetary value. Significant increase in investments. No new development since 2003 but surveys (e.g. seismic) likely to have increased			

Notes:
1: Measures of pressure reflect both spatial and temporal extent and intensity at the level of the entire UK seas
2: GVA where possible unless otherwise stated as 'Inv' (investment)
3: Trends are since Charting Progress (from 2003 to 2008/9) as follows: ↑ increase, ⬆ large increase, ↓ decrease, ⬌ no change at all, ➡ change in type of activity in some areas but no overall difference.

CHAPTER 6
CLIMATE CHANGE



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Introduction

The world is getting warmer. Global average temperatures have risen markedly since the mid-20th century and human activities are very probably responsible for much of this increase. Over the past 50 years, the warming of the oceans accounts for more than 80% of the change in the energy content of the Earth's climate system. In this chapter we look at the implications of this climate change for the marine environment (see Figures 6.1 and 6.2). Although its effects can often be masked by natural changes, we can nonetheless link a wide range of observed changes in the marine environment to the changing climate, either directly through the effects of physical and chemical parameters such as temperature and acidity, or indirectly through impacts on the timing, distribution and abundance of marine species.

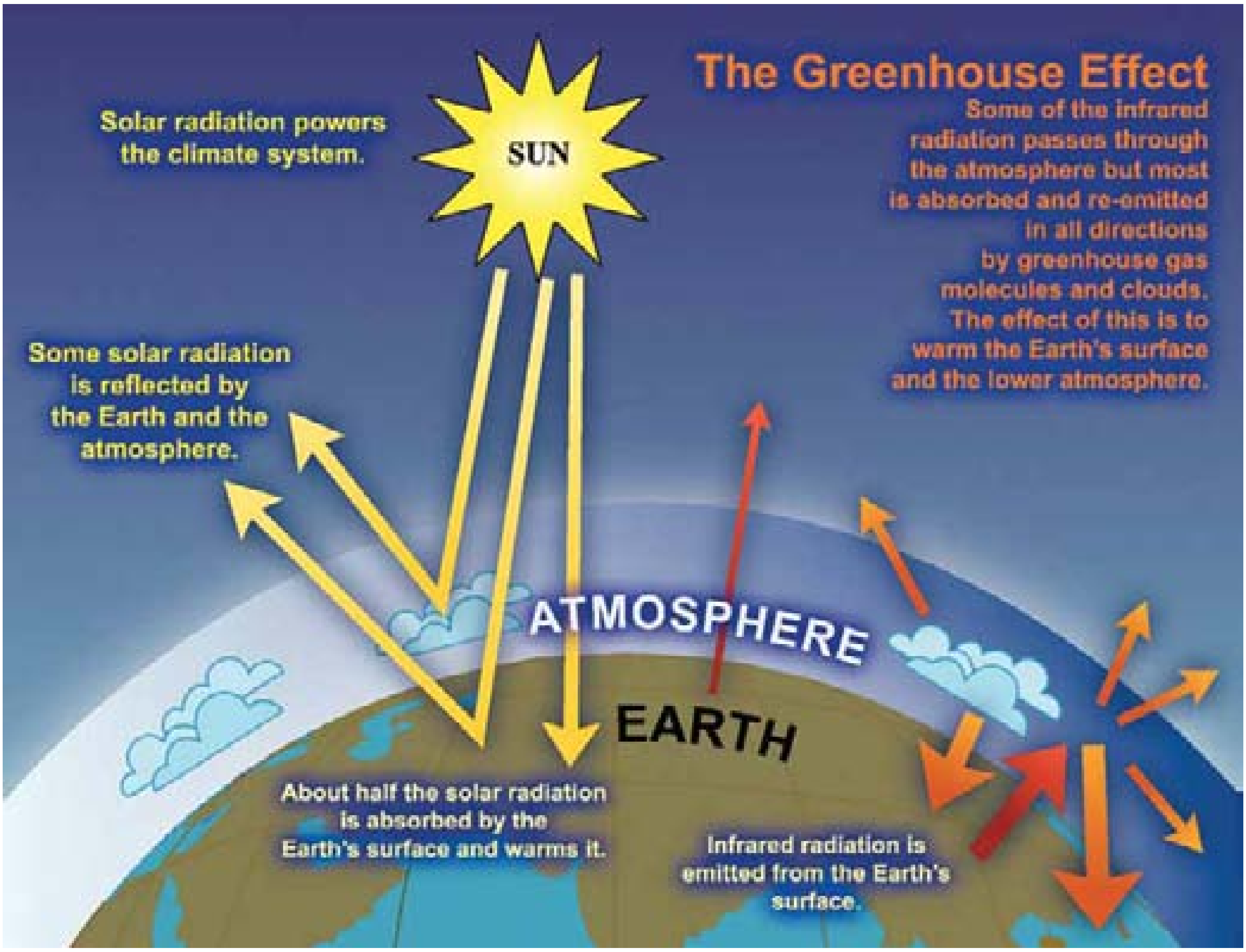
Charting Progress did not explicitly evaluate climate change but it did recommend the creation of a Marine Climate Change Impacts Partnership (MCCIP) to act as a mechanism for collating and communicating evidence. For this chapter we have combined material provided by the MCCIP with summaries of the climate-related assessments of the Feeder Reports prepared by the Ocean Processes Evidence Group, the Healthy and Biologically Diverse Seas Evidence Group, the Clean and Safe Seas Evidence Group and the Productive Seas Evidence Group, examining the evidence available for the effects of climate change on the marine environment, ecosystem and activities that rely on the sea.

We have based our assessments of what could happen in the future on both the latest report from the Intergovernmental Panel on Climate Change (IPCC) and on the latest set of climate information, the UK Climate Projections 2009, which were commissioned by the UK Government and published in June 2009. UKCP09 represents a significant advance from its predecessor, UKCIP02. As well as providing atmospheric variables such as mean air temperature, sea level pressure, total cloud and precipitation rate, it also gives extensive information about the ocean surface and sub-surface including projections of sea-level rise, storm surges, multi-level data on water temperatures, salinity and the stability of the water column around the UK, as well as changes in wave height.

While many of the changes we observe are consistent with increasing levels of atmospheric carbon dioxide (CO_2) and a warming climate, for example rising sea temperature and increasing acidification, we still do not understand many of the causative links to climate change. In particular we struggle with the rate and magnitude of future change for factors such as sea-level rise, Atlantic circulation, sea-ice extent, acidification and stratification. In other cases, for example the extent to which the oceans will continue to take up CO_2, or changes in storminess or salinity, we are not even sure which direction the change in marine climate will take. Finally, some important potential changes such as coastal erosion will be so highly localised that they are difficult to map.

Furthermore, there are often insufficient data to draw robust links between climate change and impacts on marine ecosystems, and in some cases we do not sufficiently understand the underlying effects of climate change on the physical environment. Resolving these problems will be crucial if we are to learn how to mitigate the potential effects of climate change on the marine environment, as well as to adapt to those that are already inevitable.

Figure 6.1 An idealised model of the natural greenhouse effect.



Ocean Processes

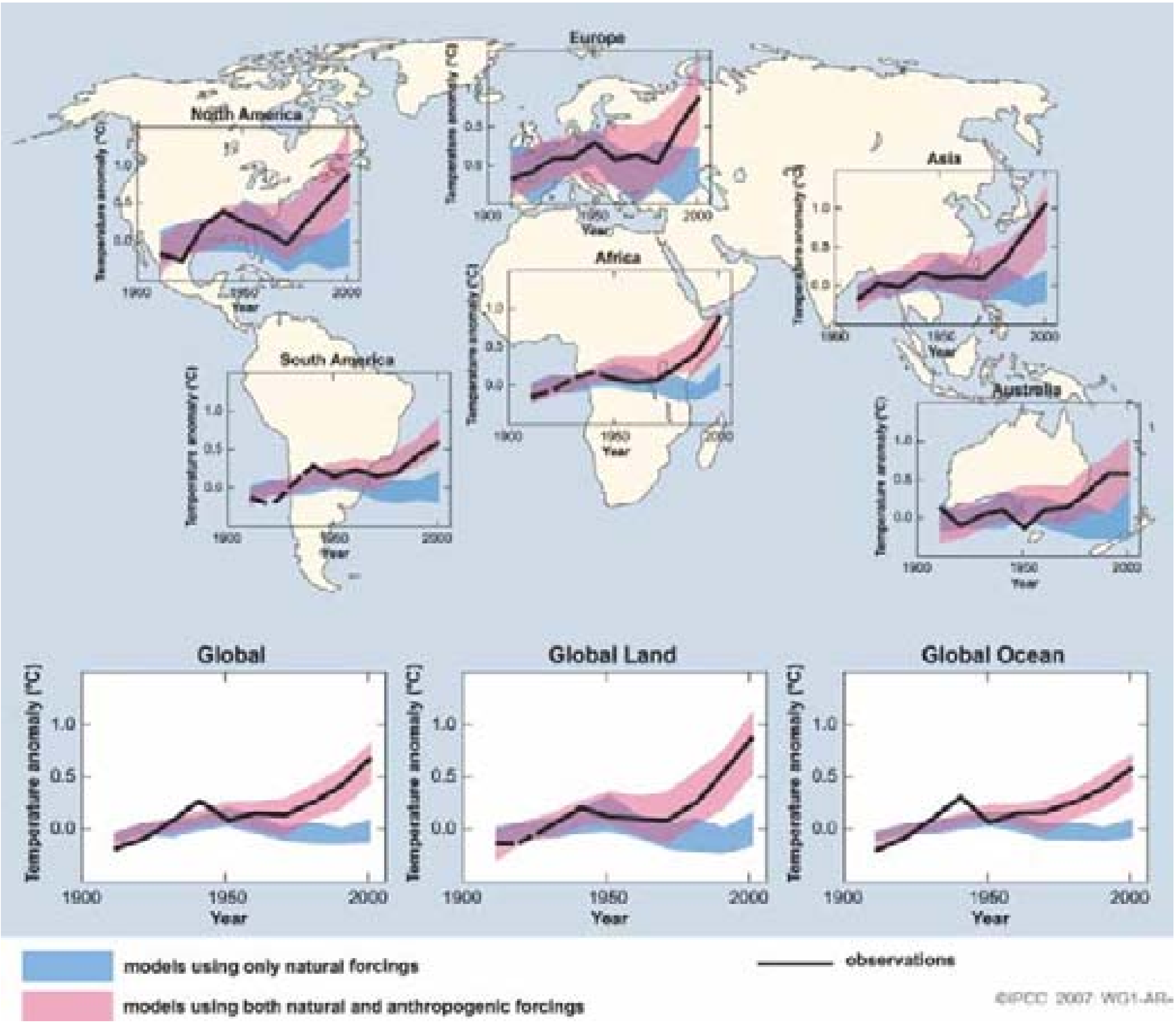
The physical state of the ocean provides the backdrop for all aspects of marine health, cleanliness, safety and productivity, from defining the nature of available habitats to determining how hazardous materials spread, and how we can best make use of our marine resources. Climate change and increasing levels of atmospheric CO_2 will affect many different aspects of the physical environment, and this will in turn have important consequences for all the other areas considered in this assessment.

Weather and climate

Weather varies on timescales from hours to years, and is governed in turn by longer-term changes in climate. The clearest evidence of climate change is a mean global rise in air temperature of about 0.75 °C since the late 19th century. Storms have changed on interannual to decadal timescales, but longer-term or future climate-related trends are not clear.

Models predict that over the 21st century all areas of the UK will grow warmer, with more warming in summer than in winter. There is predicted to be little change in the amount of

Figure 6.2 Temperature changes relative to the corresponding average for 1901-1950 (°C) from decade to decade from 1906 to 2005 over the Earth's continents, as well as the entire globe, global land area and the global ocean (lower graphs). The black line indicates observed temperature change, while the coloured bands show the combined range covered by 90% of recent model simulations. Red indicates simulations that include natural and human factors, while blue indicates simulations that include only natural factors. Dashed black lines indicate decades and continental regions for which there are substantially fewer observations.

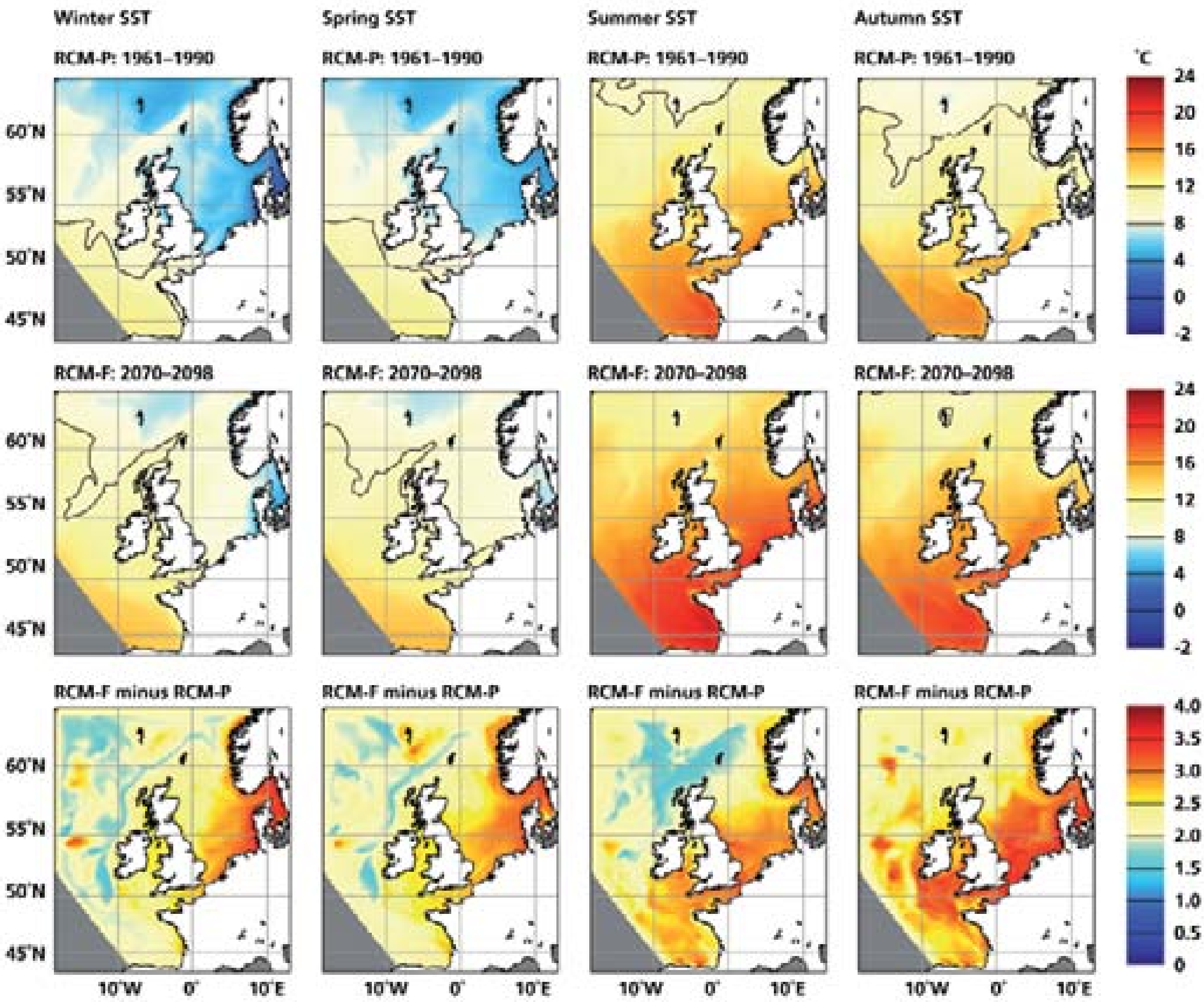


precipitation that falls annually, but it is likely that more will fall in winter, with drier summers for much of the UK. The regional pattern is more complex with generally greater changes in the Southern North Sea and Eastern Channel than in the Atlantic North-West Approaches and Scottish Continental Shelf areas.

Temperature, salinity, circulation

The three basic physical parameters determining the marine climate are water temperature, salinity and circulation patterns, and climate change affects them all. UK waters have warmed over the past 50 years, at least partly because

Figure 6.3 Projected change in seasonal mean sea-surface temperature for the NE Atlantic. The plots show the UKCP09 Marine and Coastal Projections for 1961-1990 (RCM-P; upper panels) and under a medium greenhouse gas emissions scenario for 2070-2098 (RCM-F; middle panels) and the difference between them (lower panels).



of human-induced climate change. The large-scale circulation of the Atlantic, which helps to maintain the relatively temperate climate of Northern Europe, shows high variability but no clear trend. The upper ocean to the west and north of the UK has become saltier since a fresh period in the 1970s, but trends within the shelf seas are less clear.

Climate models predict that the large-scale Atlantic Meridional Overturning Circulation will decrease over the 21st century, but not shut down completely. Although this will reduce the flow of warm Atlantic water past the west of the UK, it will not prevent a net warming of the UK seas. Under a medium greenhouse gas emissions scenario, UKCP09 projects that the

UK shelf seas will be 1.5 to 4 °C warmer by the end of the 21st century (Figure 6.3) and, with greater uncertainty, 0.2 salinity units fresher. The UK seas will seasonally stratify in the same locations as at present but this stratification may be stronger, start earlier and breakdown later each year. Circulation patterns are likely to be as variable in time and space in the future as they are today, being mainly controlled by the complex topography of the seabed around the UK, as well as by highly variable tides, winds and density differences.

Carbon dioxide and acidification

The oceans play an important role in mitigating climate change, taking up and storing about a quarter of anthropogenic CO_2 emissions through a combination of biological processes, solubility, and circulation patterns. However, dissolving excess atmospheric CO_2 in surface waters has already noticeably increased their acidity and this may in turn affect the ocean's ability to take up further CO_2. The North Atlantic reduced its uptake of CO_2 by half from the mid-1990s to 2005, but it is not yet clear whether climate change is the cause.

Further acidification of the oceans will depend on the emissions pathway society takes. On a 'business as usual' pathway, models suggest that by the end of the 21st century the acid (i.e. the active hydrogen ion concentration) content of the ocean's surface will have doubled (a decrease of 0.3 in the measured pH). Warming will tend to reduce the seas' ability to dissolve CO_2 directly from the atmosphere and this will reduce the capacity of the ocean to soak up CO_2. The projection of pH did not include this effect on the basis that the feedback would be small.

Rising sea levels will allow larger waves to approach the shore

Climate change may also alter the natural sequestration of carbon on a scale and in a direction that is presently difficult to predict. Changes in patterns of circulation on and off the shelf of the Northern North Sea may affect the natural passage of CO_2-rich waters from the shelf into the deep ocean, for example via the Norwegian Trench.

Sea level

In the 20th century, the average level of the UK seas rose by some 14 cm. The IPCC Fourth Assessment Report projected that global mean sea level will rise by 18 to 59 cm during the 21st century through a combination of thermal expansion of the seawater and melting of glaciers and ice sheets. Because the rate and magnitude of ice sheet melting is highly uncertain, the IPCC also included a higher upper limit of 79 cm, but they ascribed no likelihood to this projection and could not discount significantly higher changes. UKCP09 Projections of UK coastal sea-level rise (not including land movement) for 2095 range from 12 to 76 cm. Given that the IPCC could not rule out greater changes in sea level, UKCP09 adopted an extreme scenario for sea-level rise in the range of

93 cm to 1.9 m by 2100. However, the regional response of sea level depends upon where the water melts from geographically, and means the top end of this range is most unlikely for the UK.

Models suggest that there will only be very limited increases in the size of storm surges around the UK over the 21st century; in most cases this trend cannot be clearly distinguished from natural variability. However, models are not good at simulating future storms. Acknowledging this uncertainty, UKCP09 presents a scenario giving large rises in the surge component ranging up to a (most unlikely) 95 cm increase in the 50-year return level surge in the Thames region. When combined with the extreme scenario for sea-level rise, the upper extreme level projected by UKCP09 reaches up to about 3 m for a 50-year return period event by the end of the 21st century (an even more unlikely scenario).

Waves, suspended particles and turbidity

Wave heights around the UK depend on winds and storms both locally and in the wider Atlantic. There is considerable variability in waves, storm surges, and suspended particulate matter from year to year, and no clear trend since *Charting Progress*.

Climate change could affect wave heights by changing the intensity of storms, or their tracks, but there is very low confidence in storm projections. Models suggest that seasonal mean and extreme wave heights will increase slightly to the south-west of the UK, reduce to the north, and experience little change in the North Sea. UKCP09 projects changes in the winter mean wave height of between -35 cm and +5 cm, with changes in the annual maxima of between -1.5 m and +1 m. Projections of longer return period wave heights would reflect the same pattern but with larger errors.

Rising sea levels will allow larger waves to approach the shore and may change the type and size of particles suspended in the coastal region as more upper beach and terrestrial sediment is added to the marine environment. Any change in storminess could also change the suspension of bottom material in shallow areas. However, as yet there are no detailed projections of change for suspended particles and turbidity.

Sedimentary processes and morphology

Rising sea level has caused almost two-thirds of the intertidal profiles in England and Wales to steepen over the past 100 years, particularly on protected coasts. In low-lying coastal regions of England, 40 to 100 hectares of saltmarsh are being lost each year in a process known as 'coastal squeeze' as intertidal profiles steepen and human pressures restrict the landward migration of saltmarsh. Models suggest that coastal squeeze, habitat loss, coastal erosion and steepening of intertidal profiles will all increase in the future because of further sea-level rise and possible changes to wave conditions.

The GOCE satellite was launched to improve understanding of ocean circulation, sea-level change and ice dynamics

Healthy and Biologically Diverse Seas

Climate change will affect many marine organisms, either directly through their own physiology, or indirectly through changes in the distribution of prey and/or predator species. Within benthic habitats, rapid changes can lead to reduced survival of previously well-established species, while providing opportunities for other species better adapted to warmer waters. This in turn may change the structure of the community and lead to the decline of particular habitats if important species such as reef-builders are affected. Rising sea levels, coupled with possible changes in storms could cause increased erosion of intertidal sediments. In areas where fixed structures (artificial or otherwise) are present, this can result in habitat loss. Increased acidification of seawater will also adversely affect many marine organisms, particularly those possessing hard external skeletons containing calcium carbonate.

Sea fan with anemone

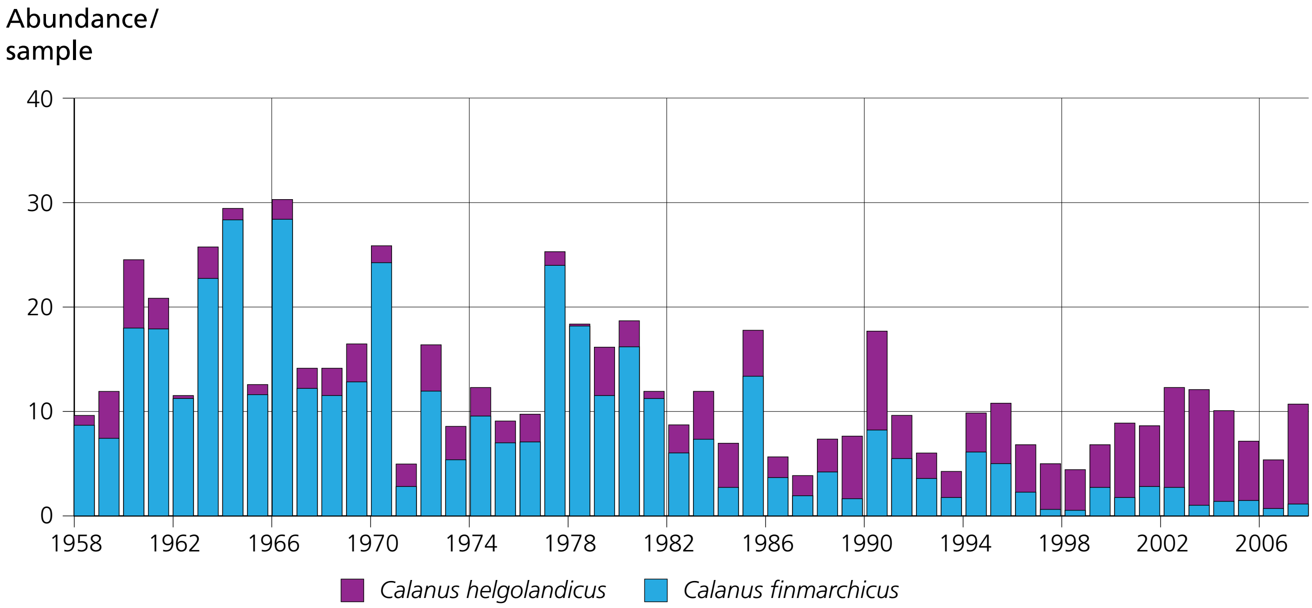
UK marine habitats

Climate change is likely to have a significant impact on coastal and shallow marine habitats, notably through sea-level rise and temperature change. Considerable changes to marine communities are likely as water temperature rises, with cold-water species potentially being replaced by southern species shifting their distribution northward. In the longer term, rising CO_2 concentrations in seawater will lead to increased acidification of marine habitats, which is likely to have a negative impact on numerous groups of hard-shelled marine organisms such as corals, molluscs, crustaceans and various plankton species. These organisms are important components of many marine habitats, and changes to them will also affect their associated food webs.

Microbes and plankton

Nearly half the Earth's basic food supply comes from photosynthesis performed by microbes and phytoplankton in the oceans. This role as the primary producer means that microbes and phytoplankton are of fundamental importance in the marine environment, both through their role as the basis of the marine food web and through the take up of carbon. Without the ability to migrate and with lifecycles that are too long for evolutionary adaptation at the rate of climate change, plankton may be particularly sensitive to acidification and warming and so particularly important in terms of climate change impacts on entire ecosystems. Microbes have lifecycles that are short relative to climate change timescales and so have a higher potential to adapt to warming and acidification. Harmful algal bloom species are thought to be primarily controlled by climate dependent factors such as mixing, temperature and circulation of the UK seas.

Figure 6.4 Relative change of Calanus helgolandicus *(a warm-water species) and* Calanus finmarchicus *(a cold-water species) since the late 1950s. Note: while the warm-water species is replacing the cold-water species the actual total* Calanus *abundance is decreasing.*



The biological component of the uptake of CO_2 is limited by the supply of nutrients and physical factors such as sunlight and mixed layer depth, all of which are potentially sensitive to climate change. If the oceans begin to lose their ability to take up CO_2, the effects of climate change will be felt more quickly and more severely.

The marine growing season has become longer since the late 1980s due to rising sea temperatures. In the mid- to late 1980s a sudden shift in plankton species in waters around the UK affected many aspects of the marine ecosystem. The shift is related to both the coincident pronounced change in the North Atlantic Oscillation and the rising Northern Hemisphere temperature.

Distributions of different types of plankton are likely to shift in response to a warming climate but this may not be smooth. Modelling using the IPCC A2 and B2 greenhouse gas emissions scenarios suggests that the poleward movement of the calanoid copepod *Calanus finmarchicus* will continue to 2100 at a rate of 1° latitude per decade and that the species will disappear from the North Sea at around that time (see also Figure 6.4). This and other associated changes in the plankton will have profound consequences for the functioning, carrying capacity for living marine resources, and conservation of UK marine ecosystems.

Earlier and longer growing seasons will change the timing of productivity within the year and may affect the lifecycles of predator species. Ocean acidification is likely to have a strong impact on planktonic ecosystems. These ecosystems may be further affected as non-native species enter warmer UK waters and pathways through the opening up of the Arctic. Changing habitats may favour certain microbial populations over others resulting in altered microbial assemblages with unknown impacts on oceanic food webs. The biological component of the ocean uptake of CO_2 is likely to be affected by warming and acidification, but we cannot yet determine plankton variability and its contribution to atmospheric levels of CO_2 at a UK, regional and global scale, and this is one of the key factors missing in global climate change modelling.

Fish

At present the overriding pressure on fish stocks comes from fisheries. However, fish have complex lifecycles with stages that have different sensitivities to climate drivers. Abundance of some warm-temperate species increased in southern UK waters during recent warming periods, and declined during cooling periods. Over the past three decades, distributions of some exploited and non-exploited North Sea fishes appear to have responded markedly to higher sea temperature by moving northward and into deeper waters.

A very different mix of fishes might exist in UK waters in years to come, including some species that are currently not native. However, as yet we have no detailed predictions – in part because of the complexity of the relationship between climate and distribution, and uncertainty about how the key drivers themselves will change.

Seals, turtles and cetaceans

We have only a poor understanding of the impact of climate change on marine mammals and turtles. In the future, climate change could influence them through for example, changes in the distribution of their prey species. It could also affect seal haul-out and turtle nesting sites, where higher incubation temperatures could lead to a female bias in the sex ratio of turtles. However, the details remain uncertain.

Little tern

Marine birds

Climate change may have direct effects on seabirds through rising sea level, and changes in temperature and weather, as well as indirect effects through changes in the ecosystems that support them – for example by reducing the number and nutritional value of prey fish. There is evidence that populations of waders have redistributed within the UK and in Europe and this can in part be attributed to climate change.

As sea temperatures continue to rise, it is likely that kittiwakes and other seabirds that feed on small shoaling fish will experience poor breeding seasons with increasing frequency. The combination of reduced recruitment and lower adult survival could lead to further very large declines in population size. Rises in sea level, particularly in the Southern North Sea, may wash away coastal nesting habitat of ground-nesting seabirds such as terns. Any increase in storminess could also lead to nests being washed away during the summer or to large-scale mortality during winter.

Clean and Safe Seas

To date, there has been little research into the influence of climate change on the cleanliness and safety of our seas. However, our understanding of possible changes in and the influence of temperature, storms and precipitation allows us to make informed hypotheses about the broad direction of future change. By considering these dominant processes we can also make some assessment of likely changes on a more detailed, regional scale, but very local processes are likely to be the most important drivers of local changes.

Hazardous substances

Changes in future rainfall and winds will have a particular effect on the distribution of hazardous substances in the UK marine environment. For example, unusually wet seasons and intense storm events could deliver untreated sewage and diffuse runoff pollutants from catchments to the coastal and marine environment. Changing seasonal river flow can also change the concentration of treated sewage and the biological oxygen demand could increase as sea temperatures rise. More intense storm events, along with increases in sea temperature and changes in salinity, may also affect the release of contaminants presently in the sediment on the seabed. More indirectly, climate change may lead to increased use of certain pesticides in farming, or of UV sunscreens, and these chemicals could find their way to the marine environment. Changes in storms and rainfall patterns could also affect sewage discharge and the pollution levels in runoff, as well as the disposal of polluted sediments.

Radioactivity

Remobilisation of radionuclides from sediment is now the principal source of caesium-137 and plutonium in the Irish Sea. Changing wind and wave conditions, a potential result of climate change, could further disturb these sediments, leading to the potential remobilisation of radionuclides into the water column and further redistribution.

Eutrophication

The key driver of eutrophication in shelf seas is the supply of nitrate, ammonia and phosphate. Recent studies in offshore North Sea areas show that hypoxic (low oxygen) events in these regions are more likely to be due to climate change than to nutrient enrichment from human sources. Future changes in the intensity of storms and the amount of seasonal precipitation could affect the supply of nutrients in runoff from catchments. Increased stratification in summer could limit nutrient supply to surface waters during the productive seasons, while potentially increasing the occurrence of hypoxic conditions in the bottom waters in deeper parts of the North Sea and Irish Sea. Other pressures such as ocean acidification are likely to complicate the biological responses to nutrient enrichment.

Oil and chemical spills

Climate change could affect the frequency or impact of spills in several ways. Potentially greater storminess increases the chance that oil-bearing vessels will get into difficulties and sink or run aground. More indirectly, changes in agricultural practices or weather patterns might affect the routes and cargo taken by ships. As yet, we have no studies on this covering UK waters, but changes in Arctic sea ice may allow a northern sea-route to become more viable.

Noise

A combination of ocean acidification (as atmospheric CO_2 is taken up by the ocean surface) and reduced ventilation (through a more stable water column) makes the ocean considerably less able to absorb sound for frequencies below about 10 kHz. The previously mentioned projection of an increase in acidity of 0.3 pH units by the end of the 21st century would decrease the capacity of the ocean to absorb low-frequency noise by almost 40%. This would mean that ambient noise levels within the auditory range critical for environmental, military, and economic interests would increase significantly when combined with the potential for increasing sources from human activities.

Microbiological contamination

If higher rainfall increases the amount of faecally derived microbes in the marine environment, this could cause more failures to comply with the values in the EU Bathing Water and Shellfish Water Directives (and worse classifications under the Shellfish Hygiene Directive). Higher temperatures may also encourage the growth of naturally occurring human pathogens such as *Vibrios*. Both of these effects could increase the health risk associated with recreational water use and shellfish consumption.

Algal toxins

Earlier spring blooms of many harmful algal species could increase their window of opportunity, and warmer waters may allow the expansion of these species into higher latitudes. If warming increases stratification of the seas around the UK, this may also favour such harmful species. There is some evidence that they are more stimulated by nutrients in warmer waters, although this process is poorly understood and could be due to changes in light availability rather than temperature.

Productive Seas

Most of the ways we use the sea are influenced by weather and many rely on oceanic and atmospheric processes. From the direct provision of fish for food to the indirect need to protect coasts, the marine climate is an important driver of economic activity. The link between our uses of the sea and its climate is intimate so it is very likely that the climate change we have already experienced in the 20th century has had an impact on productivity. However, it is difficult to separate out the influence of climate from changes in practices, management and direct pressures such as fishing, which tend to dominate developments in marine industries.

In this section we consider only the potential impacts of climate change on the different economic sectors. The subsequent section will discuss the role of the sea in helping to mitigate climate change.

Aquaculture

There are likely to be some major impacts on UK aquaculture beyond the current decade. Rising sea temperatures could lead to an increase in the prevalence of illness and parasites, and in the frequency of harmful algal and jellyfish blooms. Increased temperature or ocean acidification (for shellfish) may affect the suitability of species for farming. Changes in waves and winds could lead to escapes of farmed species through equipment failure.

Fisheries

As sea temperatures rise, cold-adapted species such as cod and herring – both of which are already heavily exploited and thus vulnerable to climatic variability – are likely to suffer poorer recruitment, and changes in growth patterns, in some sea areas around Britain and Ireland. In the longer term, the prevalence of southerly species in UK waters is likely to increase and provide opportunities to exploit species such as seabass, red mullet and John Dory. Fishing fleets may themselves be affected directly by climate change if storms become more severe making conditions more dangerous.

Leisure and recreation

Climate change is already increasing the frequency of months when conditions are more comfortable for tourists in north-west Europe than in the Mediterranean.

Warmer seas and milder air temperatures are likely to increase participation in marine leisure and recreation. An increase in the length of the tourist season would attract more visitors to the coast and open up new destinations. The extent and participation in watersports, especially those involving full immersion (e.g. surfing, SCUBA diving and swimming) is likely to increase under warming conditions. However, any increased frequency of 'extreme' events such as storms and severe rainfall could discourage tourists,

Kite surfers at Lowestoft

and disrupt travel, utilities and marine leisure services. Rising sea level and any increase in storm severity could also damage infrastructure, while an increase in the severity of rainstorms could increase run-off, leading to lowered water quality. Warming seas could alter the distribution of marine species of importance to marine wildlife watching and angling.

Offshore infrastructure

Climate change is likely to affect all forms of offshore infrastructure, including oil and gas installations, pipelines and cables, renewable energy structures and future efforts to store CO_2 beneath the seabed. Rising sea level and possible increases in waves and winds may put greater stresses on some structures in the marine environment, while changes to currents could result in altered patterns of scour around the legs and supports of offshore installations. Any increase in storminess could also affect air and sea access to offshore installations and pose operational issues for health and safety and maintenance.

Maritime transport and ports

Reduced Arctic sea-ice cover may enable the opening of trade routes, reducing the time taken to transport cargo between Asia and Europe and increasing shipping trade. Changes in weather patterns could result in changes to other shipping routes due to storm activity. Any increase in the severity of storms could also increase the strain on quayside flooding, damage to port infrastructure, cargo and timetables. The costs of maintaining navigation channels may also change.

Current and proposed climate mitigation measures

Introduction

Since *Charting Progress* was published in 2005, the world's governments – under the umbrella of the UN Framework Convention on Climate Change (UNFCCC) – have been trying to agree on a framework for reducing greenhouse gas emissions that will succeed the Kyoto protocol. Although the UN Climate meeting held in Copenhagen in December 2009 did not result in a new protocol, the parties agreed in principle to try to limit the global temperature increase to 2 °C, which has long been the EU target. The EU also reiterated its commitment to cutting greenhouse gas emissions by 20% by 2020 relative to 1990 baseline levels.

To limit temperature rise to less than 2 °C will require an extremely determined, co-ordinated effort to stabilise emission levels in the immediate future followed by a sustained and dramatic reduction. Even if we achieve the EU target, the global warming we are already committed to will lead to serious climate change impacts to which countries worldwide will need to adapt.

Climate Change Act

In the UK, the Climate Change Act became law on 26 November 2008. The act sets legally binding targets on greenhouse gas emission reductions of at least 80% by 2050, and reductions in CO_2 emissions of at least 26% by 2020, against a 1990 baseline.

The following sections show how the UK seas are likely to play an important role in helping us deliver these ambitious targets.

Pelamis Wave Energy Converter at the European Marine Energy Centre in Orkney

Marine renewables

The UK has some of the highest levels of renewable energy resources in the world. These include wind, wave (mostly on the west coast), tidal stream (focussed inshore around headlands), and tidal range. The development type that has advanced the furthest in terms of installation and operation is offshore wind farms.

In 2008, renewable energy sources supplied 2.25% of the UK's energy; to meet a binding target for 20% of the EU's energy consumption to come from renewable sources by 2020, the UK has committed to increase its share of renewables to 15% by then. While there is as yet no blueprint for how much each sector will contribute to this 2020 target, an illustrative breakdown published by the Department of Energy and Climate Change (DECC) suggests that marine renewables could participate significantly through offshore wind (19%), tidal stream (2%), tidal range (1%) and wave (<1%).

Wave and tidal stream energy sources have the potential to make a significant contribution to longer-term (2020–2050) energy and climate change goals by providing up to 20% of our electricity needs.

The resources available to tidal range technologies are primarily focused in a limited number of locations, including the Severn Estuary, Liverpool and Morecambe Bays, the Solway Firth, the Wash, the Duddon, the Wyre and the Conway.

Shipping

Estimates from the International Maritime Organization (IMO) suggest that international and domestic shipping contributed 3.3% of total global CO_2 emissions in 2007. If we count UK sales of ship fuel, emissions appear to be similar to 1990 levels, at 6 million to 7 million tonnes of CO_2 per year. However, there is currently no international agreement on how to allocate emissions from international shipping to individual countries. Within the IMO, the UK is pressing for a global agreement that would treat international shipping as if it were a country in its own right. In 2008, the UK Climate Change Committee concluded that international shipping should not be included in the UK national carbon budget because of the difficulty of attributing and measuring the UK's shipping emissions.

The long life span of ships makes changes to new, cleaner technologies unfeasible in the short to medium term. However in 2009 an IMO study identified various technologies for new and existing ships that could potentially reduce the emissions rate to between 25% and 75% below current levels. For example, solar cell technology, hydrogen fuel cells, sails/kites and improved ship aero/hydro-dynamics have all demonstrated potential to improve emissions. In 2008, the IMO agreed a work plan for discussing market-based measures, such as an emissions trading system, to address greenhouse gas emissions from international shipping; this would give a financial incentive for ship owners to improve the efficiency of their vessels, and the plan aims to indicate a preferred approach by the end of 2011.

Carbon capture and storage

Carbon capture and storage (CCS) in geological reservoirs is an important priority for both the UK and Scottish governments. Under the 'Framework for the Development of Clean Coal' announced by DECC on 9 November 2009, all new coal fuelled power stations must demonstrate CCS technology from the first day of operation on a minimum of 300 Megawatts (net) of their capacity. Under the same framework, from 2020, all new coal plant applications are expected to have full CCS operational from day one.

The UK Energy Act 2010 allows a levy on electricity generation to be charged in order to fund up to four CCS demonstrator projects across the UK. The first demonstration project, which will be the UK competition winner, should be announced in autumn 2010.

The Scottish Government is working closely with the Scottish Environment Protection Agency, Marine Scotland, Scottish Natural Heritage, Crown Estate, Health and Safety Executive as well as the UK Government to develop an integrated approach to the licensing and consents processes that will be required for any CCS project in Scotland.

In 2009, the Scottish CO_2 Storage Study highlighted the offshore potential of the North Sea Scottish sector to store CO_2 emissions for the next 200 years. A second study, also supported by the Scottish Government, will enable more detailed assessments of potential offshore storage capacity.

Biofuels

The EU Renewable Energy Directive was published on 5 June 2009. It includes an obligation on Member States to introduce mandatory requirements for biofuels and set a target for achieving 10% renewable energy in transport by 2020. Biofuels already accounted for about 2.6% of all UK road fuels in 2008/09. There are concerns surrounding the environmental and indirect impacts of land-based biofuels. Marine microalgae and nanoplankton may become important sources of biofuels through the production of biodiesel, ethanol, methane and hydrogen, by digestion or burning of seaweed biomass or by direct pyrolysis. However, the development of biofuels from marine resources is at an early stage, and production within the marine environment itself will have to satisfy sustainability constraints.

CHAPTER 7
COMMON ISSUES AND REGIONAL PERSPECTIVES

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Introduction

Each of the eight UK regions has different environmental characteristics, and supports a range of different human activities.

The physical characteristics of a region determine the types of habitat that are available and the variety of plants and animals that can exist, and can also influence some types of human activity. For example, fish tend to migrate and spawn in certain areas, and the sub-sea geological structure influences where the oil industry focuses its activities.

Historically, many large towns developed beside particular rivers and estuaries, which brought the need to dredge to keep shipping channels open, increased the physical pressure from coastal structures, and also encouraged the development of industries and consequent use of water for cooling and discharging waste.

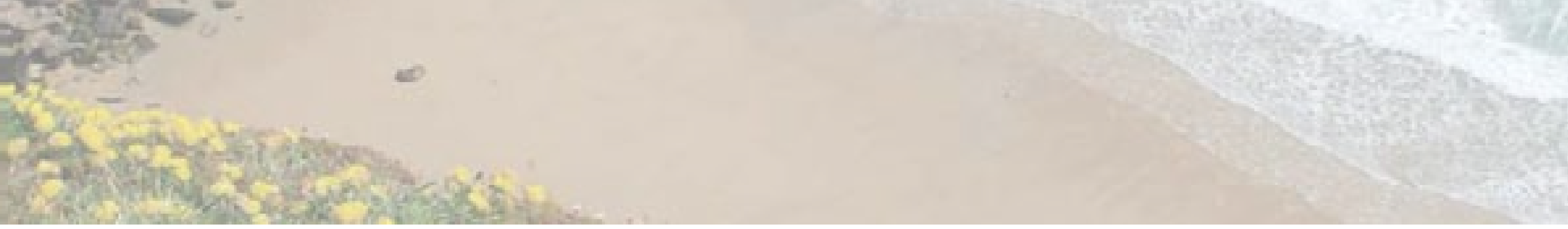
Harwich International Port

Mackerel

Because of these regional factors, the current status of UK waters and the extent to which we are moving towards the vision of clean, healthy, safe, productive and biologically diverse seas is also likely to differ from region to region. This chapter brings together the evidence from each of the individual evidence chapters to give a regional perspective of:

- The changing physical and environmental influences that affect each region
- A profile of the main human activities and the marine resources that they use
- Any improvements in the status of each region
- The main problems in each region.

These regional analyses will contribute to the development of marine plans which will help us to use our marine environment sustainably. Linking the economic benefits and pressures from human use in each region and impacts of those activities on the marine environment allows scientists and managers to focus on specific regional issues and enables national administrations to prioritise their planning and use of resources.



Common issues affecting a number of regions

The footprint of human activity extends to all eight regions as we seek to make use of the wealth of marine resources. The level of human activity is least in the more remote areas to the north and west of Scotland, and greatest close to the large centres of human population around the North Sea and Irish Sea. Coastal areas are under particular pressure from a combination of human activities, inputs of contaminants and nutrients, and climate change.

Some pressures occur in all eight regions, some are common to a number of regions and some can affect significant parts of a single region. *Charting Progress* identified fishing and the emerging pressure climate change, as the major UK-wide issues.

Fishing pressure

Fishing remains a widespread activity that continues to cause problems in most regions, with some assessed stocks fished unsustainably and some seabed habitats damaged. However, we benefit from this source of protein and there are some signs of improvements in recent years in both the status of demersal fish communities and a number of assessed fish stocks.

During the past ten years, fishing mortality has declined significantly in 67% of assessed fish stocks in UK waters. There is some way to go before the exploitation of the majority of commercial fish stocks is at safe levels. Out of 20 indicator fin-fish stocks in UK waters, the proportion being harvested sustainably and at full reproductive capacity has risen from around 10% in the early 1990s to around 25% in 2007. The proportion of these 20 indicator fin-fish stocks being harvested sustainably has risen from 10% to around 40% over the same time period. The improvements are, probably, because of a reduction in fishing effort in most regions.

Since *Charting Progress*, there have been signs of improvement in the diversity and abundance of demersal fish although life-history traits such as average size and age-at-maturity typically show little or no change. These latter traits respond more slowly to the reduction in fishing pressure. However, a number of species are suffering sharp declines, including sharks and rays which are particularly vulnerable to fishing pressure.

For estuaries, there have been improvements for some species, probably as a result of better management and pollution control in recent years, but eel recruitment has declined in some regions, reflecting an Atlantic wide downturn in the numbers of elvers returning to rivers.

Sub-tidal seabed sediment habitats in most regions are continuing to have many problems as a result of bottom trawling activity. There has been both loss of habitat and associated species, including fish, which are likely to be important to a functioning ecosystem.

Climate change and acidification

Climate change due to increasing atmospheric levels of greenhouse gases has raised sea temperatures in all regions. The clearest response to the rising temperature has been a northward shift in the distribution of plankton, certain fish species and rocky shore animals. This is particularly apparent in the North Sea which has experienced the biggest temperature change.

Some coastal habitats are under pressure from rising sea level, particularly in the south-east of England where the land is also sinking and the coast consists of soft sediments. Rising sea level

has less impact in the north-west of the UK as the land here is also rising. Coastal protection and flood defences built as a response to rising sea levels put additional pressure on coastal habitats because of the resulting ‘coastal squeeze’. This illustrates how managers need to balance the trade-offs between different actions.

There is good evidence to show that the increasing atmospheric concentration of carbon dioxide (CO_2) is contributing to the acidification of the oceans. Model assessments indicate that UK waters are acidifying but we need further evidence to confirm the rate of change. Research is underway to develop our understanding of the probable consequences of our seas acidifying and we are developing an appropriate monitoring programme.

Effects of climate change will continue to increase pressure on the marine ecosystem in all regions and this needs to be factored into monitoring programmes and assessment methods.

Hazardous substances

Inputs of measured hazardous substances included in monitoring programmes have fallen in most regions but there are still some problems in five regions. In Regions 1 to 5 the observed elevated concentrations tend to be localised to some industrial estuaries and coastal areas. The risks from eating commercially produced seafood in any region as a result of hazardous substance contamination is very low. The available evidence suggests that hazardous substances do not significantly affect the seas at a regional scale, but that there are uncertainties due to limited data and a lack of clear evaluation of biological effects.

There are also new issues emerging that relate to the development and changing use of chemicals by society. An example is the use of silver nanoparticles as an antimicrobial agent in clothing which appears to be connected with the presence of silver in the coastal environment.

Eutrophication

Nutrients from agriculture and waste water can have a significant impact on the marine ecosystem. *Charting Progress* identified those coastal waters within Regions 2, 3 and 5 where nutrient concentrations were elevated. This assessment has found that, while these areas continue to be nutrient enriched, this does not lead to eutrophication problems; confirming their overall non-problem area status. However, we have identified marine eutrophication problems in some small estuaries and harbours in Regions 1, 3, 4 and 5 and specific management of these problems is in place. Nutrient pressure will decrease as measures take effect but this is expected to take many years.

Developing issues

Charting Progress identified litter as a concern in Regions 3, 4, 5 and 7. For this assessment we have found that litter is present on all the beaches surveyed. While there is evidence of litter in offshore areas we have insufficient information to prepare a thorough assessment. Litter is clearly an avoidable aesthetic problem but it may also have a biological impact, for example, marine life may become entangled in abandoned fishing gear. The ecological significance of litter is not fully understood.

Underwater noise can be a hazard to marine life. We have a concern that the level of noise in the sea will increase because we expect there to be more, and more intense, human use of the

marine environment. However, while this may have a detrimental impact there is insufficient information about the distribution/incidence of noise or the impacts of noise to make a reliable assessment.

Maritime economy

Human use of the sea continues to make a very significant contribution to the UK economy and to jobs. The consequent pressures on the marine environment result mainly in localised problems because of the success of the regulatory process in minimising environmental impacts. In addition, concerns about the widespread impacts of fishing practices are now being tackled through reform of the EU Common Fisheries Policy.

Economic activities in the sea will continue to evolve in response to human needs – for example, the very significant expansion forecast for renewable energy development and the possible expansion of major ports. As the extent and intensity of activities and the possibility of competition between uses increases, there is a need for effective marine planning as part of an ecosystem-based approach to the management of our seas.

Underwater noise can affect marine mammals

Regional perspectives

The regional perspectives summarised in the following sections provide a pen-picture of the physical environment and major human activities taking place with in each region, together with a commentary about some of the main improvements and problems. The illustrative maps and associated text have been drawn from the previous chapters to provide an overall impression of how well we are moving towards the vision of clean, healthy, safe, productive and biologically diverse oceans and seas.

Fishing boat and offshore wind farm

Northern North Sea (Region 1)

The Northern North Sea extends from Shetland in the north to Flamborough Head in the south with water depths of between about 50 m and 200 m. The coastline is predominantly rocky but there are intertidal sediments in the bays and inlets. The main offshore habitats are large expanses of sand and mud. Sea-surface temperature varies seasonally, ranging from 6 °C in winter to 14 °C in summer and much of the region becomes stratified in summer. There is a significant inflow of high salinity Atlantic water into the north of the region.

Climate change

Sea temperature is rising and has been linked to changes in the plankton community. The length of the phytoplankton growing season has increased and the distribution of some species of plankton and fish has shifted northward. These changes may have affected the marine food web.

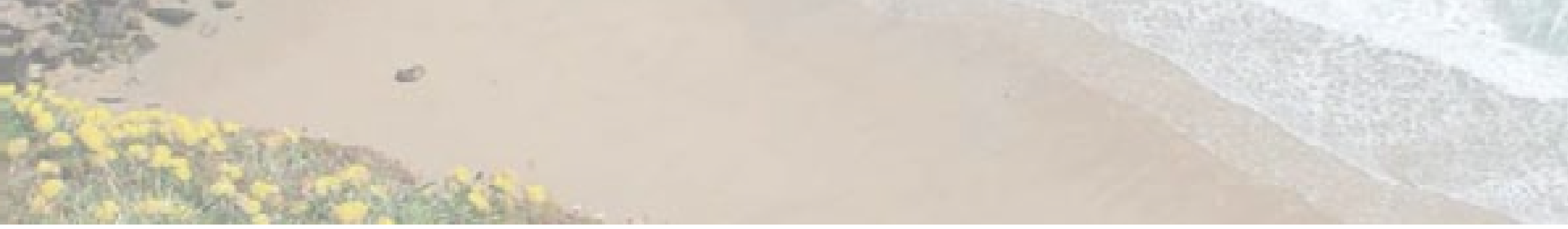
Maritime economy

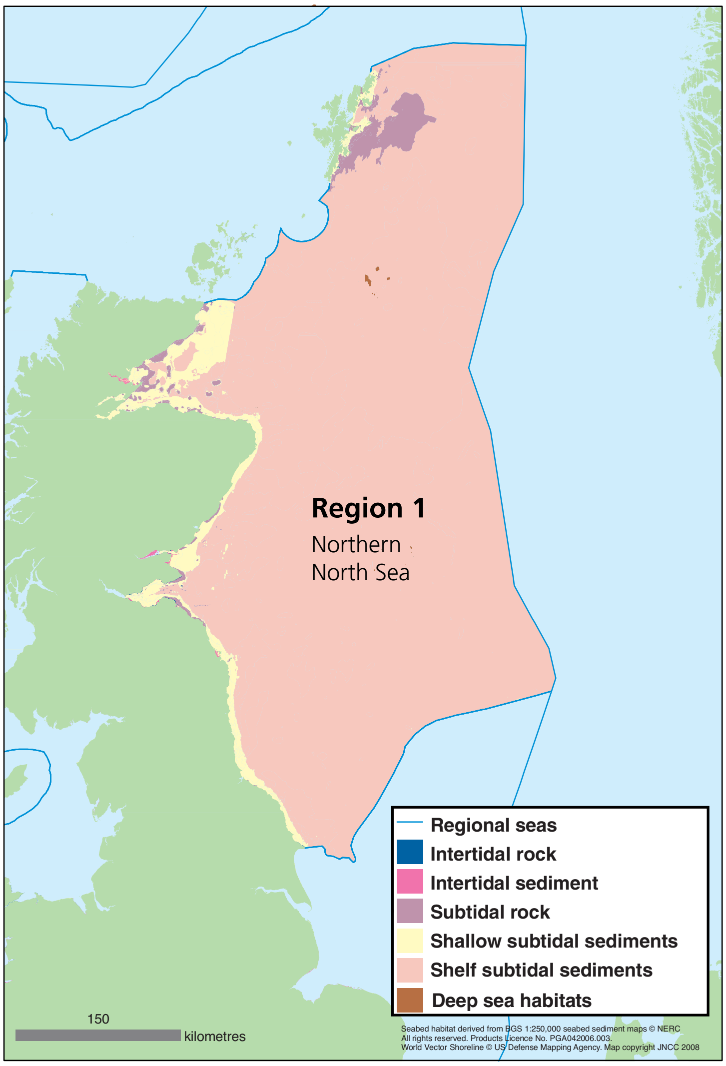
The oil and gas sector provides the greatest economic contribution to Region 1 because of the presence of major hydrocarbon fields – and this is the most economically important region for this industry in the UK. Although the industry is widely distributed, physical pressures are localised to installations and structures while contamination of the sea is declining due, for example, to a reduction in oil discharged with produced water. Shipping activity is important and provides links with northern Europe from ports in the Firth of Forth and the Port of Tees and Hartlepool. Cooling water abstraction has significant value because of the presence of a number of nationally important coastal power stations. Recreation is important locally, for example, the region supports bird watching on the East Lothian coast, cetacean watching in the Moray Firth and scuba diving at St Abbs-Berwickshire. Most industries using the seas are well regulated and create a low and localised pressure on the marine environment.

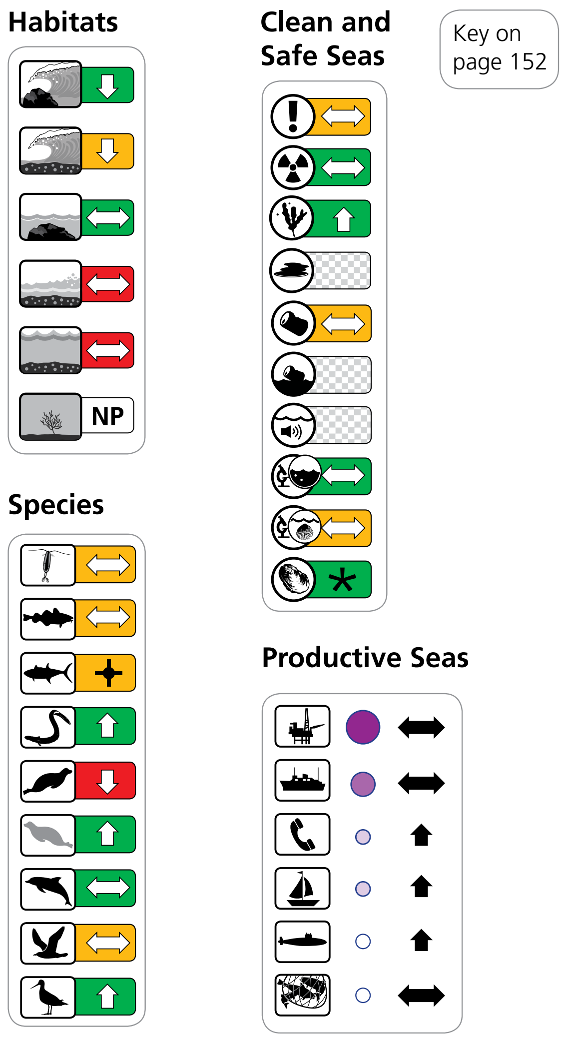
Fishing pressure

Fishing is a significant and widespread activity in this region. The Northern North Sea has the most valuable demersal and *Nephrops* fisheries in the UK, as well as fisheries for herring, mackerel and horse mackerel, and shellfish (e.g. lobster) near the coast. This intense fishing activity has an environmental impact. Assessed commercial fish stocks are either not at full reproductive capacity or are not being harvested sustainably. However, with the exception of stocks of haddock and saithe, the quality of demersal fish communities is improving; abundance, biomass and productivity are increasing but smaller fish still dominate. Coastal and seabed sediment habitats such as sands and muds are considered to be severely impacted by bottom trawling activity, which may damage ecosystem functioning.

Scottish trawler







Improvements

- Inputs of many hazardous substances are decreasing but there is a persistent legacy of some substances in industrialised estuaries
- Populations of dolphins, whales and porpoises are now considered to be in good condition
- There are signs that the quality of demersal fish communities is improving

Main issues

- Fishing is still having an impact on commercial fish stocks, demersal fish and seabed sediment habitats
- Harbour seal populations are decreasing but the cause of the decrease is not known
- Beach litter is an aesthetic and economic problem, more research is needed to assess overall ecological impact
- Seabird breeding success and survival have reduced due to food shortages possibly caused by fishing and climate change

Creating wealth

- Main contributors to the economy are the oil and gas sector and maritime transport, with smaller contributions from leisure and recreation, telecoms, defence and fishing
- Widespread physical pressures on the marine environment arise from fishing, with small and more local impacts from oil and gas, shipping, leisure and recreation and defence

Changing climate

- Rising sea temperature has caused changes in the plankton community and the distribution of some fish species
- Rising sea levels are only adversely affecting a small proportion of the coast

Southern North Sea (Region 2)

The Southern North Sea extends from Flamborough Head in the north to Dover in the south. Water depths are less than 50 m and most of the region is well mixed by tides and wind throughout the year. The coastline is varied with extensive areas of intertidal muds and sands and soft cliffs. The main offshore habitats are large expanses of sands and coarser sediments. There are large seasonal variations in sea-surface temperature, ranging from 4 °C in winter to 19 °C in summer.

Climate change

Sea level is rising, increasing the risk of coastal erosion, flooding and loss of intertidal habitat due to 'coastal squeeze'. This is a particular concern in this region as the land is sinking and the coasts of south-eastern England are low lying. The coasts are generally formed of soft sediments which are susceptible to erosion.

Sea temperature is rising and has resulted in changes in plankton production. Production has increased and the spring bloom is starting earlier, but the species present have not changed and are typical of shallow coastal areas. The increased growth in coastal waters is also related, in part, to coastal nutrient enrichment.

There has been a small decrease in salinity, which may reflect an increase in freshwater run-off from the major rivers entering the region, although our confidence in this explanation is low.

Maritime economy

This region has major gas fields, and the oil and gas sector provides the greatest economic contribution. Important gas pipelines connecting the gas fields to Europe come ashore at Easington and Bacton. Subsea caverns and depleted gas fields provide good potential for storage of natural gas or CO_2. There are wind farms at Lynn, Inner Dowsing, Scroby Sands, and Kentish Flats and further sites are being developed so the value of the renewables industry will increase. Cooling water abstraction has significant value owing to a number of nationally important coastal power stations.

Grimsby and Immingham in the Humber Estuary and London in the Thames Estuary are two of the busiest UK freight ports, benefiting from proximity to markets in Europe. 26% of UK dredged material disposal sites are associated with the port developments in the region.

The region contains the UK's most important marine aggregate resources. Licensed areas off the Humber and East Coast regions and the Thames Estuary, provide almost half of all marine construction aggregate, most to London. The region has the highest proportion of coastal defence (32%) and flood protection schemes (33%) in the UK and further development in response to rising sea level will add to the existing pressure on intertidal sediment habitats.

Recreation is also important supporting both the local population and numbers of visitors in activities such as leisure boating and bird watching at nationally significant wetland sites.

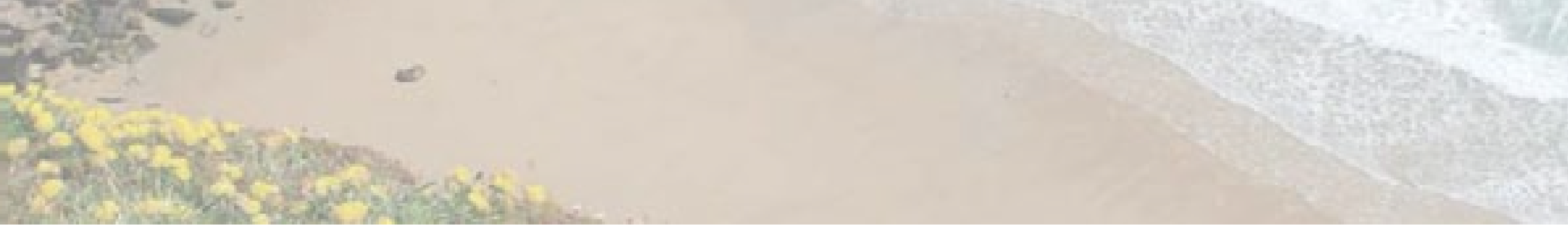
Fishing pressure

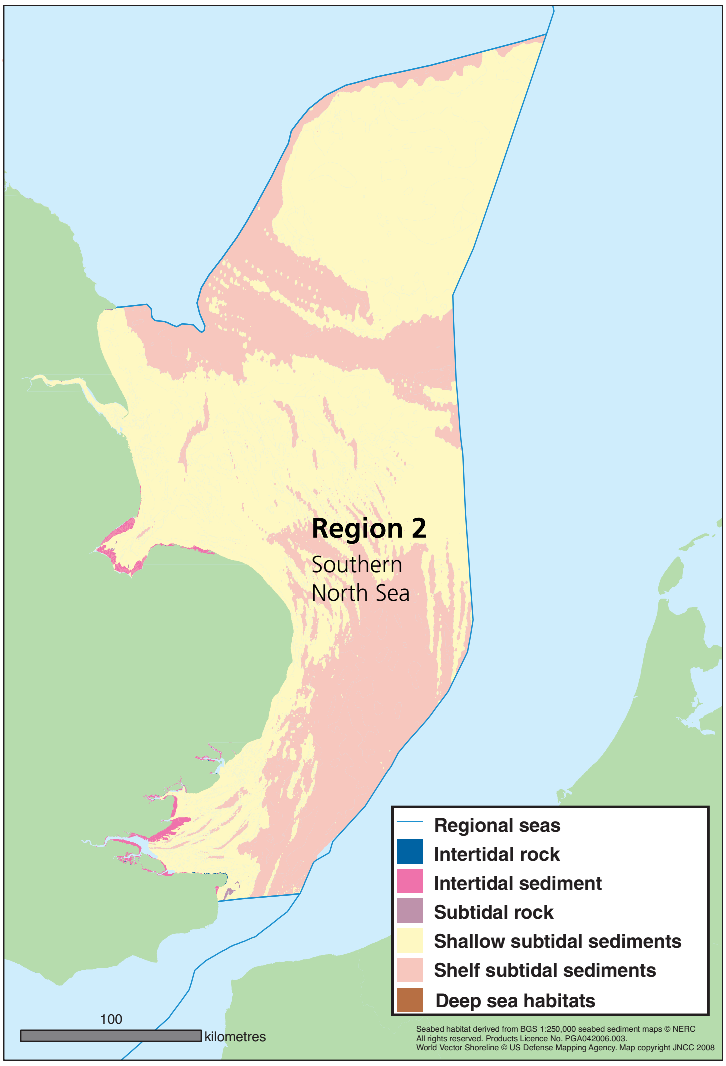
Assessed commercial fish stocks are either not at full reproductive capacity or are not being harvested sustainably. With the exception of haddock and saithe, the state of demersal fish communities appears to be improving, shown by evidence of increasing species richness and evenness. However, smaller and opportunistic fish now dominate the fish community. Salmon and eel populations in estuaries are deteriorating.

The coastal and seabed sediment habitats are severely impacted by the range and distribution of human activities that are taking place in this region; rocky habitats are impacted to a much lesser extent. Bottom trawling activity, particularly near the coast, is a major pressure.

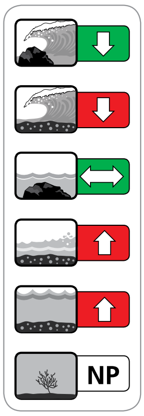
Other issues affecting status

There have been significant changes in the populations of grey and harbour seals. Harbour seals are continuing to decrease following earlier disease outbreaks although the cause of the continuing decrease is unknown. Dolphins, whales and porpoises are considered to be in good condition although there are some concerns about the level of fisheries by-catch of harbour porpoise. Some waterbird populations have declined and this has been linked to reduced food availability possibly due to pressure from shellfisheries.

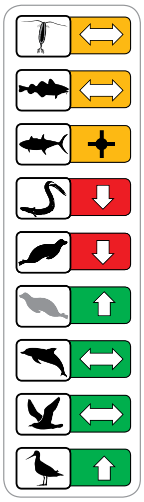




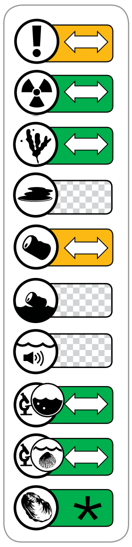
Habitats



Species

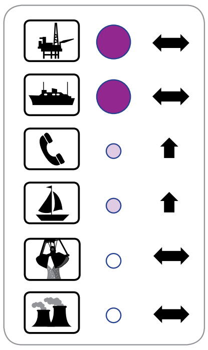


Clean and Safe Seas



Key on page 152

Productive Seas



Improvements

- Inputs of many hazardous substances are decreasing but there is a persistent legacy of some substances in industrialised estuaries
- It is now clear that eutrophication is not a problem for coastal waters
- Populations of dolphins, whales and porpoises are now considered to be in good condition
- There are signs that the quality of demersal fish communities is improving

Main issues

- Fishing is still having an impact on commercial fish stocks, demersal fish and seabed sediment habitats
- Harbour seal populations are decreasing but the cause of the decrease is not known
- Beach litter is an aesthetic and economic problem, more research is needed to assess overall ecological impact

Creating wealth

- Main contributors to the economy are the oil and gas sector and maritime transport, with smaller contributions from leisure and recreation, telecoms, mineral and water abstraction
- Widespread physical pressures on the marine environment arise from fishing, with small and more local pressures due to oil and gas, shipping, leisure and recreation and aggregate extraction

Changing climate

- Rising sea temperature has caused changes in the plankton community, lengthened the growing season and changed the distribution of some fish species
- Rising sea levels are adversely affecting a large proportion of the coast which is vulnerable to flooding and erosion

Eastern Channel (Region 3)

The Eastern Channel extends from Dover in the east to Dartmouth in the west. Water depths are generally less than 50 m but reach 100 m towards the west. The coastline is shelving sand, shingle and pebble beaches with significant stretches of cliff landscape. The main offshore habitats are large expanses of sands and gravels. Tidal currents are strong and the water is well mixed and relatively turbid. Sea-surface temperature varies from 5 °C in winter to 19 °C in summer.

Climate change

Sea level is rising, increasing the risk of coastal erosion, flooding and loss of intertidal habitats due to 'coastal squeeze'. This is a particular concern in this region, where the land is sinking and parts of the coast are low-lying and composed of soft sediment.

Sea temperature continues to rise and is thought to have resulted in the extension of the range of southern rocky shore species east of the Isle of Wight.

Maritime economy

Maritime transport provides the most important economic contribution, with ports in Dover, Portsmouth and Southampton moving container ships, cargo ships and ferries to continental Europe and serving cruise ships. Ministry of Defence activities also provide significant value because of the Portsmouth Naval Base and associated ship building activities.

Recreational activities are important. The Sussex, Hampshire and Dorset coasts support tourism, a leisure boating industry, recreational fishing and scuba diving. There is a high proportion (16%) of coastal defence and flood protection schemes although the region is less vulnerable to coastal erosion and flooding compared to other parts of south-eastern England because of the cliff coastlines. Marine aggregate resources are increasing in economic importance as they are close to areas of high population growth and development.

Fishing pressure

Assessed commercial fish stocks are either not at full reproductive capacity or are not being harvested sustainably. Demersal fish communities have not changed despite a reported decrease in fishing effort although there is some evidence that the average size of fish is increasing. However, confidence in the fish assessment is low due to limited data. Salmon and eel populations in estuaries are declining.

Fishing using mobile gear is having an impact on some seabed sediment and rocky habitats. This has resulted in loss of large slow-growing seabed organisms, for example those associated with shallow sediment habitats. Fisheries by-catch may also be affecting marine mammals.

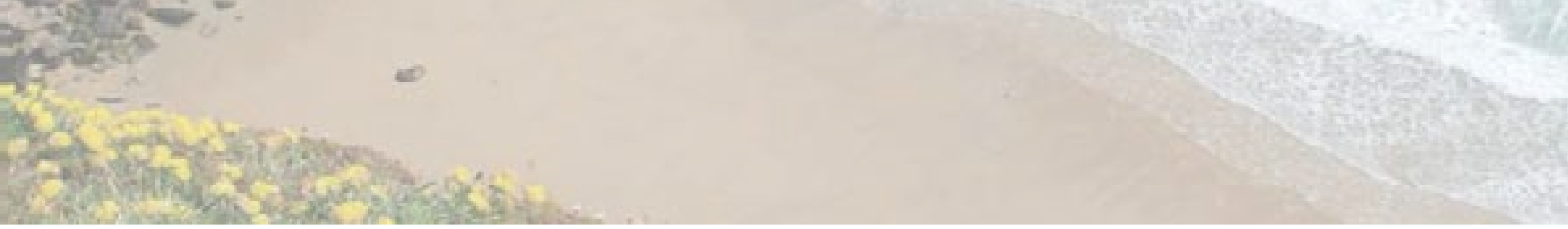
Other issues affecting status

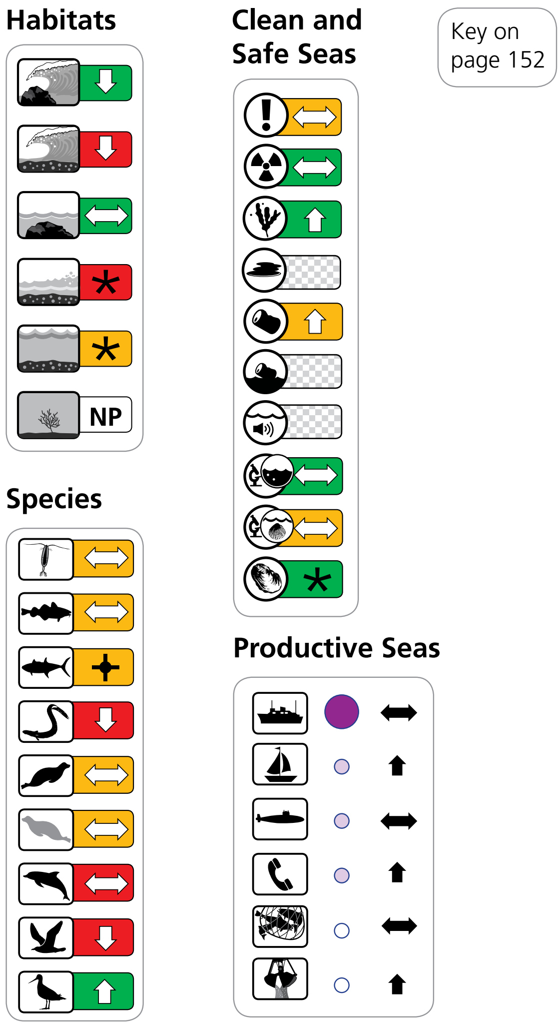
Numbers of sandwich tern and little tern declined by more than 25% between 1986 and 2007. These seabirds are of conservation importance and the decline is attributed to disturbance of the seabirds by predators and storm events.

There is evidence in this region of non-native organisms colonising appropriate habitats, for example cord grass in saltmarsh and mudflats, slipper limpets and pacific oyster on rocky shores.

Although there is a general concern about the presence and impact of marine litter this is the one region where there has been a decline in the amount of litter on beaches.

Traffic in Dover Strait





Improvements

- There are signs that the quality of demersal fish communities is improving
- It is now clear that eutrophication is not a problem for coastal waters but there are problems in coastal harbours and estuaries

Main issues

- There is a persistent legacy of hazardous substances in industrialized estuaries
- Fishing is still having an impact on commercial fish stocks, demersal fish and seabed sediment habitats
- Populations of seals, dolphins and porpoises are not in good condition as a result of fisheries by-catch
- Beach litter is an aesthetic and economic problem, more research is needed to assess overall ecological impact
- Seabird populations have experienced declines and this has been linked to summer storms and predation

Creating wealth

- Main contributors to the economy are maritime transport, with smaller contributions from leisure and recreation, telecoms, defence, mineral extraction and fishing
- Widespread physical pressures on the marine environment arise from fishing, with small and more local pressures due to oil and gas, shipping, leisure and recreation and defence

Changing climate

- Rising sea levels are increasing the risk of coastal erosion and flooding on low-lying parts of the coast
- Rising sea temperature has caused an extension of the range of southern rocky shore species

Western Channel and Celtic Sea (Region 4)

The Western Channel and Celtic Sea region extends around south-west England from Dartmouth in the east to St Davids Head in the north-west and extends across the Celtic Sea to the continental shelf edge. Water depths are generally between 50 m and 200 m, extending to 1000 m in the west. The coastline is predominantly rocky but with some areas of intertidal sediment occurring mainly in bays, inlets and around the coasts of the Bristol Channel. The main offshore habitats are largely sand and gravel with rocky outcrops. There are big seasonal variations in sea-surface temperature, ranging from 8 °C in winter to 18 °C in summer. Some areas become stratified in summer and the strong tides generate tidal fronts, which influence water circulation.

Climate change

Sea level is rising, increasing the risk of coastal erosion and flooding. This is a particular concern for the soft sediment coasts especially around the Bristol Channel where high tides and storm surges increase the risk of flooding.

Sea temperature is rising and has contributed to significant changes in the balance of warm-water and cold-water species in intertidal rocky habitat, although part of the change is due to shellfish harvesting.

Maritime economy

The south-west corner of the UK is a key point of landfall for international telecommunication connections from America and Africa, providing a significant indirect economic value. The two most valuable fisheries are beam trawling for demersal fish and cuttlefish, and pot fishing for crabs and lobsters.

The region also has important wave resources from which electricity could be generated, and is likely to become an important area for the testing of demonstrator devices over the next five years and deployment of commercial scale projects over the longer term. It also includes the Severn Estuary with the greatest potential tidal range energy in the UK and a number of options are being explored to harness this.

St Ives Bay

South Wales is particularly dependent on marine-dredged sand due to shortages in local land-won sources and there are currently no realistic alternatives. There are also two naval bases in the region, at Plymouth and Dartmouth, providing significant direct and indirect economic activity. There are also important ferry services from Swansea, Milford Haven and Pembroke dock linking with Ireland.

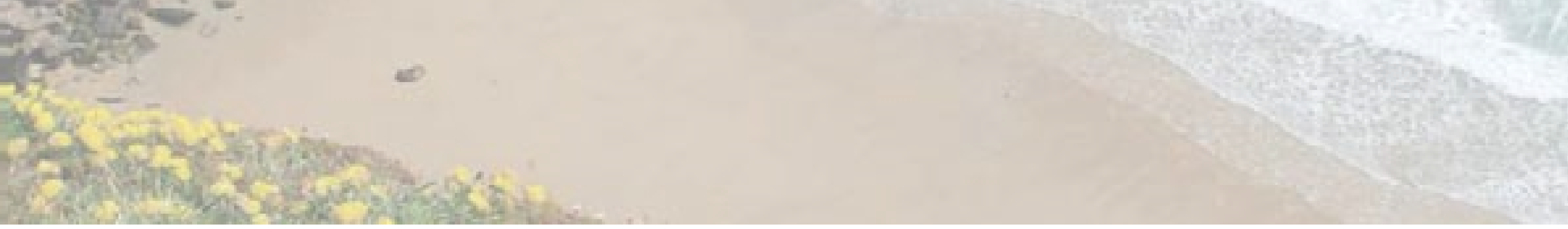
The region includes some attractive coastline ranging from exposed coasts to sheltered bays and inlets. As a result it is an important region for recreation particularly tourism, surfing and scuba diving.

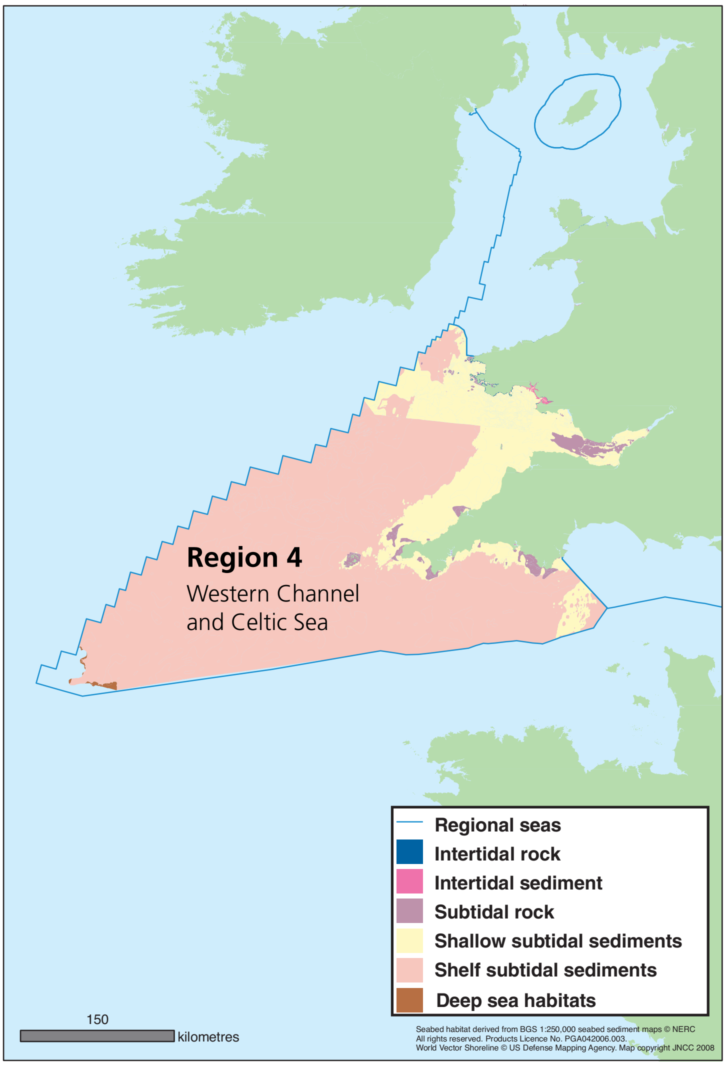
Fishing pressure

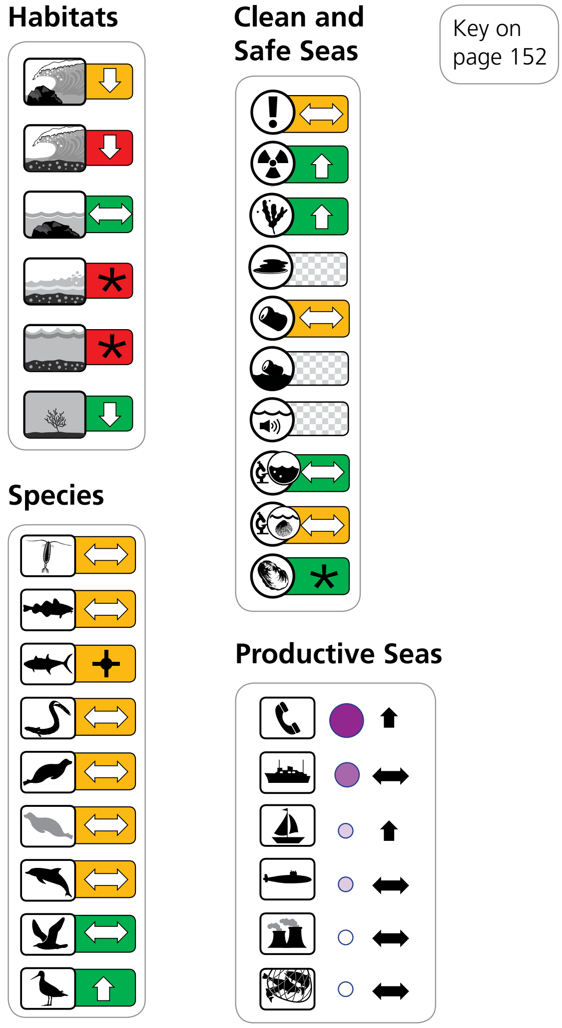
This is the only region in which fishing effort has increased. With the exception of a sole stock, assessed commercial fish stocks are either not at full reproductive capacity or are not being harvested sustainably. There have been improvements in some aspects of the demersal fish community but there is evidence, including a shift towards smaller fish that indicates continuing pressure.

Mobile fishing gears may be causing damage to seabed sediment habitats (although we have low confidence in this assessment) and this may have led to the decline or disappearance of large, slow-growing and/or fragile invertebrates from areas.

Fishing is a pressure on grey seals through indirect effects on prey and habitat but directly through by-catch. By-catch is also significant for common dolphins and harbour porpoises and relates to the types of fishing gear deployed.







Improvements

- Inputs of many hazardous substances are decreasing but there is a persistent legacy of some substances in industrialised estuaries
- There are some signs that the quality of demersal fish communities is improving

Main issues

- Fishing is increasing and is still having an impact on commercial fish stocks, demersal fish and seabed sediment habitats
- Dolphins, porpoises and grey seals are impacted through fisheries by-catch
- Beach litter is an aesthetic and economic problem, more research is needed to assess overall ecological impact

Creating wealth

- Main contributors to the economy are maritime transport and telecoms, with smaller contributions from leisure and recreation, defence, water abstraction and fishing
- Widespread physical pressures on the marine environment arise from increasing fishing activity, with small and more local pressures due to shipping, telecoms, leisure and recreation and defence

Changing climate

- Rising sea levels are increasing the risk of coastal erosion and flooding on the low-lying parts of the coast, especially in the Bristol Channel
- Rising sea temperature has contributed to changes in the balance of warm and cold water intertidal rocky species

Irish Sea (Region 5)

The Irish Sea region extends from the Mull of Kintyre in the north to St George's Channel in the south and includes the Firth of Clyde. Water depths are mostly less than 50 m but reach 100 m in the deeper western areas, which become stratified in the summer. The coastline is mostly rocky but with some extensive areas of intertidal sediment such as Morecambe Bay and the Solway Firth. The main offshore habitats are sands and gravels but mud is a feature in some areas. There are large seasonal variations in sea-surface temperature, ranging from 4 °C in winter to 18 °C in summer. Eastern areas receive significant freshwater input from the rivers of north-west England and south-west Scotland, noticeably lowering the salinity along the coastline.

Climate change

Sea level is rising and increasing the risk of coastal erosion and flooding. This is particularly important for the low-lying areas in the north-west of England, north Wales and south-west Scotland.

Sea temperature is rising and has caused a change in seabed biological communities in the eastern Irish Sea. For example, it has caused a decline in cold-water native seaweeds and has contributed to the spread of non-native species such as barnacle, wire weed and the Pacific oyster. On a positive note, the honey-comb worm has re-established on the north Wales coast, possibly due to the warming waters.

Maritime economy

The region is one of the busiest in the UK, has the major cities of Merseyside and Greater Manchester, Strathclyde and Belfast on its shores and is an important focus for a diverse array of activities. Pilot studies for marine planning have been conducted in this region.

Oil and gas is a key industry with a few discrete but productive reserves. In addition, there are important gas pipeline links from England and Scotland to Northern Ireland, the Republic of Ireland and the Isle of Man. The region has among the best sources of wind energy in the UK. There are four wind farms operating (North Hoyle, Burbo Bank, Barrow, Robin Rigg) and more are proposed. There are also important power and telecommunication links between mainland UK and Northern Ireland, the Republic of Ireland and the Isle of Man. Due to a number of strategically important coastal power stations, the value of water abstraction for cooling water is significant. The Sellafield nuclear fuel reprocessing facility is located in the region.

The largest and most valuable fishery in the Irish Sea is for *Nephrops* with a number of smaller fin-fish and shellfish fisheries. The Irish Sea is a nationally important area for shellfisheries. Species farmed are mainly mussels in Northern Ireland and the Menai Straits in Wales and oysters and scallops in the southern part of Strathclyde.

Maritime transport activities mainly comprise freight traffic between the surrounding countries. 21% of disposal sites for dredged material in the UK are located here but not all are in use at any one time.

This region has the second highest investment in coastal and flood protection. There are long stretches of attractive coast within easy reach of the population, making recreation important. Activities include surfing (e.g. along the Lleyn Peninsula), scuba diving (e.g. Strangford Lough and Anglesey) and cetacean watching (e.g. Cardigan Bay).

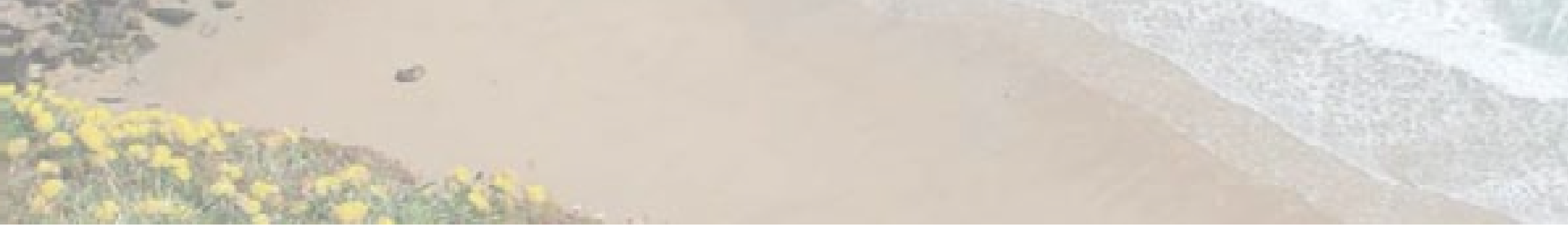
Fishing pressure

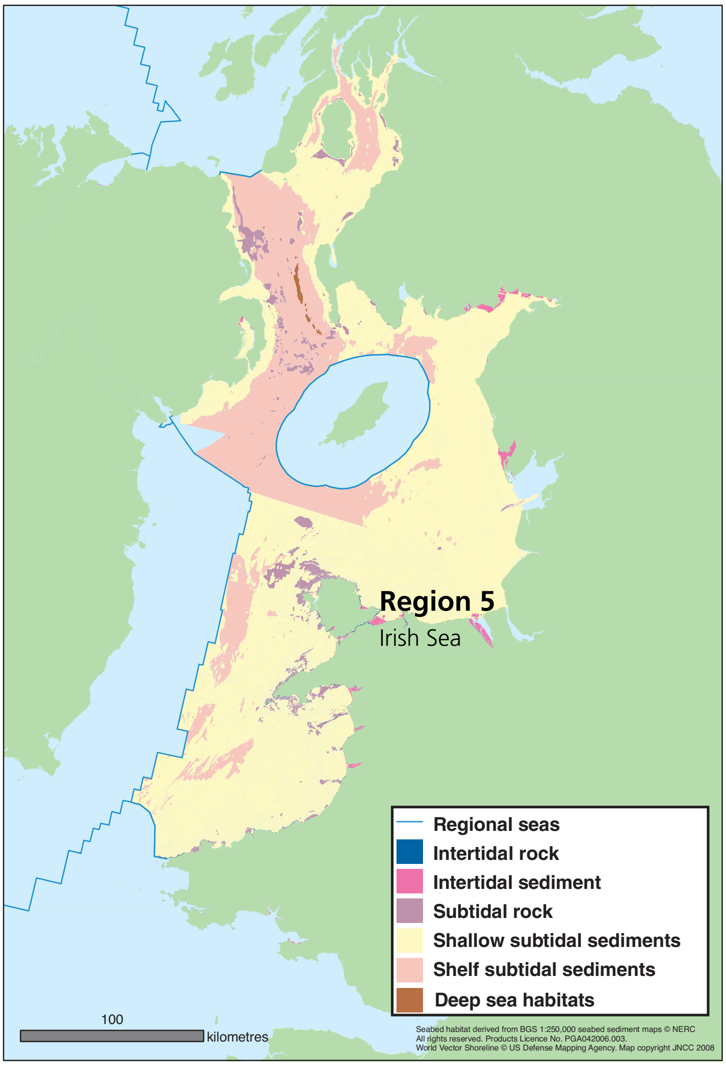
Assessed commercial fish stocks, including stocks of cod and sole, are neither at full reproductive capacity nor being harvested sustainably, with the exception of plaice stocks. However, the state of the demersal fish community as a whole is improving shown by evidence of increasing abundance, biomass, productivity and size composition. Populations of some species including cod, flounder and angel shark are not improving and smaller fish now dominate. Some rivers do not support the migration of salmon.

Coastal and seabed habitats, particularly soft sediments, are affected by bottom trawling and rocky coastlines are affected by shellfish collecting.

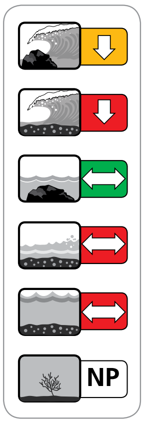
Other issues affecting status

Seabird populations are doing well: breeding numbers have increased substantially over the past 21 years. The number of waterbirds, such as waders, has decreased as more are now wintering in east coast estuaries.

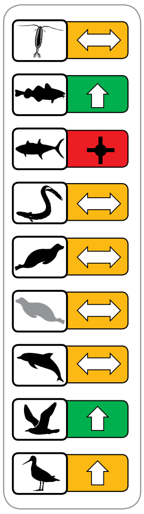




Habitats

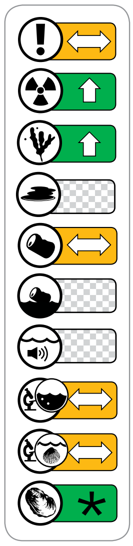


Species

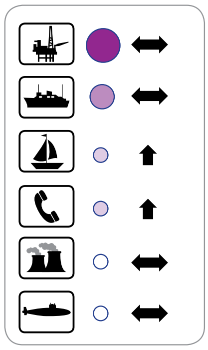


Clean and Safe Seas

Key on page 152



Productive Seas



Improvements

- Inputs of many hazardous substances are decreasing but there is a persistent legacy of some substances
- It is now clear that eutrophication is not a problem for coastal waters
- Seabird populations continue to do well with breeding numbers increasing
- The quality of demersal fish communities is improving

Main issues

- Fishing is still having a significant impact on commercial fish stocks and seabed sediment habitats
- Harbour seal populations are decreasing but the cause of the decrease is not known
- Beach litter is an aesthetic and economic problem, more research is needed to assess overall ecological impact
- Waterbird numbers in winter have declined as more birds winter in other regions

Creating wealth

- Main contributors to the economy are maritime transport and the oil and gas sector, with smaller contributions from telecoms, leisure and recreation, defence and cooling water abstraction
- Widespread physical pressures on the marine environment arise from fishing, with small and more local pressures due to oil and gas, shipping and leisure and recreation

Changing climate

- Rising sea levels are adversely affecting a large proportion of the low-lying parts of the coast which are vulnerable to flooding and erosion
- Rising sea temperature has caused changes in the seabed biological community with a decline in cold water species and has contributed to the spread of non-native species

Minches and Western Scotland (Region 6)

The Minches and Western Scotland region extends from the Mull of Kintyre in the south to Cape Wrath in the north, encompassing the extensive coastline of the Inner Hebrides and the east coast of the Western Isles. Much of the region is sheltered from the prevailing Atlantic waves. Water depths are between 50 m and 200 m and some areas become stratified in summer. The coastline is predominantly rocky but with many bays and sea lochs. The main offshore habitats are coarse sands, gravel and rock. There are large seasonal variations in sea-surface temperature, ranging from 6 °C in winter up to 15 °C in summer.

Climate change

The generally rocky coastline and the uplift of the land mean the coast is subject to little erosion and only a small proportion of the coast is vulnerable to rising sea levels. Sea temperature is rising but there are no documented changes to the ecosystem in this region.

Maritime economy

The coastline supports a range of inshore fisheries for shellfish and fin-fish. Inshore rocky areas support a widespread crustacean (lobster and crab) potting fishery and there is a significant fishery for *Nephrops* and pelagic fisheries for herring, mackerel and horse mackerel. Aquaculture includes fin-fish, particularly salmon, and shellfish, including oysters and scallops in the northern part of Strathclyde.

Marine wildlife watching is of particular value in the Minches and Western Scotland and leisure diving, particularly around the Inner Hebrides, is an important sector.

Fishing pressure

With the exception of saithe, assessed commercial fish stocks are neither at full reproductive capacity nor being harvested sustainably, including stocks of cod and haddock. This region, of all regions, has seen the most dramatic reduction in fishing effort in recent years, which has led to improvements in the composition, structure and functioning of the demersal fish community. The overall condition of the demersal fish community is on a par with that observed in 1986 when good information was available. Populations of basking sharks may be recovering following the closure of a directed fishery.

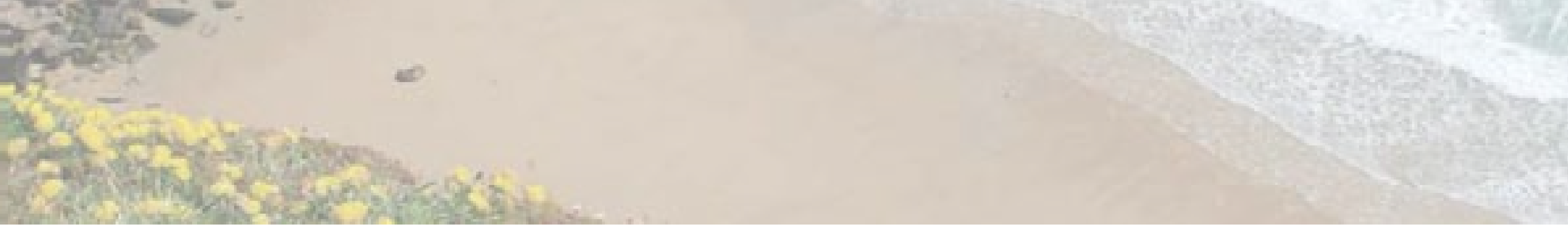
However, we found that fishing activities may still be having a significant impact on subtidal sediment habitats, although our confidence in the assessment is low.

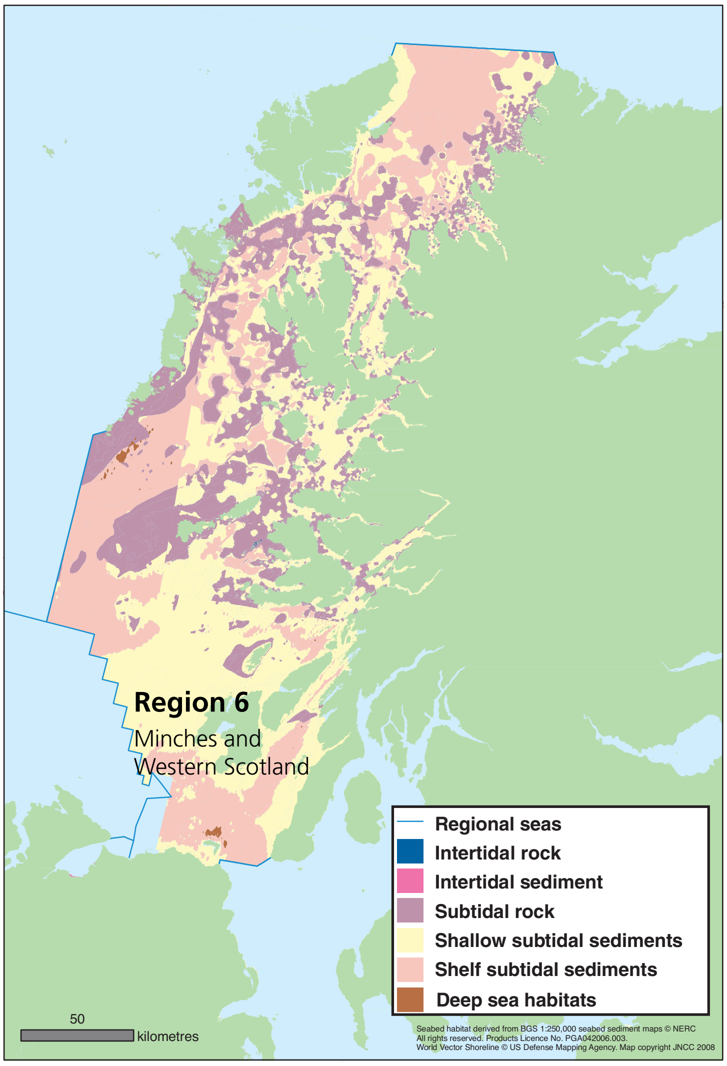
Other issues affecting status

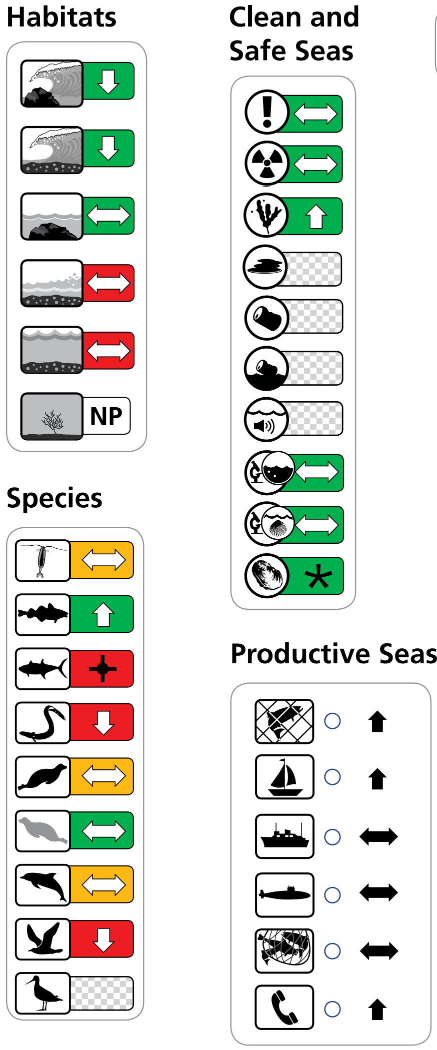
Seabird breeding numbers have declined over the past 20 years in part due to predation by introduced mammals. Management of the mammals, which include mink and hedgehogs, is leading to increasing numbers of seabirds. Poor food supply in some years may also be contributing to declining numbers.

Marine mammals may become entangled in ropes and nets and in the Minches there is concern about entanglement of Minke whales, which are important to the local economy, through marine wildlife watching. Fishing activity may be indirectly affecting seals through removal of prey but there is also some pressure on seal numbers through illegal killing.

Fish farm near Portree, Isle of Skye







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Improvements

- The quality of demersal fish communities is improving

Main issues

- Fishing effort has decreased but fishing is still having a significant impact on fish stocks and seabed sediment habitats
- Harbour seal populations are decreasing but the cause of the decrease is not known
- Seabird breeding numbers have declined due to predation by introduced mammals such as American mink but we do not know enough about other factors
- Populations of dolphins, whales and porpoises are under indirect threat from fishing and are important for the marine wildlife watching sector

Creating wealth

- Main contributors to the economy are aquaculture, maritime transport, leisure and recreation, defence, telecoms and fishing
- Widespread physical pressures on the marine environment arise from fishing, with small and more local pressures due to aquaculture, shipping, leisure and recreation and defence

Changing climate

- Rising sea levels are only adversely affecting a small proportion of the coast
- Sea temperature is rising but there are no observations of change to the plants and animals

Scottish Continental Shelf (Region 7)

The Scottish Continental Shelf includes the western coasts of the Outer Hebrides, Orkney and the western coast of Shetland and the northern coast of mainland Scotland. Typical water depths are between 100 m and 150 m and some areas become stratified in summer. The coastline is predominantly rocky. The main offshore habitats are expanses of mud, sand and coarse sediment. There are large seasonal variations in sea-surface temperature, ranging from 6 °C in winter up to 14 °C in summer.

Climate change

Sea level is rising but is not a significant issue in this region because of the generally rocky coastline. There is some evidence that rising sea temperature is leading to an extension of the northern limits of some warm-water seabed invertebrates.

Maritime economy

This region contains some of the most remote fishing communities in the UK, and the coasts support a range of inshore fisheries for shellfish and fin-fish including the most valuable UK towed-gear fisheries for demersal fish and *Nephrops*. Potting for edible crab is also now widespread. This region is the most valuable in the UK for marine fin-fish aquaculture.

There are some important hydrocarbon fields in the Scottish Continental Shelf region and there was increased activity in exploration and appraisal drilling in 2007. Production has not yet started.

Marine wildlife watching is a particularly important source of income in Northern Scotland and the Western Isles, Orkney and Shetland. The region is also important for leisure diving (e.g. Scapa Flow, Orkney) and a number of other coastal tourism activities including an annual surf championship.

Fishing pressure

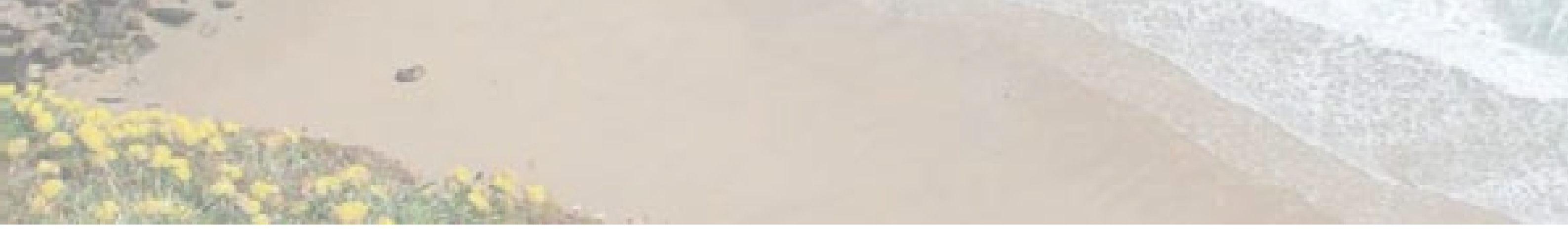
Assessed commercial fish stocks are either not at full reproductive capacity or are not being harvested sustainably. With the exception of saithe and one haddock stock, there is some indication of improvement in the demersal fish community in the south-west of the region but no obvious trend in the north-west despite a reduction in fishing effort.

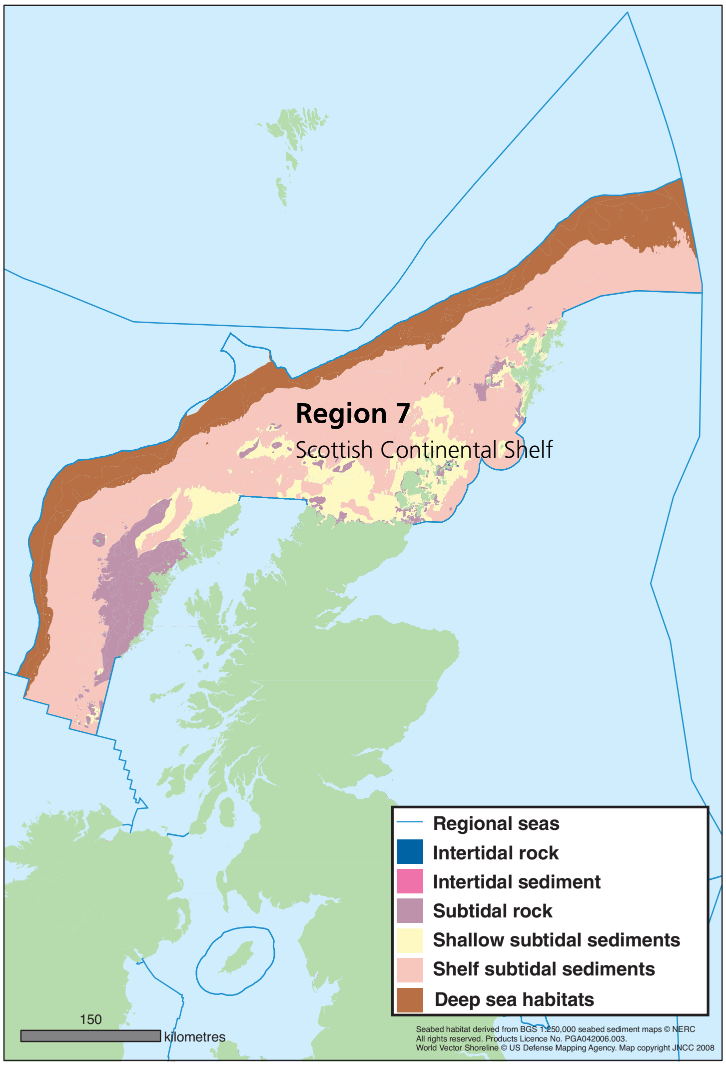
Mobile fishing gears have damaged the sedimentary habitats with particular concern for the recovery of large slow-growing and fragile species of seabed invertebrate, including damage to cold-water coral reefs. Fishing may add to the pressure on seals although the reason for the decline in harbour seal numbers is not known.

Other issues affecting status

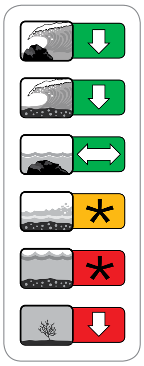
Seabird breeding numbers have declined. Breeding success has been lower than in any other UK region and particularly poor in Shetland. A shortage of food species has been associated with the declining numbers and a combination of fishing and rising sea temperature may be the cause of the reduced food supply but we do not have a good understanding of these interactions.

Muckle Flugga lighthouse, north of Unst in the Shetland Islands

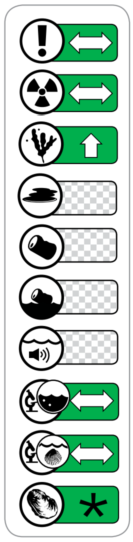




Habitats

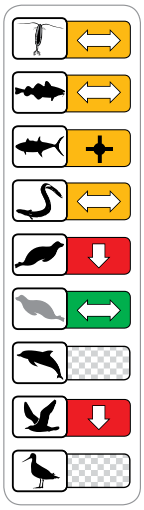


Clean and Safe Seas

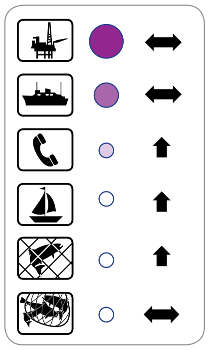


Key on page 152

Species



Productive Seas



Improvements

- There are signs that the quality of demersal fish communities is improving following a decrease in fishing effort

Main issues

- Fishing is still having an impact on commercial fish stocks, demersal fish and seabed sediment habitats
- Harbour seal populations are decreasing but the cause of the decrease is not known
- Seabird breeding numbers have declined due to poor breeding success possibly linked to food shortages and climate change

Creating wealth

- Main contributors to the economy are the oil and gas sector, with smaller contributions from maritime transport, leisure and recreation, telecoms, fishing and aquaculture
- Widespread physical pressures on the marine environment arise from fishing, with small and more local pressures due to oil and gas, shipping, leisure and recreation and aquaculture

Changing climate

- Rising sea temperature is leading to an extension of the northern limit of seabed animals
- Rising sea levels do not pose a significant threat to the coast which is rocky and rising

Atlantic North-West Approaches (Region 8)

The Atlantic North-West Approaches region differs from the other UK regions in having negligible coastline, and covers waters to the west and north of the 200 m depth contour. The main habitats are large expanses of mud and fine clay but a variety of coarser sediments are found in shallower waters on banks and seamounts. There is seasonal stratification and sea-surface temperature varies from 9 °C in winter to 14 °C in summer. Temperature in the deeper waters is colder and less variable.

Climate change

Rising sea level has no impact in this region because of the absence of coastline, but increasing sea temperature has caused changes in plankton production and distribution.

Maritime economy

The region is remote from major population centres so there are few economically important activities and therefore few pressures. At Rockall, there is a targeted fishery for haddock by Scottish and Irish trawlers (and Russian vessels in adjacent international waters). In the 1990s, some Scottish vessels diverted their activity to deep-water fisheries such as orange roughy, roundnose grenadier and black scabbard fish but low quotas to protect these particularly vulnerable species have all but stopped this activity by UK vessels. Further research is being undertaken to see if these species can be exploited sustainably.

Fishing pressure

There is some evidence that deep-water fish assemblages are less diverse and that large fish are less common than they were prior to exploitation. However, the limited data available mean that we have low confidence in this finding. More certain is the impact of mobile fishing gears on slow-growing and fragile invertebrate species on the seabed including reefs of the cold-water coral *Lophelia pertusa*.

Orange roughy

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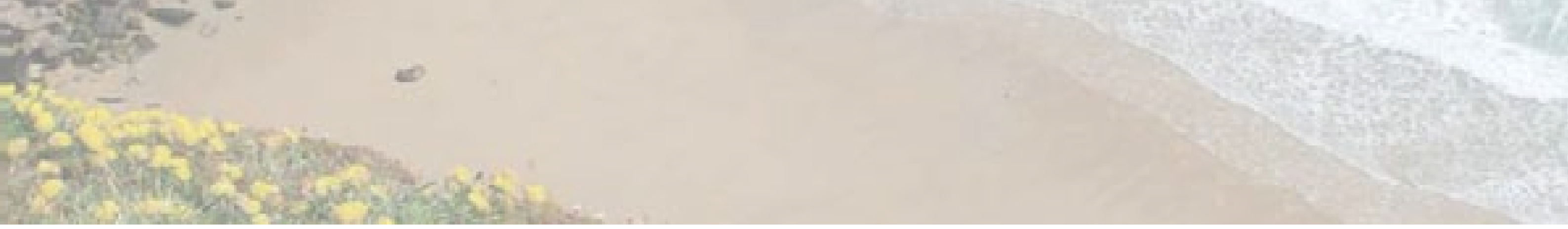
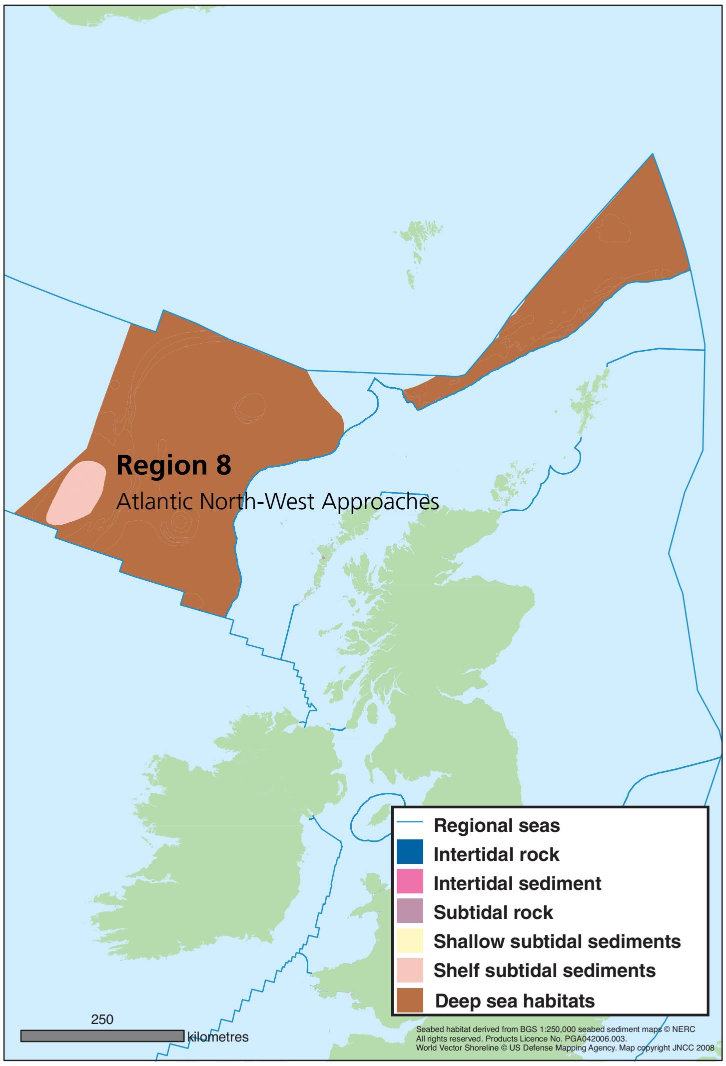
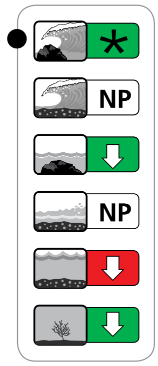
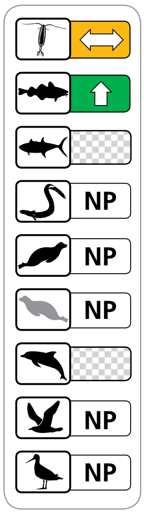




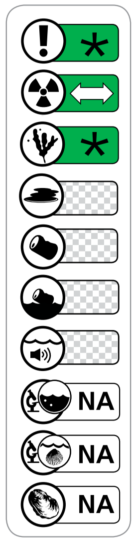
Habitats



Species

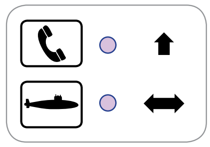


Clean and Safe Seas



Key on page 152

Productive Seas



● Rockall Island

Improvements

- There are signs that the quality of demersal fish communities is/are improving

Main issues

- Fishing has had an impact on commercial fish stocks and seabed sediment habitats

Creating wealth

- Main contributors to the economy are telecoms and defence
- Physical pressures on the marine environment arise from fishing

Changing climate

- Rising sea temperature has caused changes in phytoplankton growth and distribution

Key to regional maps

Healthy and Biologically Diverse Seas: Habitats

- Intertidal rock
- Intertidal sediments
- Subtidal rock
- Shallow subtidal sediments
- Shelf subtidal sediments
- Deep-sea habitats

Healthy and Biologically Diverse Seas: Species

- Plankton
- Bottom-living marine fish
- Commercial fish stocks
- Estuarine fish
- Harbour seals
- Grey seals
- Cetaceans
- Seabirds
- Waterbirds

Clean and Safe Seas

- Hazardous substances
- Radioactivity
- Oil/chemical spills
- Eutrophication
- Beach litter
- Offshore litter
- Noise
- Microbiological quality of bathing waters
- Microbiological quality of shellfish growing waters
- Algal toxins

- Few or no problems
- Some problems
- Many problems
- Lack of evidence and/or robust assessment criteria

Productive Seas

- Oil and gas
- Maritime transport
- Telecoms
- Leisure and recreation
- Fisheries
- Defence
- Water abstraction
- Aquaculture
- Mineral extraction

Gross Value Added (£)

- >1bn
- 500m - 1bn
- 100 - 500m
- 10 - 100m

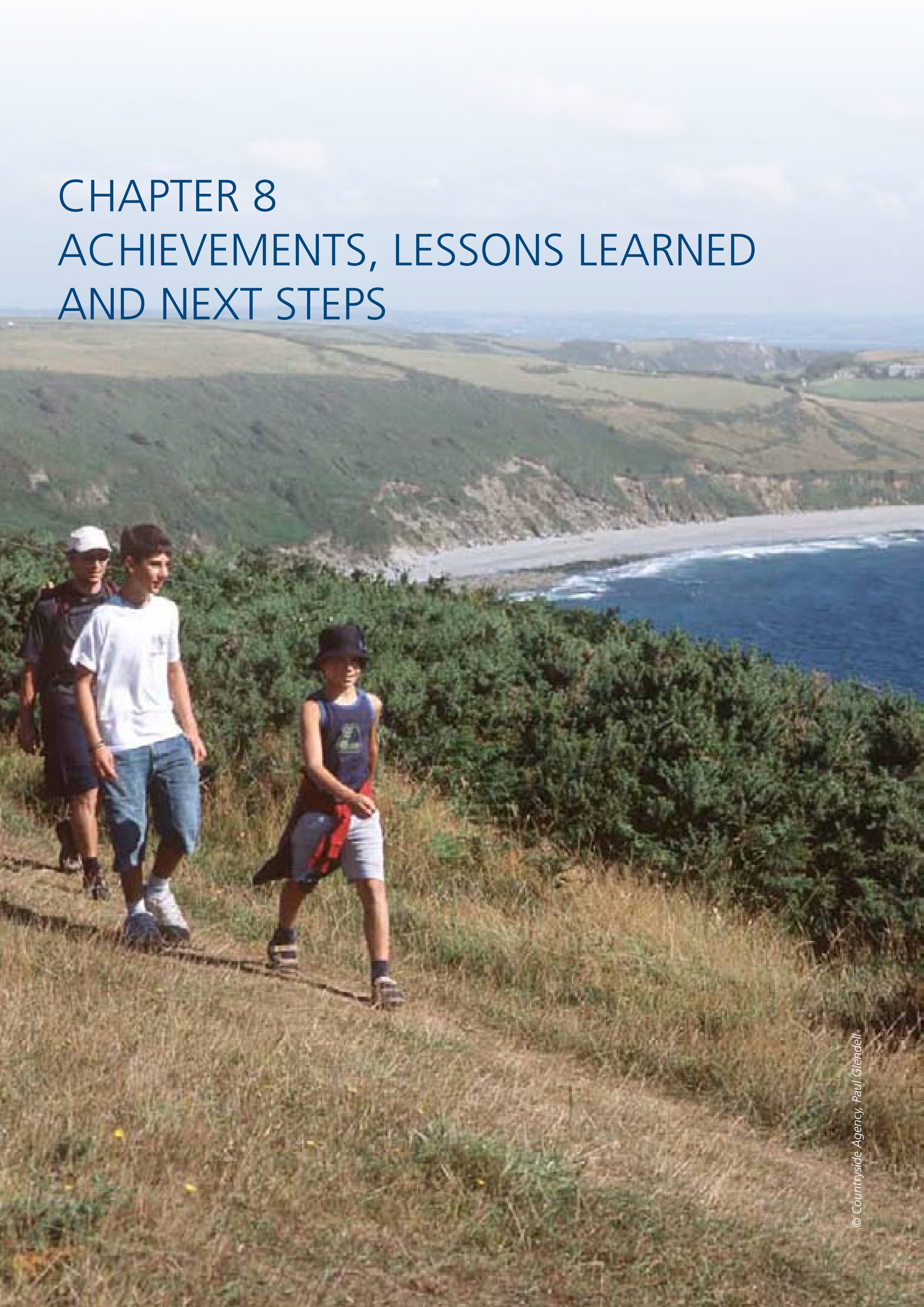
Change in pressure since 2003

- Increase
- Decrease
- No change

- * No trend information available
- ✚ Assessment of trend for each region not made
- **NA** No significant activity in the region
- **NP** Component not present in the region

- ⇧ Improvement
- ⇩ Deterioration
- ⇔ Stable (Habitats and Species) / No overall trend discernable (Clean and Safe Seas)

CHAPTER 8
ACHIEVEMENTS, LESSONS LEARNED AND NEXT STEPS



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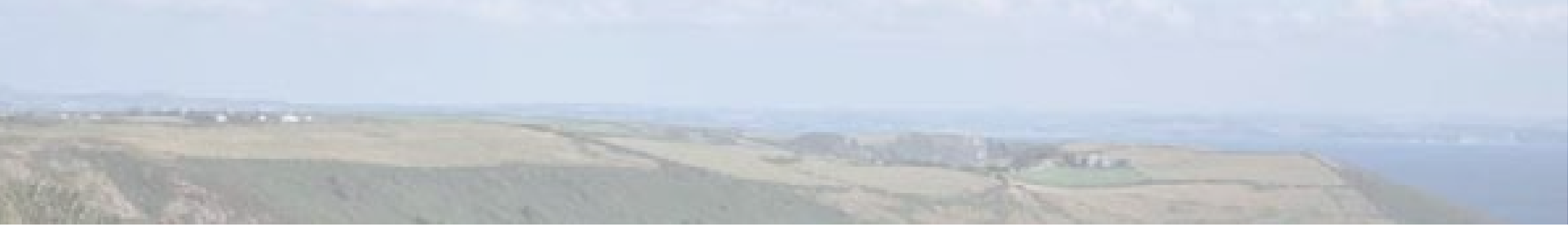


Introduction

This chapter briefly reviews what we, as the UK Marine Monitoring and Assessment Strategy (UKMMAS) community, believe we have achieved through the production and publication of *Charting Progress 2* and its associated Feeder Reports, and identifies the key lessons that we have learned and what we need to concentrate on in the coming years.

Achievements since *Charting Progress*

A broader and more integrated assessment

This report has built significantly on *Charting Progress* and provides a better picture of the state of the UK seas, by using a broader evidence base and more refined assessment tools. The assessment by the Productive Seas Evidence Group, which considers both the wealth generated by our marine industries and their pressures on the environment has been a major step forward, and has laid the groundwork for assessing the sustainable use of our seas. We now have a much clearer idea of the key issues on a regional basis. *Charting Progress 2* has also provided more robust baselines against which to measure further progress towards the vision of clean, healthy, safe, productive and biologically diverse oceans and seas and the extent to which they are used sustainably.

An interdisciplinary approach

The seas are multidimensional, and the way we assess them needs to be too. Following *Charting Progress*, we have developed a more joined-up approach to assessments, which has enabled scientists from different disciplines to work together in a more structured and coordinated way. We also have more regular exchanges between researchers and policy-makers, so that we now have a much better understanding of how evidence can be used both to shape and respond to marine policy.

Progress with methodologies for assessing the state of the seas

Chapters 2 to 6 describe in detail the improvements we have made in assessing the state of our seas since *Charting Progress*. Generally this involves using more extensive data sets and time series, monitoring more extensive areas of the seas, and obtaining more 'real time' data from continuous monitoring buoys, remote sensing devices and ferry boxes.

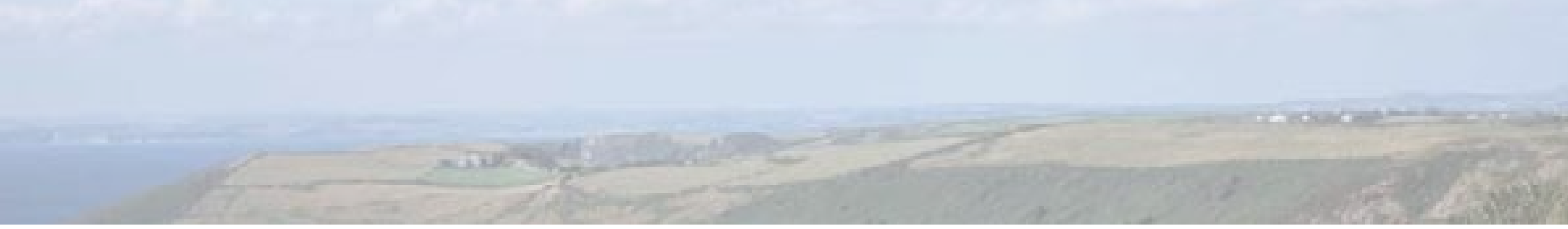
What we have learned

More clarity on the main problems

Chapters 2 to 6 and particularly Chapter 7, have identified the main problems that are preventing us from achieving the vision for the UK seas and in many cases their probable causes across the eight UK regions. This helps us to prioritise our efforts to improve our understanding of the relationships between the pressures and the impacts and informs regulators of where additional measures might be necessary.

Better criteria to determine whether the seas are clean, healthy, safe, productive and biologically diverse

All the Evidence Groups stressed the need to have clearer criteria and targets for defining what we mean by clean, healthy, safe, productive and biologically diverse seas. For this assessment we have used thresholds set in International and European frameworks or



those under development at national level, which indicate whether a desired quality has been achieved. For example, to assess whether the seas are clean with respect to particular contaminants, we took measurements of the concentrations of the contaminants in water, biota and sediment, and compared them with concentrations that cause no adverse effects to humans or sea life according to experiments. However, there are no clearly established criteria for some aspects of the vision, for example, the impacts of noise and litter on marine organisms, making it difficult to measure our progress in some areas. The EU Marine Strategy Framework Directive will help with the development of such criteria at European level.

Setting appropriate baselines and targets

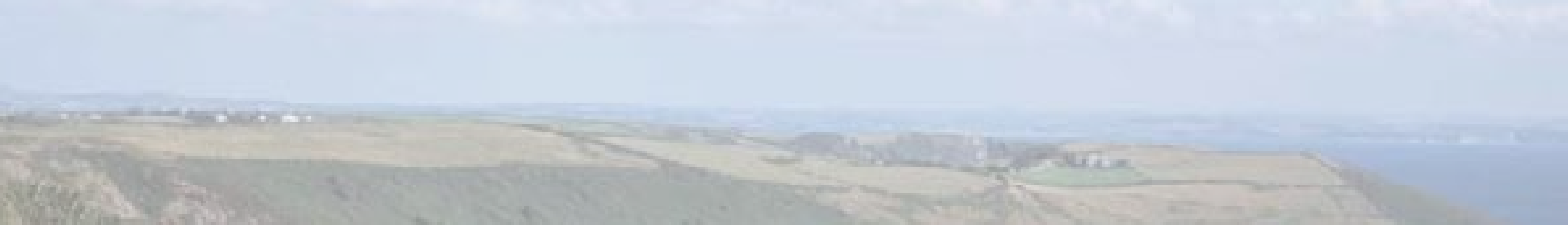
A related issue is the question of the state we want our seas to reach in order to be clean, healthy, safe, productive and biologically diverse within a framework of sustainable development. Some of the thresholds used (for example those derived from the EU Water Framework Directive) use a state that was 'natural' before human pressures were introduced as a reference. Others, for example, those for the fisheries assessment undertaken by the Productive Seas Evidence Group are based on the EU Common Fisheries Policy, which aims for the harvesting of fish at sustainable levels. When assessing habitats and species, we have sometimes found it difficult to determine what a natural state is; ecosystems are dynamic, and change due to natural causes, and in some cases monitoring programmes have started too recently to provide accurate records of natural conditions. The *Charting Progress 2* assessment has used the assessment criteria that are widely used for assessing the state of the seas, and has not attempted to resolve this issue. Policy makers will need to address this tension between natural conditions and sustainable use, particularly when developing the targets needed to achieve Good Environmental Status under the EU Marine Strategy Framework Directive.

A truly integrated approach to assessments remains a challenge

Significant progress has been made in understanding the impacts of individual pressures on sea areas, but assessing the impacts of multiple pressures and determining the most important human impacts have still to be realised. Adopting an ecosystem-based approach requires an understanding of how the various pressures contribute to any change in the structure and functioning of ecosystems. An appropriate methodology is needed. However, some thought for the scale at which these assessments must be made, which will vary in relation to the species being assessed or the pressure being investigated, will be required as part of this process. Furthermore, care is needed to avoid the possibility of aggregating data to an inappropriate scale.

More coverage

In many cases, our assessments of state are based on limited data sets or expert judgement. For example, we have habitat maps available for around only 10% of the UK continental shelf. One way we have tried to address this is to carry out risk- or pressure-based monitoring programmes, involving sampling where we expect to find problems, based on our knowledge of where the main pressures will be. However, for a more robust picture, we will need better information. Chapters 2 to 6 have highlighted a number of gaps in our knowledge of various aspects of the marine environment which limit our ability to assess its real status.



Next steps

Through its working groups, the UKMMAS community will take up the challenges of further developing the criteria and indicators for determining the state of our seas, improving the assessment methodologies and addressing the knowledge gaps at UK, European and international level.

Enhancing research to address gaps in knowledge

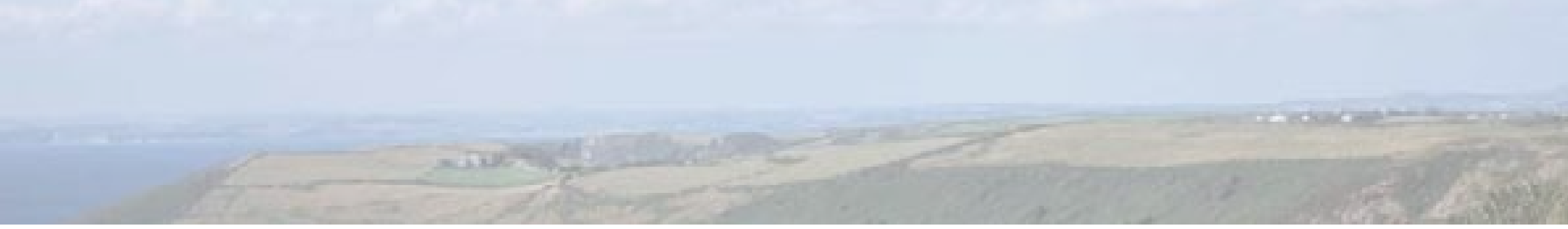
UKMMAS and its working groups will work under the Marine Science Co-ordination Committee which recently published a 15-year UK Marine Science Strategy for delivering world class marine science to inform decisions on food and energy security, managing the seas sustainably and dealing with climate change. This should bring marine research and monitoring more closely together, and should further enhance the relationship between the research community and policy makers that we developed during the combined efforts that have led to this report. This should in turn enable a more objective process for the prioritising and funding of research needed to fill the gaps in knowledge.

Developing the targets and monitoring programmes for achieving Good Environmental Status

The key tasks of developing better targets and indicators, improving monitoring methodologies and addressing gaps in knowledge will also be driven to a large extent by our obligations under the EU Marine Strategy Framework Directive. This legally binding instrument establishes a framework within which Member States must take measures to achieve or maintain Good Environmental Status in the marine environment by 2020. The achievement of Good Environmental Status under the Marine Strategy Framework Directive and the achievement of clean, healthy, safe, productive and biologically diverse oceans and seas are intimately linked and bear many common elements. A key feature of the Directive is the requirement for Member States to determine a set of characteristics for Good Environmental Status as well as associated targets and indicators. The UKMMAS community will need to provide advice in this regard, as well as playing a key role in delivering the necessary monitoring and assessment.

Initial assessment for the Marine Strategy Framework Directive

One of the key early requirements of the Marine Strategy Framework Directive is to make an initial assessment of the current status of the UK's marine waters based on an analysis of their essential features and characteristics, and an analysis of the predominant pressures and impacts on them, including from human activity. The assessment must also include an economic and social analysis of the use of the UK's marine waters and of the cost of degradation of the marine environment. The evidence compiled for the *Charting Progress 2* assessment will clearly provide the main basis for the initial assessment. Box 8.1 shows the key requirements of the initial assessment, and where the key components in *Charting Progress 2* and its Feeder Reports can be found.



Box 8.1 Location of information in *Charting Progress 2* and its Feeder Reports relevant to the Initial Assessment for the Marine Strategy Framework Directive.

The Initial Assessment requires:

- An analysis of the essential features and characteristics, and current environmental status of a Member State's marine waters, based on the indicative lists of elements set out in Table 1 of Annex III of the Directive (see Table 8.1), and covering the physical and chemical features, the habitat types, the biological features and the hydro-morphology.
- An analysis of the predominant pressures and impacts, including human activity, on the environmental status of those waters which:
  - is based on the indicative lists of elements set out in Table 2 of Annex III (see Table 8.2), and covers the qualitative and quantitative mix of the various pressures, as well as discernible trends;
  - covers the main cumulative and synergetic effects;
  - takes account of the relevant assessments which have been made pursuant to existing EU legislation;
- An economic and social analysis of the use of those waters and of the cost of degradation of the marine environment.

Table 8.1 Location of relevant information. The table is based on the Marine Strategy Framework Directive, Annex III, Table 1: Characteristics. FR stands for Feeder Report.

Physical and chemical features	Topography and bathymetry of the seabed Annual and seasonal temperature regime and sea-ice cover, current velocity, upwelling, wave exposure, mixing characteristics, turbidity, residence time Spatial and temporal distribution of salinity pH, pCO_2 profiles or equivalent information used to measure marine acidification Spatial and temporal distribution of nutrients (dissolved inorganic nitrogen, total nitrogen, dissolved inorganic phosphorus, total phosphorus, total organic carbon) and oxygen	Chapter 2 + OPEG FR Chapter 4 + CSSEG FR

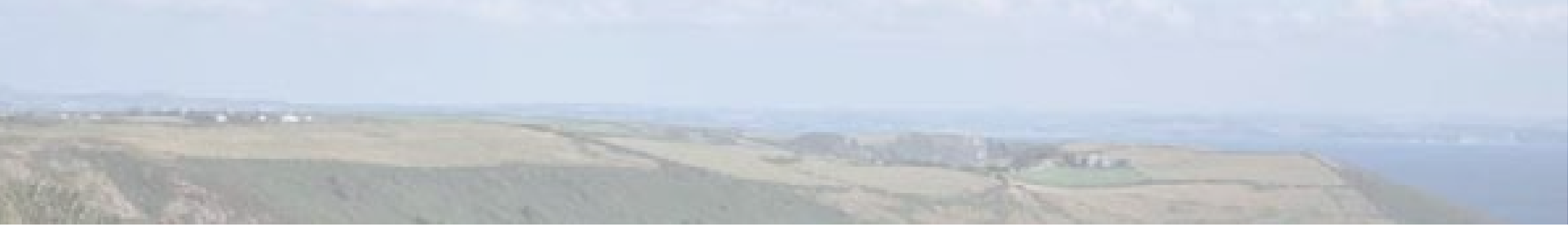


Table 8.1 continued

Habitat types	The predominant seabed and water column habitat type(s) with a description of the characteristic physical and chemical features, such as depth, water temperature regime, currents and other water movements, salinity, structure and substrata composition of the seabed Identification and mapping of special habitat types, especially those recognised or identified under EU legislation (the Habitats Directive and the Birds Directive) or international conventions as being of special scientific or biodiversity interest Habitats in areas which by virtue of their characteristics, location or strategic importance merit a particular reference. This may include areas subject to intense or specific pressures or areas which merit a specific protection regime	Chapter 3 + HBDSEG FR
Biological features	A description of the biological communities associated with the predominant seabed and water column habitats. This would include information on the phytoplankton and zooplankton communities, including the species and seasonal and geographical variability Information on angiosperms, macro-algae and invertebrate bottom fauna, including species composition, biomass and annual/seasonal variability Information on the structure of fish populations, including the abundance, distribution and age/size structure of the populations A description of the population dynamics, natural and actual range and status of species of marine mammals and reptiles occurring in the Marine Region or Sub-Region A description of the population dynamics, natural and actual range and status of species of seabirds occurring in the Marine Region or Sub-Region A description of the population dynamics, natural and actual range and status of other species occurring in the Marine Region or Sub-Region which are the subject of EU legislation or international agreements An inventory of the temporal occurrence, abundance and spatial distribution of non-indigenous, exotic species or, where relevant, genetically distinct forms of native species, which are present in the Marine Region or Sub-Region	Chapter 3 + HBDSEG FR Chapter 5 + PSEG FR
Other features	A description of the situation with regard to chemicals, including chemicals giving rise to concern, sediment contamination, hot spots, health issues and contamination of biota (especially biota meant for human consumption) A description of any other features or characteristics typical of or specific to the Marine Region or Sub-Region	Chapter 4 + CSSEG FR Chapter 7

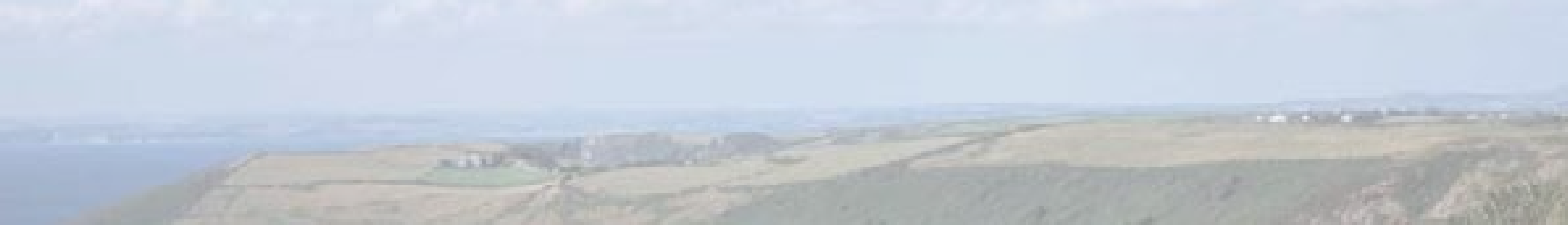


Table 8.2 Location of relevant information. The table is based on the Marine Strategy Framework Directive, Annex III, Table 2: Pressures and Impacts. FR stands for Feeder Report.

Physical loss	Smothering (e.g. by man-made structures, disposal of dredge spoil) Sealing (e.g. by permanent constructions)	HBDSEG FR
Physical damage	Changes in siltation (e.g. by outfalls, increased run-off, dredging/ disposal of dredge spoil) Abrasion (e.g. impact on the seabed of commercial fishing, boating, anchoring) Selective extraction (e.g. exploration and exploitation of living and non-living resources on seabed and subsoil)	HBDSEG FR
Other physical disturbance	Underwater noise (e.g. from shipping, underwater acoustic equipment) Marine litter	Chapter 4 + CSSEG FR
Interference with hydrological processes	Significant changes in thermal regime (e.g. by outfalls from power stations) Significant changes in salinity regime (e.g. by constructions impeding water movements, water abstraction)	Chapter 5 + Chapter 7 PSEG FR + HBDSEG FR
Contamination by hazardous substances	Introduction of synthetic compounds (e.g. priority substances under Directive 2000/60/EC which are relevant for the marine environment such as pesticides, antifoulants, pharmaceuticals, resulting e.g. from losses from diffuse sources, pollution by ships, atmospheric deposition and biologically active substances); Introduction of non-synthetic substances and compounds (e.g. heavy metals, hydrocarbons, resulting e.g. from pollution by ships and oil, gas and mineral exploration and exploitation, atmospheric deposition, riverine inputs); Introduction of radio nuclides.	Chapter 4 + CSSEG FR
Systematic and/ or intentional release of substances	Introduction of other substances, whether solid, liquid or gas, in marine waters, resulting from their systematic and/or intentional release into the marine environment, as permitted in accordance with other Community legislation and/or international conventions.	Chapter 4 + CSSEG FR
Nutrient and organic matter enrichment	Inputs of fertilisers and other nitrogen - and phosphorus-rich substances (e.g. from point and diffuse sources, including agriculture, aquaculture, atmospheric deposition); Inputs of organic matter (e.g. sewers, mariculture, riverine inputs).	Chapter 4 + CSSEG FR
Biological disturbance	Introduction of microbial pathogens; Introduction of non-indigenous species and translocations; Selective extraction of species, including incidental non-target catches (e.g. by commercial and recreational fishing).	Chapter 4 + CSSEG FR HBDSEG FR

Afterword

It is clear that much progress has been made since the need for periodic formal assessments of the state of the seas around the UK was introduced in *Safeguarding our Seas*, published in 2002. The considerable level of interest in the oceans and seas across society has never been more evident, but we have been challenged by our ability to make assessments of the type required and there is much still to do to provide a truly clear picture of the overall status of our seas as well as the condition of specific components of the marine environment. Providing evidence from the sea is an expensive business and we face significant pressures on the resources society is able to deploy to allow further exploration. Thus, there is a significant challenge to the broad science community to deliver robust yet cost-effective ways of assessing the quality of the marine environment, which will involve innovation in the way the work is carried out and a broad partnership across society. Our cultural heritage as seafaring people and the emotional attachment of many to looking after the sea bodes well for the future health of this vital part of the global life support system.

Acknowledgements

The main body of this report has been written and edited by the *Charting Progress 2* Editorial team, based on the evidence presented within the four Feeder Reports. The Editorial team (in alphabetical order) was:

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Annex 1

The following organisations are members of the UK Marine Monitoring and Assessment Strategy (UKMMAS) community

An Agency within the Department of the
Environment
www.doeni.gov.uk

ENGLISH HERITAGE

Environment Agency

Environment & Heritage Service
www.ehsni.gov.uk

Food Standards Agency
food.gov.uk

JNCC
Joint Nature Conservation Committee

The Marine Biological Association
125 years

Marine Conservation Society
MCS

Marine Environmental Change Network
MECN

MEDIN
marine environmental data & information network

mmo
marine management organisation

marine scotland

and Marine Scotland Science

mca
Maritime and Coastguard Agency

Met Office

MINISTRY OF DEFENCE

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

NATURAL ENGLAND

NATURAL ENVIRONMENT RESEARCH COUNCIL

NIEA
www.ni-environment.gov.uk
Northern Ireland Environment Agency

Northern Ireland Executive
www.northernireland.gov.uk

PML
Plymouth Marine Laboratory

renewableUK
The voice of wind & marine energy

SEPA
Scottish Environment Protection Agency

The Scottish Government

Scottish Natural Heritage
All of nature for all of Scotland

SMRU

SAHFOS

THE CROWN ESTATE

THE UNITED KINGDOM HYDROGRAPHIC OFFICE

UKMPG

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

WRc

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Figure 2.3: Circulation of surface waters in the North-East Atlantic (Courtesy of S. Hughes, Marine Scotland, © Crown copyright 2010

Figure 2.4: Church, J.A., Woodworth, P.L., Aarup, T. and Wilson, W.S. 2010. Understanding sea-level rise and variability. Published by Wiley-Blackwell, London (in press ISBN-13: 978-1444334524)

Figure 2.5: Courtesy of the Geological Survey of Norway, NGU

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Figure 3.5: Courtesy of JNCC and British Trust for Ornithology (BTO) on behalf of Seabird Monitoring Programme and Wetland Bird Survey partnerships

Figure 3.6: Courtesy of BTO on behalf of Wetland Bird Survey Partnership

Figure 3.7: Courtesy of JNCC on behalf of Seabird Monitoring Programme Partnership

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Figure 5.4: Source: R3 Developer Programmes, as of December 2009 – The Crown Estate

Figure 5.5: [Justine Saunders] Oxford Economics (2009)

Figure 6.1: Reproduced from [Intergovernmental Panel on Climate Change (IPCC)-AR4 WG1 FAQ1.3 Figure 1, page 98)

IPCC, 2007: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Figure 6.2: Reproduced from IPCC AR4 WG1 Chp 9 FAQ 9.2 Figure 1, page 703

IPCC, 2007 as above

Figure 6.3: Source: Lowe, J. A., Howard, T., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., Ridley, J., Dye, S., and Bradley, S. (2009), UK Climate Projections science report: Marine and coastal projections. Met Office Hadley Centre, Exeter, UK. ISBN 978-1-906360-03-0

Figure 6.4: Source: Edwards, M., Beaugrand, G., John, A.W.G., Johns, D.G., Licandro, P., McQuatters-Gollop, A. and Reid, P.C. (2009) Ecological Status Report: results from the CPR survey 2007/2008. SAHFOS Technical Report, 6: 1:12. Plymouth, UK. ISSN 1744-0750

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