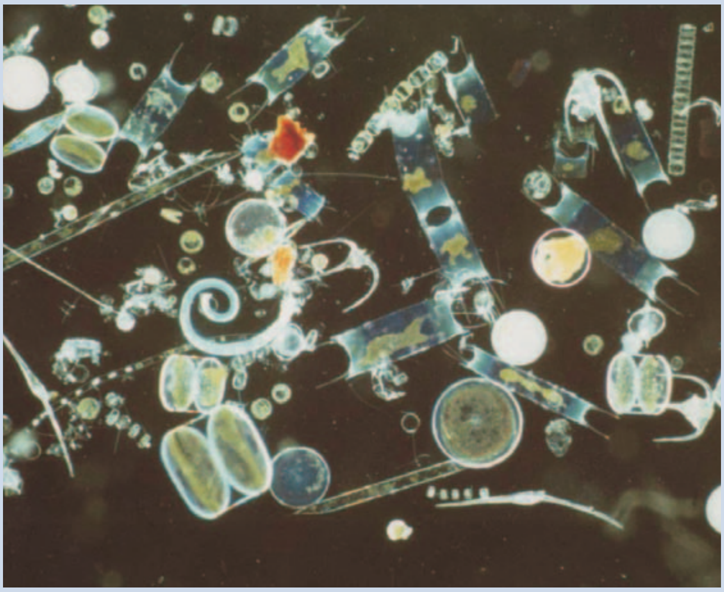
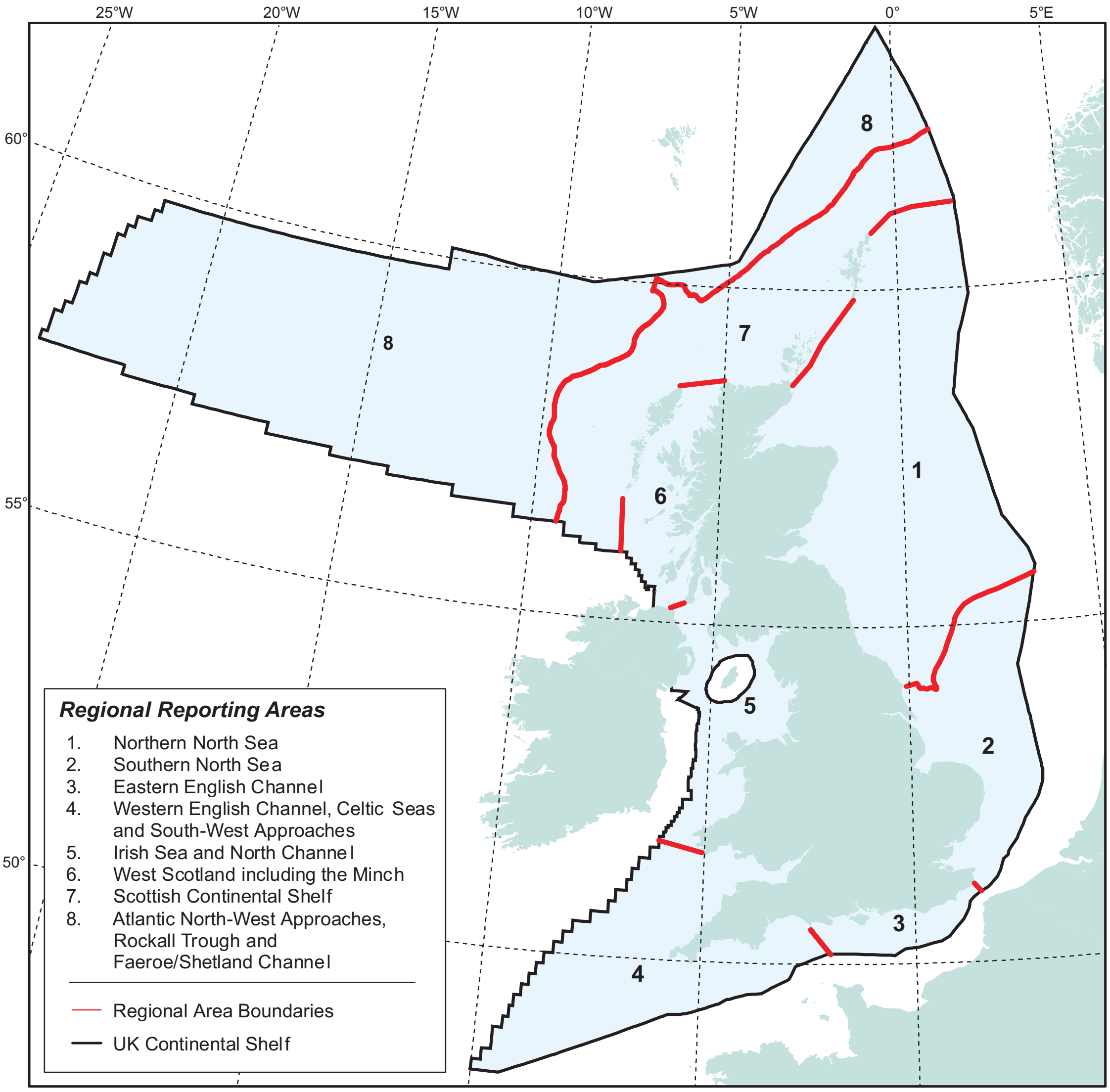
3: Marine Habitats and Species



The Marine Biodiversity contribution to Charting Progress - an Integrated Assessment of the State of UK Seas (The 3rd of 5 Reports)



Note: The exact limits of the UK Continental Shelf are set out in orders made in Section 1(7) of the Continental Shelf Act 1994.

Figure 0.1 The Regional Reporting Areas around the UK

This report is one of five that have been produced to provide detailed scientific assessment in support of '*Charting Progress – an Integrated Assessment of the State of the UK Seas*'; published by the Department for Environment, Food and Rural Affairs on behalf of the UK Government and Devolved Administrations in March 2005.

The five reports in the series are as follows:

1: Marine Environment Quality
2: Marine Processes and Climate
3: Marine Habitats and Species
4: Marine Fish and Fisheries
5: Integrated Regional Assessment

All reports can be found on the Defra website: www.defra.gov.uk

The 3rd of 5 reports produced to support **Charting Progress** – an Integrated Assessment of the State of UK Seas

Marine Habitats and Species

2005

Contents

NB: The state of fish can be found in the Marine Fish and Fisheries assessment.

Cover photograph credits:
Top left - Phytoplankton (SAHFOS).
Bottom left - Circalittoral rock with the southern sea fan *Eunicella verrucosa* and red sea fingers *Alcyonium glomeratum* (Keith Hiscock/JNCC).
Top right - Kittiwakes on cliffs of Fowlsheugh, Crawton, Aberdeenshire (Matt Parsons).
Bottom right - Minke whale (Jim Reid/JNCC).

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Executive summary

The present report represents the contribution from the UK government's Biodiversity Conservation Sector to the Department for Environment, Food and Rural Affairs State of the Seas Report (SOTS) (Defra, 2005). It was drafted by contributors from a number of organisations and coordinated by the Joint Nature Conservation Committee (JNCC).

The terms of reference for this sector report are that it should provide the evidence drawn from the 'sector' monitoring programmes for subsequent 'integration' in the final report. This sector report does not provide any data analysis or review scientific literature, for this could not have been completed within the resources available. It is acknowledged that this is not the most appropriate method and that such elements should form part of a comprehensive SOTS report and this should be addressed for future reports. This sector report aims to present available information on the current state of marine habitats and species in UK marine waters, and where possible an assessment of status against defined targets. It covers seabed habitats, plankton, benthos, seals, cetaceans and seabirds; and it cross-references to the partner volume on fish. It is not the intention to draw over-arching conclusions across these elements, but rather to provide key messages for each element. Unfortunately, it is not possible to draw any conclusions on the status of most of these features because there is work in progress and results are not yet available, or because appropriate UK datasets held by government agencies are not yet available, or because there is no appropriate systematic surveillance or monitoring programme in place to provide data on trends in these features. There is, however, much ongoing work to address this deficiency, which should enable a full assessment of status in coming years.

The UK has agreed to the environmental objectives set out in a number of international conventions and agreements, and European Directives. Each section describes the relevant objectives and provides a summary of current progress towards meeting these objectives. In general, the UK is making significant progress in establishing the mechanisms to meet these objectives, particularly in coastal waters; it is proving a challenge to meet these objectives for offshore waters out onto the UK's continental shelf.

The following text repeats the key messages from each of the sections in the present report describing the status of habitats and species in UK seas. (See also the Marine Fish and Fisheries report for fish.)

HABITATS

- The status of marine habitats in UK seas reflects a combination of natural influences and the degree of disturbance arising from anthropogenic activities. The latter vary in nature and magnitude depending upon location.

- The total area of marine Special Areas of Conservation (SACs) is approximately 13000 km^2, which represents about 8% of the seabed within 12 nm or 1.8% within UK continental shelf designated area. Therefore establishing the status of habitats in UK seas cannot be undertaken simply by using the status of protected areas, and the wider marine environment must be considered.

- The condition of ASSI/SSSIs is assessed by the nature conservation agencies following the Common Standards for Monitoring guidelines (*CSM Guidance for Marine*). At the present time (December 2004) the state of SSSIs for the whole of the UK is unknown. UK conservation agencies are currently assessing the status of these sites, with the end of the first CSM reporting period for SSSIs being March 2005.

- UK conservation agencies are currently assessing the status of inshore Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) to report in 2006. Many areas beyond 12 nm have not previously been considered for SAC selection. The UK is currently considering potential sites away from the coast to meet the full requirement of the EC Habitats Directive.

- Work identifying SPAs for birds in the UK was published by the Joint Nature Conservation Committee (JNCC 2001). Guidance to extend breeding colony SPA boundaries for Atlantic puffin, common guillemot and razorbill by 1 km and northern gannet by 2 km from mean low water (mean low water springs in Scotland) was agreed by the JNCC in March 2003. An initial scoping exercise for inshore areas used by birds in the non-breeding season has resulted in a list of more than 40 inshore sites where seaduck, divers and grebes congregate. Seabird concentrations away from the coast will be identified through analysis of data hosted in the European Seabirds at Sea database. It is likely that additional sites will be identified as survey analyses proceed.

- The UK government signed the Ramsar Convention in 1973 and ratified it in 1976. In doing so, it accepted a commitment to designate suitable wetlands within its territory for inclusion in a List of Wetlands of International Importance. Of the196 Ramsar wetlands designated in the UK and OT and Crown Dependencies , there are 73 (64 in the UK, 9 in the OTs), with a marine/coastal element meaning that 37% of the total number of Ramsar sites have a marine/coastal element.

- The OSPAR Commission has agreed an international programme of work to implement the '*OSPAR Convention*' long term strategy for the protection of ecosystems and biological diversity (Annex V). Part of the implementation programme will be the establishment and management of a system of marine protected areas by 2010 (OSPAR MPA Programme). Implementation of this strategy is still at an early stage and none of the Contracting Parties have yet submitted proposed MPAs to the OSPAR Commission. Therefore at this present time (December 2004) no information is available with regard to status.

- The UK has identified and drafted *Biodiversity Action Plans* (BAP) for 14 priority marine habitats as part of its implementation of the *Convention on Biological Diversity* (CBD). The full distribution of BAP priority habitats in UK waters is unknown at the present time (December 2004).The status of nine of these BAP priority marine habitats in unknown, three are declining, one is stable and the other is fluctuating with no trend. There is no systematic surveillance programme for these habitats and therefore these assessments are based on an 'informed view'.

PLANKTON

- Natural atmospheric and hydrographic variability appears to be the major contributor to ecosystem change in the shelf seas of North-West Europe. This overriding natural variability, possibly forced by global warming, needs to be considered in any assessment of the ecological state of UK coastal waters.

- On the basis of evidence from the plankton the seas around the British Isles that are sampled by the CPR are relatively pristine and unaffected by anthropogenic inputs of contaminants or eutrophication.

- However, nearshore estuarine and coastal waters have not been sampled as systematically and impacts from contaminants and eutrophication in these areas will thus be more difficult to assess.

- Since 1946 there have been considerable changes in many ecosystems around the UK with a pronounced regime shift around 1982–1988.

- In addition to the regime shift there has been a northerly biogeographic movement of warm water plankton of 10° of latitude in forty years and a parallel retreat of cold water plankton to the north.

- Some plankton species are occurring earlier in the season (including dinoflagellates), which has important implications for the monitoring and study of Harmful Algal Blooms.

- After the mid 1980s the planktonic ecosystem moved from a cold temperate to a warmer dynamic regime around the UK.

- The regime shift is evident in chlorophlyll, phytoplankton and zooplankton, fish, birds, benthos, oxygen and hydrographic variables, and is also reflected in changes in nutrient concentrations of relevance to the understanding and development of policy on eutrophication.

- The regime shift coincides with a sharp increase in Northern Hemisphere Temperature (NHT), Sea Surface Temperature (SST) and the North Atlantic Oscillation (NAO).

- It is likely that the high temperatures experienced in the North Sea and British waters in recent years, after the regime shift, are generated by the combined effect of a generally highly positive NAO and high and increasing NHT.

- The evidence for a stepwise increase in chlorophyll levels in the North Sea in the late 1980s could, at face value, be taken as due to eutrophication. However, the exact same pattern and increase was also seen in oceanic waters to the west of the British Isles. Therefore it must be assumed that a strong overriding climatic signal is apparent in the phytoplankton data recorded by the CPR survey.

- The changes in chlorophyll observed in regional areas of the North-East Atlantic are also likely to have affected coastal areas around the British Isles and in the North Sea.

- The effects of eutrophication on European regional seas cannot be assessed without taking into account wider hydroclimatic influences on phytoplankton populations.

- The above changes have had marked effects on fish stocks (e.g. cod and salmon). If the International Panel on Climate Change (IPCC) predictions of a continuing rise in global temperatures prevail then it can be expected that the returns of salmon to home waters will continue to decline, especially at the southern edge of its distribution in Spain and France and possibly in the UK.

- There is clear evidence for forcing by global warming in the signals seen in the plankton and the observed changes are likely to have a major impact on biogeochemical cycles and living marine resources and might ameliorate or exacerbate any contaminant or eutrophication impacts.

- It is unlikely that any changes in UK policy will make any difference to the climatic forcing parameters or to the plankton within one decade. A longer term view needs to be taken.

- The long time series of data and wide coverage of the Continuous Plankton Recorder (CPR) survey makes it possible to determine baseline conditions for a range of planktonic species and indices in terms of abundance, biomass and biodiversity.

- There are considerable spatial differences in the plankton communities around the UK as we are at a biogeographic node between warm temperate and boreal faunas. On the basis of this variability it is difficult to develop a target of what might be considered as a mean planktonic state for UK waters.

- Good information exists on most mesoplankton. In contrast, limited knowledge exists on gelatinous plankton and micro and ultraplankton.

- No time series of plankton production exist in UK waters, However, new methods and use of satellite data may make this possible in the near future.

- Methods used in long-term plankton surveys should be standardised and maintained over long periods.

- An historical overview should be undertaken of past planktonic research in UK waters that brings together information from single point time series, one-off surveys and the results of the Continuous Plankton Recorder (CPR) programme.

BENTHOS

The diversity of the animals and plants which live within or on our sea floor is ranked amongst the highest in Europe. The benthos is important in its own right to provide food for humans, but it is also a vital component of the marine food web providing habitat and food for other marine species.

The key messages to emerge from the sections considering the different aspects of the status of the benthos in UK seas are:

Marine survey programmes:

- Assessing the status of marine benthic communities requires spatial and temporal survey data. Survey effort has declined in the past 10 years, but recent survey effort has increased the spatial 'baseline' for many regions of the UK's seas; early historical surveys of adequate scale or data quality are generally lacking, particularly in offshore areas. In our current data holdings we have only recorded about 40% of the taxa on the UK's national checklist. Data on temporal changes in marine benthic communities are only available for a limited number of locations.

- There are no agreed tools (indices) to assess the state of benthic communities at a UK level. However, a number of developments, including those arising from the Water Framework Directive programme, will help resolve this issue.

- On available evidence, there is no indication of significant structural or distributional changes to benthic communities arising from recent human activities on a regional or UK-wide sea scale. However, there is evidence that benthic communities are severely affected by certain fishing activities in some areas, particularly those in more stable environments. On the basis of the widespread but patchy distribution of fishing in our seas it is likely that the benthos remains modified in areas where fishing intensity prevents recovery.

- The health of benthic communities as assessed by the National Marine Monitoring Programme and various research projects shows that they are affected by a number of different activities and their response can be used as an indicator of change.

- Overall there is no evidence of broad scale impacts of nutrients or hazardous substances on benthic communities but they do show signs of stress in local areas often close to the source of the pollution.

Progress against objectives:

- The UK is taking appropriate measures to undertake the assessments against the objectives of the European Directives. It is not clear at present how the UK will contribute to the broader targets agreed through International Conventions and Agreements, particularly in areas away from the coast in the wider offshore parts of UK seas.

Recommendations:

- The UK needs to establish an appropriate surveillance programme to meet its international and national commitments to assess the status of benthic communities in UK seas. There is an urgent need to establish a process to gather data for the wider marine environment – both existing data and new data – and to develop nationally agreed indicators or assessment measures to properly assess the status of benthic communities.

- Human activities should be considered in an integrated manner to assess the overall anthropogenic impact on marine benthic ecosystems, and to contribute to a more holistic, ecosystem-based approach to management.

- There is a need to address the problems which exist on a local level from known human impacts such as polluting discharges or physical disturbance arising from dredging/disposal, and to consider further the potential for wider-scale damage incurred from fishing activities.

SEALS

- The UK holds 39% of the world population of grey seal; 90% of British grey seals breed in Scotland.

- Grey seal population has grown steadily since the 1960s to an estimated maximum population of 123,000 in 2002.

- Grey seal pup production increased steadily from 1984–1996; it has remained broadly static since 2000.

- The UK holds approximately 40% of the world population of the European sub-species of common seal. Total population estimate is 50–60,000, 5% of the world population.

- Currently there is one Ecological Quality Objective (EcoQO) for seals: seal population trends in the North Sea. Further analysis of existing data collection could establish and report against this Ecological Quality Objective (EcoQO).

- The UK has selected 11 Special Areas of Conservation (SACs) for common seals and 11 Special Areas of Conservation (SACs) for grey seals under the EC Habitats Directive.

- No current assessment of SAC status is available, although mechanisms are being implemented to report the status of seal features at the end of 2006.

CETACEANS

- Of the 28 species of cetacean that occur, only about 10 are commonly recorded in UK waters.

- Strategic, systematic monitoring *sensu strictu* of cetacean populations needs to be carried out at a UK-wide scale. It is therefore not possible to report on trends in the status of cetacean populations.

- Baseline data for future surveillance of cetacean populations should be collected through enhanced coordination of cetacean sightings programmes special projects (such as SCANS II), and via development of the Joint Cetacean Database project.

- The UK needs to continue to maintain current surveillance of cetacean populations to determine trends.

- No indicators of state have yet been determined for UK cetacean populations and as yet there are no reliable methods of using sightings data to establish population trends.

- The UK needs to develop statistically robust methods to monitor cetacean density at appropriate geographical scales.

- Assessments to give an indication of status under the requirements of the EC Habitats Directive have not yet been carried out. There is a target to assess and report on these by 2006. There is therefore currently no information available on the status of bottlenose dolphins (*Tursiops truncatus*) at Special Areas of Conservation (SACs).

- There are three Special Areas of Conservation (SACs) for bottlenose dolphins in the UK. Although no sites have yet been proposed for harbour porpoise, the UK is actively considering doing so.

- Ecological Quality Objective (EcoQO): The UK and other signatory states are committed to reduce porpoise bycatch to less than 1.7% of the best available estimate of abundance for major fishing areas in the short term.

SEABIRDS

- Baseline data from which subsequent monitoring can be compared are available from complete censuses providing total population estimates of all seabirds in UK.

- An assessment of status through population changes is possible as sufficient data on breeding numbers and breeding success of seabirds are collected both regionally and nationally through the Joint Nature Conservation Committee's Seabird Monitoring Programme (SMP).

- Between 1969–70 and 1998–2002, the UK coastal populations of 12 species have increased in size by more than 10%, two have decreased by more than 10% and six have changed by less than 10%.

- Trends in the population status vary both positively and negatively between species and thus it is inappropriate to merge data from different species to derive composite indices as indicators of the state of the sea.

- Currently there is only one seabird-related Ecological Quality Objective (EcoQO) under testing relating to the proportion of oiled common guillemots among those found on North Sea beaches. Others are under consideration by the OSPAR Commission.

- The UK has designated 95 Special Protection Areas (SPA) due to their qualifying populations in one or more seabird species or seabird assemblage.

General introduction

In its first report on marine stewardship, Safeguarding Our Seas, the Department for Environment, Food and Rural Affairs (Defra) promised to produce an integrated assessment of UK waters (the whole of the UK EEZ – see Figure 0.1) in the form of a State of the Seas report in 2004. This present report is a contribution to the State of the Seas process, providing the evidence to assess the status of marine habitats and species in UK waters. Defra developed a set of objectives and a draft outline of the proposed State of the Seas Report. Defra established agreements with the four main sectors to provide an appropriate contribution on their sector. The Joint Nature Conservation Committee (JNCC) were asked to coordinate the production of the section describing 'Habitats and Species' where 'species' includes contributions describing plankton, benthos, fish, birds and mammals (seals and cetaceans). The purpose of this section is to set out the objectives of the State of the Seas Report in relation to the 'Habitats and Species' contribution. It does not however provide any data analysis or extensively review scientific literature, for this could not have been completed within the time frame and with the resources available. It is acknowledged that this is not the most appropriate method and that such elements should form part of a comprehensive SOTS report and this should be addressed for future reports.

How might we define 'status'? It is taken to refer to the current condition (of an entity) at a particular time. It requires a measure, the value of which can be compared over time to determine whether there is any trend or change in the value. Such changes can help judge the 'status', noting that an improvement in 'status' could be either a positive or negative change depending upon circumstance. In the context of the present report, 'status' is interpreted as a judgement of 'quality' of marine habitats and species. There are no agreed measures of quality in the State of the Seas process, so to help define this term it should be possible to use measures of quality/status in international conventions (such as the Oslo–Paris convention (OSPAR)) or European Directives (such as the EC Habitats Directive or EU Water Framework Directive). The concept of 'Favourable Conservation Status' is set out in Article 1 of the EC Habitats Directive for both habitats and species. For habitats, it requires measures of extent, structure, function and typical species; for species it requires measures of population status, range and habitat quality. Under the EU Water Framework Directive, 'ecological status' is based on measures of 'quality elements' that include both habitat (hydromorphology, chemistry) and biology (abundance/diversity of plants, algae, invertebrates, plankton and fish). Using these concepts, 'status' of habitats and species in terms of the State of the Seas process may be defined in terms of quantity (extent, distribution, range) and quality (abundance, population status, diversity) of habitats and species. It is also necessary to define the direction of an acceptable trend in status: for example the number of marine protected areas should have a positive trend, whereas the number of harmful non-native species entering UK waters should have a negative trend.

Defra's objectives relate to the entire report and therefore not all are applicable to the *Habitats and Species* report. Furthermore, these objectives are necessarily wide-ranging to encompass the work of the four sectors and the relative progress of each sector towards the objectives will vary. It is Defra's stated intention that the sector contributions should draw on existing published material wherever possible, rather than initiate new work programmes.

[1] Ocean Processes and Climate, Biodiversity, Fisheries, Environment (Human Impacts)

Of the objectives set out by Defra, two describe the principal aim of the project and thus set the framework for the individual sector contributions:

- to describe the current state of our seas.

- to conclude with an [integrated] assessment of how we are doing, probably by each regional sea separately, identifying the major management issues in those seas.

Combining and analysing the individual sector contributions to achieve an 'integrated assessment' will be the most important aspect of the State of the Seas Report that will set this report aside from other previous reports on the status of the marine environment. Each sector's contribution must therefore provide information to facilitate this integrated assessment. The Joint Nature Conservation Committee (JNCC) and its partners have concentrated on delivering a contribution that 'describes the current state of the marine life of our seas' to contribute to a 'regional sea assessment'. The regional reporting areas used for the State of the Seas report are shown in Figure 0.1

The following text sets out the other objectives that directly relate to the *Habitats and Species* section together with an interpretation to their meaning in relation to the information that could have been made available to the sector report.

- to explain how we will know whether we are getting closer or further away from the vision we set in the first marine stewardship report (i.e. that of clean, healthy, safe, productive and biologically diverse oceans and seas, with a real difference made within one generation); in other words, how we will be using science to check whether we are delivering our policy;

Specific State of the Seas objective	Interpretation for Habitats and Species section
Assess performance against the vision in the first marine stewardship report – that of clean, healthy, safe, productive and biologically diverse oceans and seas.	Provide a commentary on whether we can reliably measure productive and biologically diverse oceans and seas.Provide a description of the productivity and diversity of marine life – ideally the 'baseline' condition.Evidence for current 'state' against this baseline condition based on existing [statutory] monitoring programmes, or other relevant source of data (research).
How we will be using science to check whether we are delivering our policy.	Provide a commentary on current research that contributes to an assessment of 'state'. If necessary, offer views on how the research agenda should change to measure performance against the overall target at future date.

- to carry the ecosystem approach a step forward, by defining how we will know whether we are maintaining the system in a good state through a system of indicators (or if we have not got to the stage where we can specify a set of indicators, an indication of our approach to this issue and what progress we have made). This might also refer to some of the sector objectives (e.g. for hazardous substances and eutrophication) to which are committed through the Oslo–Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (the 'OSPAR Convention')

- to give an assessment of how we are doing on the set of Ecological Quality Objectives (EcoQOs) which are being developed in OSPAR following the commitments Ministers made in the 5th North Sea Conference – this should overlap with the previous item

Specific State of the Seas objective	Interpretation for Habitats and Species section
Assess progress on implementing an ecosystem approach [to management], by defining indicators of state (or if we have not got to the stage where we can specify a set of indicators, an indication of our approach to this issue and what progress we have made).	Present results of any established indicator of state in the form of a summary (a graph plus supporting, qualifying text) plus relevant detailed supporting information and source of data. Provide a commentary on any progress in identifying appropriate indicators[2] (for example those suggested by the Department for Environment, Food and Rural Affairs (Defra) in the England Biodiversity Strategy).
Assess progress on the set of OSPAR Ecological Quality Objectives (EcoQOs).	Provide evidence of current state against the EcoQO where data are readily available. Describe the process for gathering data on other EcoQOs.

- to report on progress in relation to national and international marine environment objectives, targets and where possible using performance indicators developed through our research programmes

Specific State of the Seas objective	Interpretation for Habitats and Species section
Assess progress against national and international marine environment objectives, targets, where possible using performance indicators developed through our research programmes.	Provide a summary of relevant biological objectives and targets (OSPAR (Annex V), Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS), Habitats Directive, Water Framework Directive, Convention on Biological Diversity (CBD)-Biodiversity Action Plan (BAP), EC Gothenburg target, World Summit on Sustainable Development). Provide summary information for any established performance indicator (for example the number & area of protected sites).

[2] Use of indicators is a contentious issue but one that has to be addressed by each sector.

WHAT IS THE BASELINE?

There is no agreed position on the baseline against which the current state should be assessed. Consequently it was difficult to provide advice on the exact requirement for each sub-section in the *Marine Habitats and Species* report and the following guidelines were adopted:

- Contributions were to be drawn from existing monitoring/survey programmes and the current state could be presented in relation to the starting point of the programme.

- Where there was no existing monitoring programme, the contribution used available data to describe the current state with no reference to a previous state. The current state could potentially form the baseline for future reports to determine whether 'a real difference [is] made within one generation'.

1. State of habitats

KEY MESSAGES

- **The status of marine habitats in UK seas is a function of the type of anthropogenic activity, its frequency/duration of occurrence and the spatial extent of the seabed affected.**
- **Managing activities to protect or improve the status of marine habitats can be achieved by either (1) setting aside an area where the activity is prohibited or tightly controlled or (2) by implementing a policy that manages the activity over the entire marine environment to reduce the impact to an 'acceptable' level or (3) through a combination of both.**
- **Establishing the status of habitats in UK seas cannot be undertaken simply by using the status of protected areas, and must consider the distribution and extent of the habitats in the wider marine environment.**
- **There are no systematic surveys, surveillance or monitoring programmes to enable an assessment of the status of habitats in UK marine waters at this time (December 2004).**
- **National legislation provides for the designation of marine protected areas – Sites of Special Scientific Interest (SSSI), Marine Nature Reserves (MNR), RAMSAR, Special Areas for Conservation (SAC) and Special Protection Areas (SPA).**
- **The UK has proposed SACs for marine features in nearshore waters and, to meet the full requirements of the EC Habitats Directive, is currently considering potential sites away from the coast and out to 200 nautical miles or to the limit of the UK Continental Shelf designated area.**
- **The total area of marine SACs is approximately 13000 km^2, which represents about 8% of the seabed within 12 nm or 1.8% within UK Continental Shelf designated area (source: JNCC designations database for SAC boundaries, percentages are derived from using JNCC GIS data).**
- **The UK nature conservation agencies are currently assessing the status of these sites and will report on Sites of Special Scientific Interest (SSSIs) in 2005 and Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) in 2006. At the present time (December 2004) there is no current information on the status of the habitats on these sites at a UK level.**
- **For SSSIs in England, the majority of sandy and muddy shores (74%) and [sea cliffs] and rocky shores (87%) are considered to be in favourable or recovering condition.**
- **In January 2003, 3.3 km^2 within Lundy MNR and SAC was designated as the first statutory No Take Zone for marine nature conservation in UK.**
- **UK has identified and drafted *Biodiversity Action Plans* (BAP) for 14 priority marine habitats as part of its implementation of the *Convention on Biological Diversity* (CBD).**
- **The status of nine of these priority marine habitats is unknown, three are declining, one is stable and the other is fluctuating with no trend. There is no systematic surveillance programme for these habitats and therefore these assessments are based on an 'informed view'.**
- **The full distribution of BAP priority habitats in UK waters is unknown at the present time (December 2004).**

PURPOSE OF THIS CHAPTER

The purpose of this chapter is to provide background information that is available to help meet the objectives of the State of the Seas Report. It highlights existing published material, existing [statutory] monitoring programmes and provides a commentary on current work that will contribute to an assessment of 'state' to give an assessment of what we are doing in order to be able to report on progress in relation to national and international marine environment objectives, which is particularly pertinent to this *Habitats and species* sector report where our knowledge of ecosystem state is limited for some (many) aspects. Consequently it is difficult to provide a description of current state.

In order to address this, information is provided on what the UK is doing to designate and protect marine habitats in the UK through various national and international legislation and conventions, and the various threats that pose a risk to marine habitats around the UK. Although this chapter mostly focuses on habitats, there is inevitably an overlap with work carried out on their constituent benthic communities, the status of which is not discussed within this chapter but in Chapter 3. Chapter 3 also contains information on the status of habitats and therefore should not be read in isolation.

INTRODUCTION

Marine habitats are an essential component of our seas because they provide the environmental conditions that the many types of marine life need to survive. Marine habitats can be distinguished into those of the seabed and those of the water column. A seabed marine habitat is considered to be the nature of the seabed and the prevailing physical environmental parameters that influence the seabed structure and its associated biological communities. Each species needs a particular set of habitat conditions (e.g. seabed sediment or rock type, salinity or temperature regime) to survive, with suites of species frequently occurring together as communities in particular habitat types (e.g. on a rocky shore). Sometimes habitats are formed by the species themselves (e.g. the biogenic reefs formed by mussels or tube worms or algae such as the coralline algae called maerl).

For the purpose of this document, the marine habitats only refer to those seabed habitats specifically considered to be 'marine' and found below the High Water Mark. They do not include habitats such as saltmarsh, sea cliffs, sand dunes and their associated sub-habitats, but do include very broad physiographic features such as estuaries and bays that themselves comprise a complex array of more clearly defined habitats such as rocky reefs, mudflats and sandbanks.

One of the principle objectives set out by Defra, of the State of the Seas Report is to describe the current state of our seas in order to explain how we know whether we are getting closer or further away from the vision set in the first marine stewardship report – that of clean, healthy, safe, *productive* and *biologically diverse* oceans and seas. To assess our progress, we need to provide evidence for the current 'state' based on existing information or other relevant sources of data (research) for UK-wide geographical coverage. Where evidence of the current state is not available, the text will indicate our approach to this assessment and outline what progress has been made based on information drawn from existing programmes or other sources of information.

The term 'state' is thus distinguished from 'status', in that whilst 'state' indicates the current condition of the habitat, 'status' is measuring this current state against a target, and where possible measurements over time will show a positive trend. An assessment of status requires an estimate of 'anthropogenic modification' for the habitat if such measurements are to assess our 'performance' in maintaining (or restoring) the habitat to match our 'vision'. Clearly it is necessary to define the 'acceptable' state against which the current state can be compared and then subsequently assigned a qualitative descriptor. Such an approach of establishing an 'environmental objective' is the basis of the assessments required under the EC Habitats Directive and the EU Water Framework Directive (WFD), and the concept behind the Ecological Quality Objectives (EcoQOs) that are being developed by the OSPAR Commission.

Arguably, an assessment of state is only necessary because anthropogenic activities are modifying the natural environment. Modifications to physical environmental processes are considered in the Marine Processes and Climate sector assessment.

Modifications to the seabed structure itself have two important components: the spatial extent of the modification and the duration/frequency of the perturbation. The state of marine habitats in UK seas is therefore a function of the type of anthropogenic activity, its frequency/duration of occurrence and the spatial extent of the seabed affected. Improving a degraded habitat requires the identification and management of the damaging activity over space and time.

Managing activities to protect or improve the state of marine habitats can be achieved at two spatial scales: firstly by setting aside areas where the activity is prohibited or tightly controlled; and secondly by implementing a policy that manages the activity over the entire marine environment to reduce the impact to an 'acceptable' level. Setting aside 'protected areas' has been the cornerstone of conservation management in the terrestrial environment and, more recently, in the marine environment. This approach invariably focuses on the identification of habitats considered to have conservation value, often due to their rarity or the diversity of the associated biological assemblages, rather than protecting examples of all habitats regardless of their perceived value. More recently, the value of establishing a suite of protected areas to construct an 'ecologically coherent network of protected areas' that includes a wider range of habitats has been clearly recognised (Roberts *et al*., 2003). The EC Habitats Directive requires member states to designate Special Areas of Conservation (SAC) and subsequently implement management regimes to protect the designated habitats; some marine habitats are listed in the directive (see below). UK national legislation also has provision for the designation of protected sites in the form of Marine Nature Reserves and Sites of Special Scientific Interest (for marine features). International agreements such as the OSPAR Convention and the Ramsar Convention also require the designation of protected sites.

One possible measure of the *State of the Seas* would be an assessment of compliance with these agreements and legislation in relation to the designation of protected areas, the implementation of a management regime, and the status of the protected feature. A site-based policy for habitat protection is advantageous where the location of the target habitat is known and/or an anthropogenic activity is spatially restricted; for example the dumping of waste material in a licensed area. The area of impact could then be compared with the area of protection and an 'acceptable' ratio of impact to protection derived. A site-based policy is not, however, appropriate for an activity that occurs over a wide geographic area where the precise areas of impact are unknown, and/or where the location and full extent of habitats is unknown; demersal fishing is a good example of this type of activity. Furthermore, the identification and designation of a protected site is a complex and time-consuming process – only three Marine Nature Reserves have been designated since the legislation was enacted in 1981, along with 75 marine SACs with a marine component since 1992. Consequently, the proportion of UK seas within protected areas is currently very low (~1.8% for SACs alone based on JNCC data) and unlikely to attain a majority proportion in the foreseeable future.

Establishing the state of habitats at the level of the UK seas cannot be undertaken simply by using the state of habitats within protected areas, it must also consider their state in the wider environment. The legal framework under the EC Habitats Directive gives an obligation to monitor 'status' for all habitats of community interest. Assessing whether a habitat is at 'favourable conservation status' as defined in the directive must therefore consider both its status *within* SACs and in the *wider* environment. Another approach could be to define the status in relation to the level of adverse anthropogenic activity on a habitat: this is the basis of the concept of 'ecological status' in the EU Water Framework Directive (WFD).

'High ecological status' in the WFD is defined as:

> *There are no, or only very minor, anthropogenic alterations to the values of the physico-chemical and hydromorphological quality elements for the surface water body type from those normally associated with that type under undisturbed conditions.*
>
> *The values of the biological quality elements for the surface water body reflect those normally associated with that type under undisturbed conditions, and show no, or only very minor, evidence of distortion.*

'Very minor' is not quantified and consequently there has been considerable discussion over its actual interpretation in relation to the current level of anthropogenic activities. The key environmental objective of the WFD is that all water bodies achieve 'good ecological status' by 2015 as set out under Annex V of the directive. Exactly what constitutes 'good ecological status' is still under discussion, but it will allow for some departure from the aquatic ecology that you would expect to find in undisturbed conditions largely unaffected by human influences. Establishing ecological objectives for ecosystem state based around anthropogenic pressures and activities would facilitate an assessment of the status of marine habitats for UK seas. This would require information on the spatial extent and temporal variability of these activities to be successful. Such an approach would fit with the concept of 'marine spatial planning' that has been promoted recently, where activities are managed in a spatial context. Article 5 and Annex II of the WFD require information to be collected on the type and magnitude of the significant pressures to which water bodies are liable to be subject and to undertake an assessment of the risk of water bodies failing to meet the Directive's environmental objectives. The first review of pressures and impacts must be completed by December 2004 and reported by March 2005. However, this review will be an ongoing process underpinning the setting of environmental objectives, the programme of measures and the monitoring programme.

The following sections are organised to reflect the site-based and the wider environment-based aspects of assessing the status of marine habitats in UK seas with a summary of the type of activities causing deterioration in the condition of these habitats. The final section summarises our progress towards achieving our environmental objectives for marine habitats.

POLICY DRIVERS FOR HABITAT PROTECTION

Policy drivers for habitat protection may be divided into national legislation, European directives and international conventions and agreements.

National legislation and/or programmes:
Wildlife and Countryside Act 1981 (as amended, for Sites of Special Scientific Interest (SSSIs) in Britain) and the Nature Conservation and Amenity Lands (Northern Ireland) Order 1985 (for Areas of Special Scientific Interest (ASSIs) in Northern Ireland). Biodiversity Action Plans (BAP) as part of the implementation of the Convention on Biological Diversity (CBD).

European legislation and International agreements and conventions:
EC Birds Directive (Special Protection Areas, SPAs), EC Habitats Directive (Special Areas of Conservation, SACs) and the EU Water Framework Directive, Ramsar Convention (Ramsar sites), OSPAR, Convention on Biological Diversity (CBD).

These policy drivers operate at two spatial scales: some require the designation of protected areas (for example Special Areas of Conservation (SAC) are required by the EC Habitats Directive); others relate to the wider/entire marine environment (Biodiversity Action Plans). In general, the legislative approach is based on site protection and the broader agreements relate to the wider environment. Traditionally, the government agencies have focussed on meeting legislative drivers, although it is now generally recognised that a site-based approach to conservation will not necessarily deliver the target for marine biodiversity in the wider environment alone.

POLICY DRIVER: THE DESIGNATION OF PROTECTED AREAS

The traditional approach to habitat protection has been on a site by site basis. There are different types of protected area in UK seas, and it should be noted that sites are not 'marine protected areas' *per se*, and it would be misleading to state that the UK is well placed in terms of national legislation to protect the marine environment. Our legislation has no provision to implement strict protection on the sites, and most of our sites are multiple use, for example Plymouth Sound is an SAC but within it there are ports and industry, recreation, infrastructure and of course important habitats and species. Balancing of these activities to formulate an ecosystem approach to protect everyone's interests is generally done through a management scheme; however, not all sites have one and we do not always know what activities are happening on the sites. Through the Review of Marine Nature Conservation working group, research has gone into determining what extra measures are needed and making recommendations on national site protection measures.

It should be noted that determining the status of a habitat will generally include an assessment of the status of the associated biological assemblage, although the status of benthos is covered under a later chapter. Whilst it is possible for the habitat component to be in an acceptable state and the biological component degraded, in practice, it is likely that the unacceptable biological state will be linked to a component of the overall habitat where it includes the seabed and the fluid medium. Reporting the status of the habitat is therefore considered appropriate and this chapter focuses on the structure and state of habitat, avoiding reference to the status of its associated biological communities.

NATIONAL LEGISLATION

Sites of Special Scientific Interest (SSSI) and Areas of Special Scientific Interest (ASSI)
Sites of Special Scientific Interest (SSSI) in England, Wales and Scotland have been designated under the Wildlife and Countryside Act 1981 Section 28 (as amended), with the equivalent Areas of Special Scientific Interest (ASSI) designated under the Nature Conservation and Amenity Lands (Northern Ireland) Order 1985 in Northern Ireland to protect areas of important flora, fauna, geological and/or physiographical features, including marine habitats. However, the boundaries of these ASSI/SSSI sites extend only to the point of the mean low water mark in England and Wales and the point of mean low water spring tides in Scotland.

ASSIs/SSSIs also provide the basis for other national and international designations such as SACs and SPAs, but only cover the intertidal interests of these sites (Laffoley *et al*., 2000).

The condition of ASSI/SSSIs is assessed by the Nature Conservation agencies, using categories agreed across England, Scotland, Wales, and Northern Ireland, through the Joint Nature Conservation Committee. There are seven reportable condition categories: favourable maintained; favourable recovered; unfavourable recovering; unfavourable no change; unfavourable declining; part destroyed and destroyed.

The status of SSSIs for the whole of the UK is currently unknown. The end of the first reporting period for SSSIs is March 2005. JNCC will compile a report on the status of SSSIs by the end of 2005 based on the information provided from the nature conservation agencies; it will be summarised by broad habitat SSSI feature types. Nevertheless, there is some information on the current status of SSSIs in England.

English Nature has a Public Service Agreement (PSA) target that requires all SSSIs to be in favourable condition by 2010. English Nature has reported on the current state of England's best wildlife and geology sites and identified action to achieve their recovery (English Nature, 2003). This report details progress with bringing sites into favourable condition and some of the management issues currently faced by these sites. Further reports of this nature will be produced on a regular basis. Their reporting of SSSI condition has been divided up into broad habitats; the ones of relevance here are 'Sandy shores, muddy shores, rocky shores and sublittoral habitats'. The condition of inter-tidal SSSIs report is available on the English Nature website (http://www.english-nature.org.uk).

Sandy and muddy shores cover 241,400 hectares, 23% of the total SSSI area in England. They are the most extensive of the SSSI broad habitats. The majority (74%) of sandy and muddy shores in SSSIs are considered to be in favourable or recovering condition (English Nature, 2003).

There are 3,000 hectares of rocky shore in SSSIs. The majority (87%) of rocky shores [including sea cliffs] in SSSIs are considered to be in favourable condition (English Nature 2003).

Exact conclusions as to why each particular SSSI did not meet their objectives were not included within this report, although possible reasons and impacts were stated. Coastal squeeze (which occurs when fixed, hard sea defences prevent vegetation migrating naturally landwards in response to sea level rise) was cited as the major cause of unfavourable condition due to loss of shoreline habitats. Fisheries for cockles and mussels can also cause unfavourable condition on SSSIs if they are carried out at unsustainable levels. Some fishing activities, such as suction dredging, can also damage or disturb the habitats and non-target species. This is highlighted as a major issue on the Wash SSSI. Inappropriate coastal management interrupts the coastal processes that shape the coast. Using rock armour to prevent erosion, or breakwaters or groynes that interrupt sediment transport along the coast, can change patterns of sediment

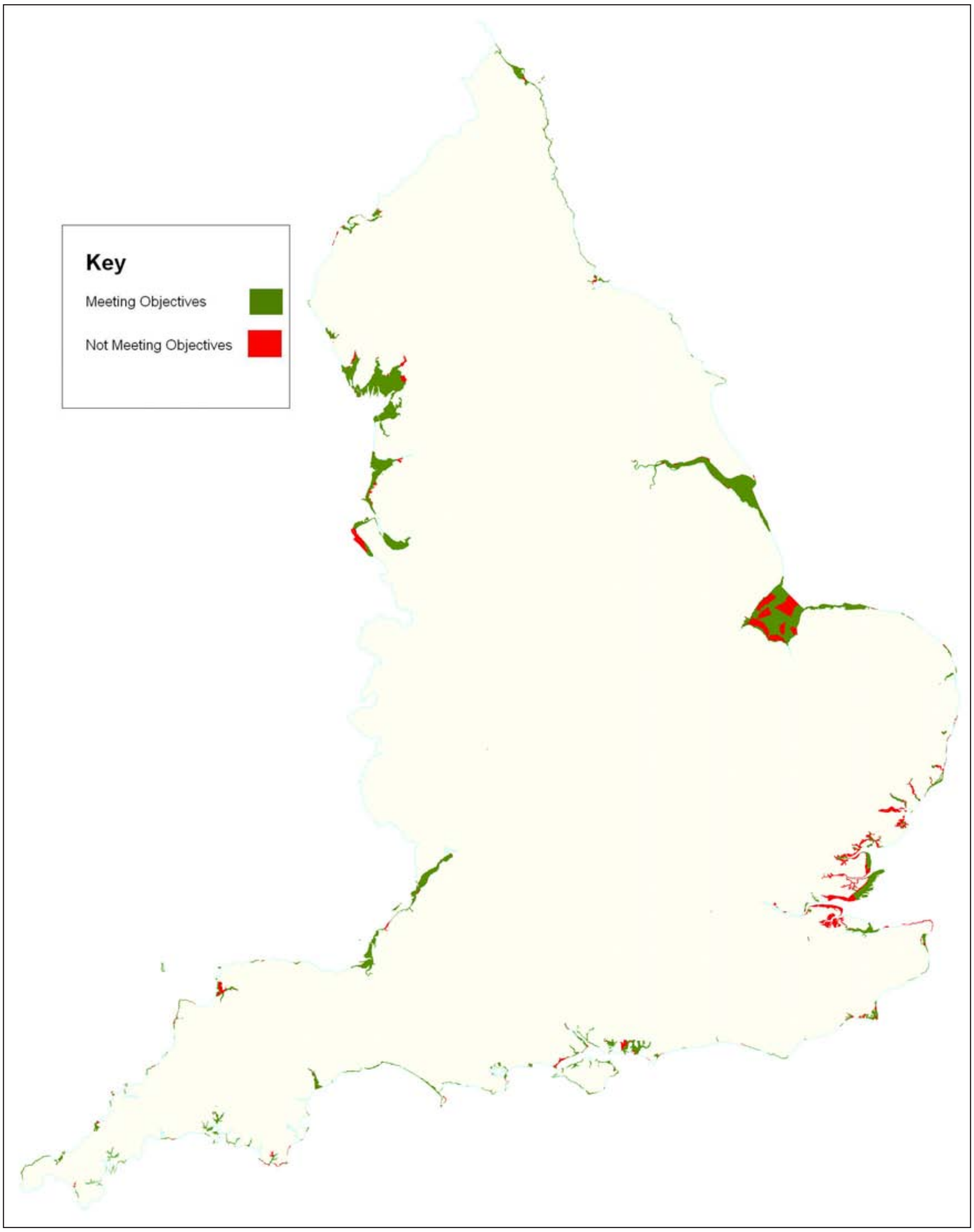

Figure 1.1. The condition of Sites of Special Scientific Interest (SSSIs) with a marine component in England in 2003 (figure provided by English Nature)

deposition along long stretches of coastline, causing unfavourable condition. Dredging can also cause unfavourable condition within some SSSIs. Maintenance dredging for navigation occurs in many estuaries and can reduce the sediment available to maintain saltmarsh and mudflats.

The Countryside Council for Wales (CCW) is currently gathering information on all individual sites and will report on the condition of SSSIs in Wales by July 2005. Scottish Natural Heritage (SNH) is currently gathering information on the 60 SSSIs in Scotland which contain a marine component. SNH will also report on the condition of these by July 2005. The Environment and Heritage Service Northern Ireland (EHSNI) has currently designated 27 coastal/maritime Areas of Special Scientific Interest (ASSIs) totalling 13,382 Ha. These sites also include earth science features and maritime features such as sand dunes and saltmarsh, as well as species features such as common seal. Additional sites have been selected for marine features and are awaiting the production of boundaries and citations. Northern Ireland has been trialling condition assessment procedures over the last six years, although formal condition assessment only started in 2002 with the aim of assessing all sites by 2007.

Marine Nature Reserves (MNRs)

Marine Nature Reserves (MNRs) are also designated under the Wildlife and Countryside Act 1981 (as amended, section 36) or the Nature Conservation and Amenity Lands (Northern Ireland) Order 1985 in Northern Ireland to conserve intertidal and shallow-sea ecosystems and coastal features. An MNR can be designated for any area of land or water from the high water mark to a line three miles from the baseline established for measuring the territorial waters (section 36). Additionally, by order in the Privy Council, MNRs can be designated out to twelve nautical miles.

Only three MNRs have been designated since 1981: these are Lundy Island in the Bristol Channel, Skomer Island and the Marloes off west Wales, and Strangford Lough in Northern Ireland.

Lundy Island

Lundy Island Marine Nature Reserve (MNR) comprises the shores and sea around Lundy. All five British shallow inshore species of stony coral are found here: *Caryophyllia smithii* and the nationally rare *Balanophyllia regia*, *Caryophyllia inornatus*, *Hoplangia duotrix* and *Leptopsammia pruvoti*. Other long-lived, slow growing south-western species include the soft coral *Parerythropodium coralloides*, the sea fan *Eunicella verrucosa* and a variety of erect branching sponges, found in deep sheltered conditions on the east coast of the island. The high species richness of the area is reflected in the large number of rare or unusual species, and the large numbers of individuals of fragile long-lived species which are present on very stable reefs around the island, including solitary corals, sea fans and erect sponges. The southern kelp *Laminaria ochroleuca* and the seaweeds *Carpomitra costata*, *Grateloupia dichotoma* and *Bifucaria bifurcata* are at or near the northern limit of their distribution on Lundy.

The current status of Lundy Island MNR is unknown. English Nature is currently undertaking an assessment of its status that will be completed by 2005, to be reported in 2006; intertidal areas are covered under the SSSI reporting (see above).

In January 2003, a 3.3 km^2 area of sea on the eastern side of Lundy Island MNR and Special Area of Conservation (SAC) was confirmed by the Government as the first statutory No Take Zone (NTZ) to provide enhanced protection for the island's marine wildlife through a Devon Sea Fisheries Committee bylaw. NTZs are areas where all fishing is prohibited and no living natural resources, including lobsters, crab and fish, can be taken from the area. These areas, and those where all forms of extraction are removed, can help reverse the decline of the marine environment. English Nature views these areas as an essential contribution to the recovery and protection of our coasts and seas. A 3–5 year programme of monitoring will compare the status of the seabed within the NTZ with surrounding areas of the reserve to evaluate its effectiveness in protecting seabed habitats. A press release in October 2004 by English Nature states that the NTZ is revealing promising results after its first year of monitoring: after 18 months, lobsters were both bigger and more abundant inside the NTZ compared with control areas outside, and on average the NTZ contained three times as many lobsters above the minimum landing size compared with control areas. English Nature hopes that, although it is very early days in the monitoring programme, the population will increase further and spill over into areas outside the NTZ where fishermen can benefit.

Skomer Island

Skomer Island Marine Nature Reserve (MNR) was established in 1990 around Skomer Island and the Marloes Peninsula in south-west Wales and is situated within the Pembrokeshire Coast National Park and Pembrokeshire Marine SAC.

The Countryside Council for Wales (CCW) employs a small team to monitor and manage the MNR. Since its designation, the team has focussed on developing a range of projects to monitor the condition of the Reserve's wildlife and investigate the relevant aspects of species life histories for baseline information. Two project status reports have been produced to date and it is intended that they will become annual reports (Lock *et al*., 2003; Burton *et al*., 2004). However, Skomer MNR's current status has not yet been formally assessed. Skomer MNR lies within the larger Pembrokeshire Marine SAC, the status of which will be assessed by the end of 2006.

Recent and ongoing projects that address the status of Skomer MNR include:

- The Littoral Monitoring Project
- The Sponges Monitoring Programme
- The yellow trumpet anemone, *Parazoanthus axinellae* programme (Burton *et al*., 2002)
- Commercial Potting Activities Project (Burton 2002)
- The Scallop Survey 2000, the results of which suggest that the scallop population has increased since 1984 from 1 scallop every 100 m^2 to 1 scallop every 27 m^2. This is probably due to the designation of the Marine Nature Reserve and the South West Sea Fisheries Committee bye-law banning scallop collecting, introduced in 1990 (Lock and Newman, 2001).
- Distribution and Abundance of *Zostera marina* in North Haven, was surveyed in 2002. The results of the survey determined that The North Haven *Z. marina* bed is in favourable condition as it is currently within the limits detailed in the Skomer Marine Nature Reserve Management Plan 2000 (Lock, 2003).

Strangford Lough

Strangford Lough was designated a Marine Nature Reserve (MNR) in July 1995 and is also designated a Special Area of Conservation (SAC), Special Protection Area (SPA) and a Ramsar site. It contains extensive areas of mudflat, saltmarsh and rocky coastline and is designated an SAC for its Annex I habitats: Coastal Lagoons, Mudflats and sandflats not covered by seawater at low tide, and Reefs. It is also a Large Shallow Inlet and Bay.

Following concerns over the current condition of the Strangford Lough horse mussel *Modiolus modiolus* biogenic reef feature, the Environment and Heritage Service Northern Ireland (EHSNI) commissioned an investigation into the current ecological status of the whole of Strangford Lough. An extensive diving survey demonstrated that the feature was in unfavourable condition and that the damage was possibly linked to seabed disturbance following the publication of these results. The Department of Agriculture and Rural Development introduced a temporary ban in December 2003 on all mobile fishing gear within the confines of Strangford Lough. EHSNI has now published the final report of the Strangford Lough Ecological Change Investigation http://www.ehsni.gov.uk/natural/conservation/SLECI/sleci.shtml. Efforts will focus on the options for restoration back to favourable condition.

EUROPEAN LEGISLATION, INTERNATIONAL AGREEMENTS AND PROGRAMMES

EC Habitats Directive

In 1992 the European Community adopted the Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, known as the EC Habitats Directive.

The EC Habitats Directive requires the establishment of a coherent European ecological network of special areas of conservation. This network of sites is expected to make a significant contribution to conserving the habitat (nine of which are marine, although one is not found within British Waters) and species types (four of which are found within British waters), which are identified in Annexes I and II of the Directive respectively.

The listed habitat types and species are those considered to be most in need of conservation at a European level. Protection requires Member

States to designate areas containing good examples of these habitats and populations of species [of conservation interest found on or within these habitats] as Special Areas of Conservation (SACs). These Special Areas of Conservation (SACs), along with Special Protection Areas (SPAs), classified under the EC Birds Directive (see below) will form the Natura 2000 network.

The Directive was transposed into UK national legislation by the Conservation (Natural Habitats, &c.) Regulations 1994 (for Great Britain) and the Conservation (Natural Habitats, &c.) Regulations (Northern Ireland) 1995. Unlike on land, where SACs and SPAs are underpinned by Sites of Special Scientific Interest (SSSIs), there is no existing legislative framework for implementing the Habitats Directive in marine areas. Therefore the Regulations have a number of provisions specifically for new responsibilities and measures in relation to marine areas. Within the Regulations, the nature conservation bodies have a special duty to advise the other relevant authorities as to the conservation objectives for a site and the operations that may cause deterioration or disturbance to the habitats or species for which it has been designated (Regulation 33 (2)). This advice forms the basis for the establishment of management schemes on European marine sites[3] as a key measure in meeting the requirements of the Habitats Directive.

The primary focus of a management scheme is to encourage the wise use of an area without detriment to the environment, to manage those operations and activities that would cause deterioration or disturbance to the features for which a site has been designated taking place within a European marine site, and to promote its sustainable use. It may also provide guidance for the assessment of plans and projects (i.e. any operation which requires an application to be made for a specific statutory consent, authorisation, licence or other permission). It is not the aim to exclude human activities from European marine sites, for these have been selected with many activities already taking place, and it is recognised that these need to be managed to ensure continuation of the conservation interest at their current levels.

An initial tranche of marine Special Areas of Conservation (SACs) have been identified within the UK for Annex I habitats that occur in UK waters (Table 1.1; Figure 1.2). It is important to note that a single SAC may have multiple habitat features (and Annex II species).

[3] The term 'European marine site' is defined to mean any SPA and SAC or part of a site that consists of a marine area, including inter-tidal areas.

Table 1.1. The marine Annex I habitats which occur in the UK. 'No. of SACs' refers to the number of sites where the habitat is listed as a qualifying feature

Habitat feature	Definitions[1]	No. of SACs
Coastal lagoons	Lagoons are areas of shallow, coastal salt water, wholly or partially separated from the sea by sandbanks, shingle or, less frequently, rocks. Five main sub-types of lagoon (isolated, percolation, sluiced, silled and lagoonal inlet) have been identified in the UK, on the basis of their physiography, as meeting the definition of the habitat type. The variety of lagoonal communities appears to relate to the intrinsic variation in salinity within lagoons.	**19**
Estuaries	Estuaries are complex ecosystems linking the terrestrial and aquatic environments and are composed of an interdependent mosaic of subtidal, intertidal and surrounding terrestrial habitats. There is a gradient of salinity from freshwater at the head to increasingly marine conditions towards the open sea. Input of sediment from the river, shelter from wave action and, often, low current flows lead to the presence of extensive sediment flats. Similar large geomorphological systems where seawater is not significantly diluted by freshwater are classified within the Annex I habitat *Large shallow inlets and bays.* The physiographical character of estuaries is similar to that of a large shallow inlet and bay but is influenced to a greater extent by freshwater. The intertidal and subtidal sediments of estuaries support biological communities that vary according to geographic location, the type of sediment, tidal currents and salinity gradients within the estuary. The parts of estuaries furthest away from the open sea are usually characterised by soft sediments and are generally more strongly influenced by fresh water. Many habitats found within estuaries, such as intertidal mudflats and sandflats, sandbanks, saltmarshes and rocky reefs, are identified as notified features in their own right.	**15**
Large shallow inlets and bays	These are large indentations of the coast, generally more sheltered from wave action than the open coast. They are relatively shallow, usually averaging less than 30 m in depth across at least 75% of the site. They are often complex systems composed of an interdependent mosaic of subtidal and intertidal habitats. Many of these habitats, such as intertidal mudflats and sandflats, sandbanks, saltmarshes and reefs, are identified as notified features in their own right and are covered in separate guidance. Inlets and bays may also support populations of important species. The physiographical character of inlets and bays is similar to that of an estuary, but the influence of freshwater is reduced by comparison.	**14**
Mudflats and sandflats not covered by seawater at low tide	This definition covers sedimentary habitats located between high and low water – although it does not cover saltmarsh, sand dune or vegetated shingle habitats. Sand and mudflats contain diverse intertidal communities of invertebrates and algae and are of particular importance as feeding grounds for wildfowl and waders. They often form part of very dynamic systems and interact with other adjacent features such as subtidal sandbanks, saltmarshes and sand dunes (although for the purposes of this report these saltmarshes and sand dunes habitats are not addressed). The prevailing physical environmental conditions and geomorphological processes determine the structure, function and biological composition of sediment flats.	**27**
Reefs	Reefs comprise a wide range of sub-features, particularly where rock extends from the top of the intertidal zone through the infralittoral[5] to the deep circalittoral[6] zone. Reefs are very variable in form (this includes boulder and cobble[7] habitats, and biogenic concretions) and in the communities that they support. These reefs generally support a zonation of benthic communities of algae and animal species including concretions, encrustations and corallogenic concretions[8].	**33**

Table 1.1. continued: The marine Annex I habitats which occur in the UK. 'No. of SACs' refers to the number of sites where the habitat is listed as a qualifying feature

Habitat feature	Definitions[4]	No. of SACs
Reefs (cont:)	The specific communities that occur vary according to a number of factors, these could include rock type, topographical features such as vertical rock walls, gully and canyon systems, outcrops from sediment and rock pools on the shore, exposure to wave action, temperature changes and turbidity.	
Sandbanks which are slightly covered by sea water all the time	Sublittoral sandbanks consist of soft sediment types that are permanently covered by shallow sea water, typically at depths of less than 20 m below chart datum. The diversity of associated species and communities are determined by sediment type and a variety of other physical factors. These include geographical location reflecting biogeographical trends, the relative exposure of the coast (from wave-exposed open coasts to tide-swept coasts or sheltered inlets and estuaries) and differences in the depth, turbidity and salinity of the surrounding water. Subtidal sandbanks often display considerable spatial heterogeneity in topography, sediment structure and sediment composition. These changes in the physical environment generally result in corresponding heterogeneity in their biological composition.	**23**
Submerged or partially submerged sea caves	Sea caves around the UK coast display a wide range of structural and ecological variation, depending on the prevailing physical and geological conditions. Caves can vary in size, from only a few metres to more extensive systems, which may extend hundreds of metres into the rock. No definition for caves states what the lower size limit is for a cave, there may be tunnels or caverns with one or more entrances, where vertical and overhanging rock faces provide the principal marine habitat, large overhangs, blowholes that include enclosed fully shaded areas and archways that support 'cave' biotopes. A high proportion of sea caves are found in the intertidal or in shallow water. Caves on the shore and in the shallow sublittoral zone are frequently subject to conditions of strong wave surge and tend to have floors of coarse sediment, cobbles and boulders. These materials are often highly mobile and scour the cave walls. Physical conditions, such as inclination, wave surge, scour and shade, change rapidly from cave entrance to the inner parts of a cave and this often leads to a marked zonation in the communities present. Caves are typically colonised by encrusting animal species but may also support shade-tolerant algae near their entrances. Cave systems, with extensive areas of vertical and overhanging rock, and those that extend deeply into the rock, generally support the widest range and highest diversity of plants and animals.	**15**
Submarine structures made by leaking gases	Spectacular submarine complex structures, consisting of rocks, pavements and pillars up to 4 m high. These formations are due to the aggregation of sandstone by a carbonate cement resulting from microbial oxidation of gas emissions, mainly methane. The methane most likely originated from the microbial decomposition of fossil plant materials. The formations are interspersed with gas vents that intermittently release gas. These formations shelter a highly diversified ecosystem with brightly coloured species[8].	**0**

[4] These definitions have been adapted from the Marine Monitoring Handbook (www.jncc.gov.uk/page-2430) and the CSM guidance (www.jncc.gov.uk/page-2236)
[5] The infralittoral is the subtidal zone in which kelps and seaweeds are the dominant feature of the community. The depth of this zone is variable; in clear waters it can extend as far as 15 m.
[6] The circalittoral is the subtidal zone characterised by faunal communities. No lower limit is defined, but species composition changes below about 40 m to 80 m depth. This zone can be subdivided into the upper circalittoral where foliose algae are present and the lower circalittoral zone where they are not.
[7] Cobbles are generally >64 mm in diameter.
[8] Definitions of habitats which occur beyond coastal waters are currently being examined by the Marine Expert Group, a sub-group of the EU Habitats and Ornis Committees, for their applicability to the EU marine environment beyond inshore waters.

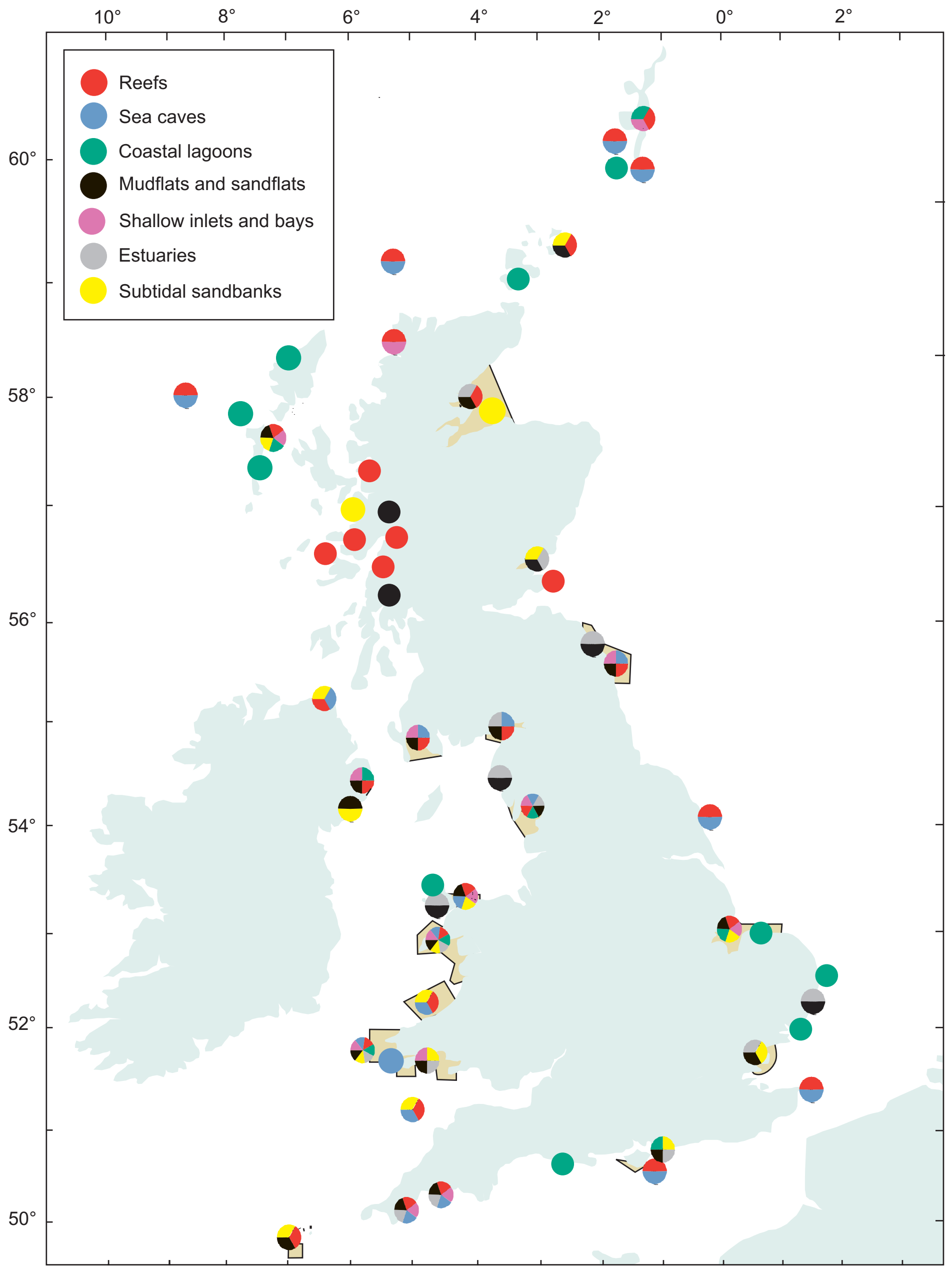

Figure 1.2. The location of candidate Special Areas of Conservation in UK showing the habitat features of the site. The symbols only show the number of features at a site, and do not represent the relative proportions of each habitat[9]

[9] Further information on the location (maps) and features of the UK candidate marine SACs, can be found on the Marine Environmental Resource Monitoring and Information Database (MERMAID: http://www.jncc.gov.uk/page-1598), although it should be noted that the biotope information contained refers to the 1997 Marine Biotope Classification (Connor *et al*., 1997 a,b) and this information is now out of date.

The total area of Special Areas of Conservation (SACs) is approximately 13,000 km^2, which represents about 8% of the seabed within 12 nm or 1.8% within UK Continental Shelf designated area (source: JNCC designations database for SAC boundaries; percentages are derived from using JNCC GIS data). There is currently no information available on the status of Annex I habitats since the first monitoring and assessment period is in progress. An indication of status will be available after the reporting deadline at the end of 2006. The proposed assessments are intended to fulfil the requirements of the EC Habitats Directive and the UK's common standards for monitoring programme.

Special Areas of Conservation away from the coast

All marine sites in the current suite of Special Areas of Conservation (SACs) around the UK have a coastal element. The EC Habitats Directive (transposed by the subsequent Offshore Marine Conservation (Natural Habitats &c.) Regulations 2003 to apply the directive to waters of the UK Continental Shelf and as far as the 200 nm limit over which the UK exercises sovereignty) is now accepted as applicable to the entire extent of UK waters and many areas have not previously been considered for SAC selection. This includes all waters beyond the territorial seas limit and a portion of territorial waters around each country away from the coast.

The Joint Nature Conservation Committee (JNCC) has developed a methodology for identifying areas of seabed which may qualify as Annex I habitat in areas not previously considered for SAC designation (Figure 1.3). This approach uses geological and bathymetric datasets, mostly from the British Geological Survey (BGS), to identify areas which may be classified as 'Reef' (rocky reef, stony reef and biogenic reef), 'Sandbanks which are slightly covered by sea water all the time' (sandy sediment in less than 20 m water depth) and 'Submarine structures made by leaking gases' (pockmark fields). Efforts are under way to use existing data to clarify further the physical and biological characteristics of areas identified as one of these three habitats. Where data are available, areas of habitat can be assessed against the Directive's selection criteria and, if deemed suitable, may be proposed as SACs. In areas where insufficient data are present to enable evaluation, further survey is needed.

JNCC is undertaking this assessment process in offshore waters (i.e. beyond 12 miles) and will advise the Department for Environment, Food and Rural Affairs (Defra) on areas that are recommended for selection as SACs. The Darwin Mounds (off North-west Scotland) were the first offshore site to be recommended to Defra under this process; the site contains biogenic reef formed from cold water corals. English Nature is undertaking the same process in English waters in order to identify potential SAC sites for sandbanks and reefs within the 12 nautical mile limit. This review has been restricted to sites that are not connected to the coast. English Nature is also looking critically at any possible sites that are adjacent to or contiguous with existing sites unless the latter support new or different features of interest. Further work is needed, building on the current information, to help identify a scoping list of possible sites. Such work will include drawing on other sources of information to qualify and fill in gaps in the geological data. For example, data do not provide information on biogenic reefs or on 'submerged or partially submerged sea caves' and 'submarine structures made by leaking gas'. Further progress beyond the initial scoping list will depend on new surveys. The amount of investment required will depend on the quality of biological information expected to justify site selection compared with the current sites along the coast. This issue is currently under debate within the JNCC-led project and with government.

Regulations to enable the designation of SACs in waters beyond the territorial seas are currently being re-drafted following public consultation. Management of offshore sites will be enabled through these regulations and also through the reformed EU Common Fisheries Policy where appropriate.

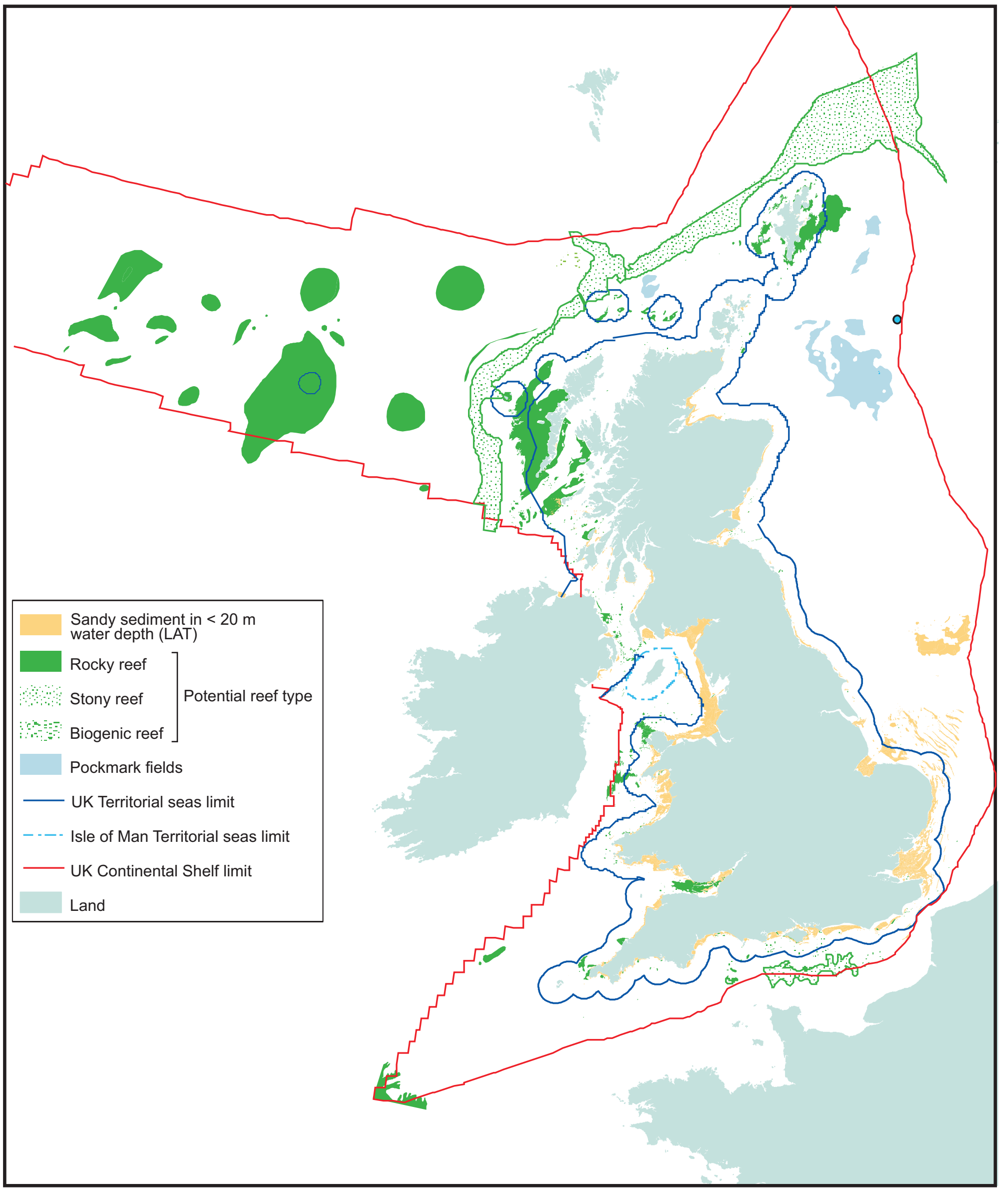

Figure 1.3. A map showing potential areas of Annex I habitat around the UK.

EC Birds Directive
Special Protection Areas (SPAs), designated under the EC Directive on the Conservation of Wild Birds (79/409/EEC), commonly known as the EC Birds Directive provide for the protection, management and control of all species of naturally occurring wild birds in the European territory of Member States. In particular it requires Member States to identify areas to be given special protection for the rare or vulnerable species listed in Annex I (Article 4.1) and for regularly occurring migratory species (Article 4.2) and for the protection of wetlands, especially wetlands of international importance.

Special Protection Areas (SPAs) are designated around the UK coast for their number of internationally important bird species. These SPAs contain marine habitats that are not protected for their habitat features per se (and hence will not be covered any further under this section). Nevertheless, these habitats are afforded some protection against damaging activities which may directly or indirectly affect the bird populations which depend upon the habitat for their survival.

Ramsar Convention
Ramsar sites are designated under the 'Convention on Wetlands of International Importance especially as Waterfowl Habitat' (commonly known as the Ramsar Convention). The UK government signed the Convention in 1973 and ratified it in 1976. In doing so, it accepted a commitment to designate suitable wetlands within its territory for inclusion in a List of Wetlands of International Importance, which is maintained by Wetlands International. The convention ensures the conservation of internationally important wetlands and their flora and fauna (many wetland fauna are migratory species) by combining far-sighted national policies with coordinated international action. For the purpose of the Convention wetlands are defined as areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres. The convention takes into account the fundamental ecological functions of wetlands as regulators of water regimes and as habitats supporting a characteristic flora and fauna, especially waterfowl, which are ecologically dependent on wetlands.

The total number of Ramsar wetlands in the UK, Overseas Territories (OT) and Crown Dependencies is 196 (144 in UK), with an area of 1,020,692.75 ha (758,822 ha in UK). Of these sites the number of Ramsar wetlands in the UK and OT and Crown Dependencies with a marine/coastal element is 73 (64 in UK, 9 in the OTs), meaning that 37% of the total number of Ramsar sites have a marine/coastal element.

It would be misleading to give the site names for these sites (as many also include a non-marine element), and there is no straightforward method to provide the extent of marine habitat, but out of these marine Ramsar sites (and including the OTs):

- 25 sites include coastal brackish/saline lagoons
- 26 sites include estuarine waters
- 11 sites include marine beds (e.g. seagrass beds)
- 21 sites include rocky shores
- 55 sites include sand/ shingle shores (including dune systems)
- 3 sites include shallow marine waters
- 54 sites include tidal flats

OSPAR Marine Protected Areas (OMPAs)
The OSPAR Commission has agreed an international programme of work to implement the Oslo–Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (the 'OSPAR Convention') long-term strategy for the protection of ecosystems and biological diversity (Annex V). Part of the implementation programme will be the establishment and management of a system of marine protected areas by 2010 (OSPAR MPA Programme) which was approved by the commission in 2003.

MPAs are used as management tools to protect, maintain or restore natural and cultural resources in coastal and marine waters. Through the establishment and management of a network of Marine Protected Areas, the OSPAR MPA programme aims to protect habitats and species throughout the OSPAR region, including the entire Exclusive Economic Zone (EEZ), or equivalent of contracting parties, and the areas outside national jurisdiction ('high seas').

Implementation of this strategy is still at an early stage and none of the Contracting Parties have yet submitted proposed MPAs to the OSPAR Commission. It is expected that the Natura 2000 marine SAC and SPAs will make a significant contribution to OSPARs MPA requirements.

Key points on the status of protected areas for habitats

- National legislation provides for the designation of marine protected areas – Sites of Special Scientific Interest (SSSI), Marine Nature Reserves (MNR), Special Areas for Conservation (SAC) and Special Protection Areas (SPA).

- The total area of marine Special Areas of Conservation (SACs) is approximately 13,000 km^2, which represents about 8% of seabed within 12 nm or 1.8% within UK Continental Shelf designated area.

- The UK nature conservation agencies are assessing the status of these sites to meet established reporting deadlines – Sites of Special Scientific Interest (SSSIs) in 2005 and Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) in 2006. At the present time (December 2004) there is no current information on the status of the habitats at these sites at a UK level.

POLICY DRIVER: WIDER/ENTIRE MARINE ENVIRONMENT

Protected areas represent a tiny proportion of the UK seas. Any assessment of the status of habitats in UK waters must consider the wider marine environment beyond protected sites. The following text describes policy drivers that relate to the wider marine environment.

Convention on Biological Diversity

In June 1992, the Convention on Biological Diversity (CBD) was signed by 159 governments at the Earth Summit in Rio de Janeiro. It became operational on 29 December 1993 and was the first international treaty to provide a legal framework for biodiversity conservation through the development of national action plans to halt the worldwide loss of animal and plant species.

In 1994, as a direct response to the CBD, *Biodiversity: the UK Action Plan* was launched (Anon, 1994). The UK Biodiversity Steering Group was created and in 1995 published *Biodiversity: The UK Steering Group Report Meeting the Rio Challenge* (Anon, 1995) which contains costed action plans to conserve 116 species and 14 habitats together with recommendations for future Biodiversity Action Plans (Tranche 1). These are referred to as the BAP Priority habitats and species. Action plans include targets for protection, restoration and enhancement of a suite of maritime features

A series of 'Broad habitat' statements have provided summary descriptions of habitats found within the UK, identifying the current issues affecting the habitat and the broad policies which can be put in place to address these. The marine broad habitats for which statements have been prepared are supralittoral rock, supralittoral sediment, littoral rock, littoral sediment, inshore sublittoral rock, inshore sublittoral sediment, offshore shelf rock, offshore shelf sediment and oceanic seas.

Some progress has been made through producing Priority Habitat Action Plans which provide more detailed descriptions of habitats and set out detailed actions that can be taken by a number of agencies in order to safeguard and enhance these habitats. For example, the Countryside Council for Wales (CCW) has been mapping the intertidal communities around the coast of Wales – the Intertidal Phase 1 project, which will be finished by April 2005. CCW has also recently produced detailed marine Biodiversity Action Plan (BAP) guidance for local officers to help them write their marine action plans. Other Biodiversity Action Plan (BAP) work is funded by CCW under the Welsh Assembly's Species Challenge Fund. However, at a UK level there are relatively few data on the overall distribution of Biodiversity Action Plan (BAP) priority habitats, and no information as such in relation to trends due to a lack of a systematic surveillance programme.

Marine priority habitats for which Biodiversity Action Plan (BAP) statements have been prepared are: saline lagoons, tidal rapids, littoral and sublittoral chalk, mudflats, mud habitats in deep water, sheltered muddy gravels, sublittoral sands and gravels and the biogenic habitats of maerl, *Sabellaria alveolata* and *S. spinulosa* reefs, *Lophelia pertusa* reefs, Serpulid reefs, *Modiolus modiolus* beds and seagrass beds.

Status information is vital if we are to measure progress towards UK Biodiversity Action Plan (BAP) targets. In many cases, basic information is still missing for priority species and habitats, reaffirming the importance of conducting new surveys and improving the accessibility of existing data, for example through the National Biodiversity Network (see http://www.searchnbn.net).

Monitoring and reporting are crucial to assess progress, evaluate priorities and address emerging issues. At the end of 2002 the Lead Partners of the action plans and Local *Biodiversity Action Plan* officers reported on their progress (see http://www.ukbap.org.uk/2002OnlineReport/2002Report.htm). There are many different definitions of 'status', but for the 2002 UK Biodiversity Action Plan (BAP) report it has been taken to mean a change in the area of habitats. For the majority of the coastal and marine habitats (61%) and some species (35%), the conservation trend is currently unknown (Figure 1.4 and Table 1.2), emphasising the lack of current knowledge and the need for further survey and monitoring of these important habitats. The continuing declines of many UK BAP priority species and habitats do not mean that their action plans have had no impact, and it is encouraging to see that in many cases lead partners have reported that the declines are slowing. Reversing these negative trends and achieving sustainable recovery will often require long-term programmes involving detailed research, wide-scale habitat improvements, and changes in the way society interacts with the environment.

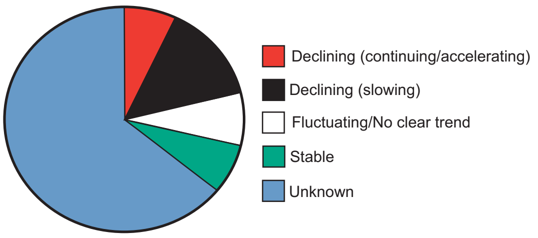

Figure 1.4. A diagram of the proportion of the 14 marine Biodiversity Action Plan (BAP) habitats in each of the trend categories

A summary of the current status of these habitats and factors affecting them is reported in the *UK Biodiversity Group Tranche 2 Action Plans Maritime Species and Habitats*. This can also be found on the UK biodiversity website: http://www.ukbap.org.uk/Habitats.aspx.

In recent years the nature conservation sector has been encouraged to develop a more planned and strategic approach to conservation activities. Both nationally and regionally there is an increasing requirement to deliver and report on key biodiversity targets.

In response to this requirement and wider needs a National Biodiversity Network (NBN) was initiated with the aim of using Internet and GIS technology to collate data from a network of contributors and disseminate biodiversity information to the widest possible range of users through a single Internet Gateway.

Data on habitat distribution, extent and condition at a UK wide level are at present not available. Although some data are available there are significant gaps. Data have not been collected at a sufficient spatial scale to show the exact distribution of habitats across the whole of the UK, and thus the production of maps to show distribution would be significantly misleading. Most references to a habitat type within the Marine Recorder database are based on a biological one-off survey at a fixed point and is not appropriate time series data for widespread assessment of change in habitats over time. Both the UK Habitat Action Plans and Species Action Plans are fundamentally dependent on information on the distribution and status of habitats. Thus a key aim of the agencies has been to address the shortfall in habitat information by producing habitat inventories to describe the distribution and extent of each habitat.

CCW commissioned a study to build an 'atlas' of marine Biodiversity Action Plan (BAP) habitats (and species) based on existing survey data and additional information drawn from a review of published and unpublished documents (Moore, 2002); It would be appropriate to extend this approach to the remainder of the UK to develop a greater understanding of the distribution of BAP habitats that would help develop a surveillance programme to assess future status. The data collection exercise to further populate the NBN that is described in the *marine benthos section* can be used to contribute to developing a UK BAP atlas.

Table 1.2. A summary of the status of marine BAP priority habitats. Information on the distribution of these habitats is available on the UK biodiversity website http://www.ukbap.org.uk/Habitats.aspx

BAP Priority Habitat	Summary of current resource[1]	Information on factors affecting (taken from UK biodiversity website http://www.ukbap.org.uk/habitats.aspx unless referenced otherwise)	Assigned current status[2]
Mudflats	The total UK estuarine resource has been estimated as c588,000 ha of which 55% is intertidal area, mostly mud and sandflats with a lesser amount of saltmarsh. Intertidal flats cover about 270,000 ha. The UK has approximately 15% of the north-west European estuarine habitat. They are widespread in the UK with significant examples in the Wash, the Solway Firth, Mersey Estuary, Bridgwater Bay and Strangford Lough.	It has been estimated that sea level rise will result in a loss of 8000 to 10,000 ha of intertidal flats in England between 1993 and 2013. Much of this loss is expected in southern and south-east England although research suggests that the major firths in Scotland will also be affected. Land claim, for urban and transport infrastructure and for industry, has removed about 25% of Great Britain estuarine intertidal flats and up to 80% in some estuaries. Barrage schemes for water storage, amenity, tidal power and flood defence continue to pose a threat to the integrity and ecological value of mudflats in estuaries and enclosed bays. Fishing and bait digging can have an adverse impact on community structure and substratum. For example, suction dredging for shellfish or juvenile flatfish bycatch from the shrimp fisheries may have a significant effect on important predator populations.	Unknown
Sheltered muddy gravels	Available descriptions of intertidal muddy gravel beds are often sparse on detail due to a lack of comprehensive data. They are not easy to survey and monitor, due to the large quantities of coarse material that would need to be laboriously sampled and sieved. Information from surveys carried out in the early 1900s in certain inlets (particularly the Kingsbridge Estuary and Helford River) highlights the extremely diverse communities found in muddy gravel habitats at that time. A review of sediment shores in Great Britain in the late 1970s described a similar distribution of muddy gravel communities to that shown by more recent surveys. Muddy gravel biotopes also occur in a number of candidate Special Areas of Conservation (SAC), under the EC Habitats Directive, including Plymouth Sound, the Fal and Helford Estuaries, the Sound of Arisaig and Lleyn Peninsula. There are, however, areas in many other inlets that are not currently protected by any legislation.	Physical disturbance: Coastal developments including the construction of marinas and slipways, sediment extraction, the widening and dredging of channels and sea defences such as barrages.Fisheries: Intertidal mollusc beds, including *Venerupis senegalensis*, have been the subject of small fisheries in the past. The current fishery is small, but has the potential for a resurgence, whereas *Mercenaria mercenaria* dredging in Southampton Water has severely disrupted this habitat. Introduction of non-native species: *Crepidula fornicata* can dominate the fauna resulting in the smothering of the sediment surface leading to anoxia in the sediment. They are also considered a pest of oyster beds	Declining (slowly)

Seagrass beds	Three species of *Zostera* occur in the UK, and all are considered to be scarce (present in 16-100 ten km squares). Dwarf eelgrass *Zostera noltii* is found highest on the shore, often adjacent to lower saltmarsh communities, narrow-leaved eelgrass *Zostera angustifolia* on the mid to lower shore and eelgrass *Zostera marina* predominantly in the sublittoral. The Cromarty Firth supports what is most probably the largest total area of dwarf eelgrass and narrow leaved eelgrass in Britain (approximately 1200 ha) while the Maplin Sands is estimated to be the largest surviving continuous population of dwarf eelgrass in Europe (covering around 325 ha). The Fleet has the most extensive population of all three *Zostera* species in Britain. Other important sites are the Exe Estuary, Maplin Sands, the Solents marshes and the Isles of Scilly, Morfa Nefyn, Milford Haven, the Moray Firth, Carlingford Lough, Dundrum Bay, Strangford Lough and Lough Foyle.	A wasting disease was responsible for die-back of large areas of seagrass in the UK in the 1930s. Between 1987 and 1992, symptoms of wasting disease appeared in several populations in north-west Europe, including estuaries on the southern coast of England and the Isles of Scilly (Fowler, 1992 taken from Davison & Hughes 1998). The extent of seagrass beds may change as a result of natural factors such as severe storms, exposure to air, and freshwater pulses. Grazing by wildfowl can have a dramatic seasonal effect. Portig *et al*. (1994) taken from Davison & Hughes 1998, found that in Strangford Lough, 65% of the estimated biomass (~1100 tonnes fresh weight) of *Zostera* was consumed by grazing wildfowl but that up to 80% was disturbed by their feeding activity. Epiphyte grazers such as *Hydrobia ulvae* however can contribute to the health of *Zostera* plants by removing the algae which foul the eelgrass leaves. Physical disturbance, for example by trampling, dredging, and use of mobile bottom fishing gear, land claim and adjacent coastal development through the construction of sea defences and potential for changes in the hydrological regime. Nutrient enrichment , at low levels, may increase production in *Zostera* while high nitrate concentrations have been implicated in the decline of mature *Z. marina*. Eelgrass is known to accumulate Tributyl, tin and possibly other metals and organic pollutants.	Unknown
Littoral and sublittoral chalk	Coastal chalk is exposed principally in the south and east of England from Dorset in the west to Flamborough Head in the north. Marine and sub-aerial erosion of chalk has resulted in the formation of vertical cliffs and gently sloping shore platforms. The most extensive areas of littoral and sublittoral chalk occur in Kent and Sussex. In Britain, chalk forms less than 0.6% (113 km) of the coastline. The conservation of important subtidal sitesis mostly dependent on non-statutory initiatives. For example, subtidal chalk habitat has been included within Sensitive Marine Areas and Voluntary Marine Conservation Areas (VMCA) such as the Seven Sisters VMCA off East Sussex .	Only 1% of the British coastline is composed of chalk, yet this represents 75% of the chalk reefs in Europe (Brown *et al.* 1997). Of the 75%,Thanet comprises 12% and Flamborough Head 9% (Jones *et al*. 2004). A recent survey of chalk cliffs throughout England revealed that 56% percent of coastal chalk in Kent and 33% in Sussex has been modified by coastal defence and other works. On the Isle of Thanet (Kent) this increases to 74% and has resulted in the loss of a wide range of micro-habitats on the upper shore and the removal of splash-zone communities. There has been less alteration of chalk at lower shore and subtidal levels, although large ports have been developed at Dover and Ramsgate with harbour developments at Margate, Folkestone, Newhaven and Brighton Marina. Elsewhere in England, coastal chalk remains in a largely natural state. A potential factor affecting the chalk biota is human disturbance of littoral plant and animal communities especially by trampling, stone-turning, small-scale fishery, and damage to rocks through removal of piddocks. Chalk exposures in the Strait of Dover are also vulnerable to oil spills due to the proximity of major shipping lanes. Sea level rise and post-glacial land adjustment will submerge a greater area of littoral (intertidal) chalk platform.	Unknown

BAP Priority Habitat	Summary of current resource[1]	Information on factors affecting (taken from UK biodiversity website http://www.ukbap.org.uk/habitats.aspx unless referenced otherwise)	Assigned current status[2]
Sabellaria alveolata reefs	In Britain, *S. alveolata* reefs are found on shores with strong to moderate wave action in the south and west, between Lyme Bay on the south coast of England and the Scottish coast of the Solway Firth. There is evidence of a significant contraction in range on the south coast of England over a period of at least 20 years until 1984. Declines have also been reported in the western part of the north Cornish coast, the upper parts of the Bristol Channel and in North Wales and the Dee Estuary. Causes have not been postulated and it is difficult to assess the true significance of these changes given the natural variability of the species. For example, *S. alveolata* reefs have recently developed off Heysham (in Morecambe Bay), dominating two hectares of boulder scar from where it had been absent for 30 years. *S. alveolata* reefs also occur as sub-features of non-reef Annex 1 habitats (eg intertidal mudflats and sandflats) under the Habitats Directive and are present in a number of Special Areas of Conservation (SACs), including the Solway Firth, Lleyn Peninsula and the Sarnau, Cardigan Bay and Morecambe Bay. However, many examples of S. alveolata reefs lie outside these areas.	*Sabellaria alveolata* reefs are at the northern end of their range in Britain and are affected by extremely cold winters, after which they may die back for many years, particularly at higher shore levels. By their nature, *S. alveolata* reefs occur in areas which are naturally subject to large scale changes in the amount of sand. They can tolerate burial for a period of days or even weeks, but prolonged burial will cause mortality. *S. alveolata* reefs are potentially vulnerable to accumulations or losses of sand as a result of shoreline development, which is the major cause of loss in parts of Europe.	Fluctuating/ no clear trend
Tidal rapids	Both the Menai Strait in North Wales and the Scilly Isles provide good examples of tide-swept communities considered to be of national importance. Also, the Dorn in Strangford Lough MNR is remarkable for its diversity of flora and fauna and for displaying a marked emergence phenomenon. Coarse gravel is a more difficult habitat for animals to colonise, as it is constantly moving, yet even here there are typical animals, such as sea cucumbers, worms and burrowing anemones. Maerl beds are also closely identified with the conditions found in tidal narrows and rapids in the south-west (the Fal estuary) and the north of the British Isles (Orkney).In deeper water, such as between islands, strong tidal streams may be felt down to 30 m. For example, between the Pembrokeshire islands strong tidal currents in the centre of Ramsey Sound provide conditions for a distinctive community, unrecorded elsewhere in south-west Britain. An important range of tidal rapid habitats are found in Scottish and Irish fjordic and fjardic sea lochs.	Solid causeways with no provision for water exchange, or with only small culverts, have been built across rapids, for instance the causeway joining Vatersay with Barra (Churchill Barriers, Orkney. In general, tidal rapids are little affected by fishing because the strong tidal streams make fishing operations difficult. However, rapids often have dense beds of animals, for example mussels, which may become attractive for exploitation in the future. Rapids can be a sanctuary for crustaceans because strong tidal currents make creeling difficult.Rapids may contain species sensitive to water pollution. Although the currents in rapids may quickly disperse one-off sources of pollution, chronic continuing pollution could affect sensitive marine life.	Declining (slowly)

Modiolus modiolus beds	Beds are known from Shetland, Orkney, the Hebrides and other parts of western Scotland, the Ards Peninsula, Strangford Lough, off both ends of the Isle of Man, off north-west Anglesey and north of the Lleyn Peninsula. EHSNI have now published the final report of the Strangford Lough Ecological Change Investigation which has clearly demonstrated that the Horse Mussel reefs are in unfavourable condition. Efforts in Strangford Lough now will concentrate on the options for restoration back to favourable condition.	Fishing, particularly using trawls and dredges for scallops and queen scallops, is known to have caused widespread and long-lasting damage to beds in Strangford Lough and off the south-east of the Isle of Man. *Modiolus* beds are likely to be badly damaged by any other physical impacts, such as aggregate extraction, trenching and pipe/cable-laying, dumping of spoil/cuttings, or use of jack-up drilling rigs.	Unknown
Sabellaria spinulosa reefs	Given its few key requirements, and its tolerance of poor water quality, *S. spinulosa* is naturally common around the British Isles. Examples are found on the west Wales coast, particularly off the Lleyn Peninsula and Sarnau Special Area of Conservation (SAC) and the Berwickshire and North Northumberland Coast SAC, and in the Wash. There is currently no statutory protection for known examples of this sublittoral habitat in the UK. The marine SACs list is incomplete with respect to biogenic reefs, although *Sabellaria spinulosa* reefs may represent important sub-features of other Annex I habitats for which a site was selected.	The greatest impact on this biogenic habitat is considered to be physical disturbance from fisheries activities. A detrimental effect on *S. spinulosa* was reported during the 1950s in Morecambe Bay.	Unknown
Sublittoral sands and gravels	Sublittoral sand and gravel sediments are the most common habitats found below the level of the lowest low tide around the coast of the United Kingdom. The sands and gravels found to the west of the UK (English Channel and Irish Sea) are largely shell derived, whereas those from the North Sea are largely formed from rock material.	Sand and gravel habitats are subjected to a variety of anthropogenic factors including the influence of pollutants in riverine discharge, and physical disturbance by fishing and aggregate dredging activities. Most flatfish fisheries are found in areas of sandy seabed and are subjected to intensive perturbation by bottom fishing gears (such as beam trawling) in the southern North Sea and English Channel. Gravel substrata are also disturbed by scallop dredging, particularly in the English Channel and northern Irish Sea. Gravel habitats are severely modified by aggregate extraction in licensed areas off the east and south-east coast of England. These disturbances are less prevalent north of the Firth of Forth, on the west coast of Scotland, and in large parts of the Irish Sea. Other physical disturbances include land claim, construction of marinas and slip ways, the widening and dredging of channels, pipe and cable laying and the construction of sea defences. These activities can alter tidal flow regimes and wave exposure, or result in deposition of sediments that influence the structure of sedimentary habitats.	Unknown

BAP Priority Habitat	Summary of current resource[1]	Information on factors affecting (taken from UK biodiversity website http://www.ukbap.org.uk/habitats.aspx unless referenced otherwise)	Assigned current status[2]
Maerl beds	Maerl beds are found off the southern and western coasts of the British Isles, north to Shetland, but are particularly well developed around the Scottish islands and in sea loch narrows, around Orkney, and in the south in the Fal Estuary. The current list of candidate SACs includes the Sound of Arisaig, selected particularly for its extensive series of maerl beds. Loch Maddy and The Vadills also contain maerl communities. In Northern Ireland, Strangford Lough (a SAC and statutory Marine Nature Reserve) contains maerl. In England, the Fal and Helford SAC includes the largest beds in south-west Britain. The Pembrokeshire Islands SAC also includes maerl communities.	Direct effects by human activities include maerl extraction. Maerl is extracted in large amounts for use in animal food additives, water filtration systems, etc, but mostly to replace lime as an agricultural soil conditioner. Dead maerl is currently extracted from an area of the seabed within the Fal Estuary, part of the Fal and Helford SAC. A marine ecological survey to determine whether maerl extraction is having an effect on the infaunal communities of the maerl beds in the SAC has been carried out (Posford Haskoning 2004). The study stated that without a pre-extraction baseline for comparison, the results cannot be conclusive however they found that there is no significant difference in the mean number of taxa per core in the infaunal community of the maerl beds in the extraction areas and in the reference areas, but that the number of individuals per core is significantly lower in the high extraction area. In contrast, the infaunal communities were found to be significantly more diverse. The results suggest that high levels of extraction are causing depletion in the abundance of individuals in the infaunal community but increasing diversity. The authors go on to say that it is not impossible that the difference in the communities of these sites could be due to other factors (such as fishing pressure, wave exposure) and not due to the extraction regime and recommend that if maerl extraction continues, monitoring should take place to monitor the condition of the maerl beds and provide further information on the effects of extraction.Scallop dredging has been identified as the biggest impact on maerl beds in the Clyde, causing serious decline of both maerl, by breaking and burying the thin layer of living maerl, and the associated species. Other types of mobile fishing gear are also likely to damage the living layer of maerl on top of the bed.	Stable

Lophelia pertusa reefs	The full extent of the present geographic distribution of Lophelia pertusa is still unknown. It has been recorded mainly off the continental shelf. Most records are from west Scotland and Ireland. Some specimens recorded from deep (ca. 50-100 m) inshore waters in Scotland. Also known from the North Sea attached to oil industry structures (Peckett 2003).	Until relatively recently the deep waters where *Lophelia* is found remained entirely undisturbed by human activity. This is no longer the case as fish trawling is moving into ever deeper water. There is growing concern over the effects of bottom fishing activities, bottom trawls and dredges are considered the greatest threat (Freiwald et al. 2004). and although skippers attempt to avoid the coral which can shred their nets, it is still trawled up and thrown back over the side. Technological advances during the last twenty years have now made it economically viable to extract oil and gas in deep waters such as those of the Atlantic Frontier to the west of Shetland. The development of the 'Atlantic Frontier' oil fields is being undertaken in areas where *L. pertusa* pseudo-colonies may be found. When drilling an oil well drill cuttings may have to be discharged which could, in theory, impact upon *L. pertusa*. if such corals are in the vicinity of operation. However, in order to ensure such impacts would not take place all oil and gas operations are subject to strict regulation under The Offshore Petroleum (Conservation of Habitats) Regulations 2001. Little is known about this coral and the impact of human exploitation also remains unknown, however one precaution would be to protect this cold water coral in British waters.	Declining (continuing/ accelerat-ing)
Saline Lagoons	Coastal saline lagoons are an unusual and rare habitat. The largest lagoon in the UK is in excess of 800 ha (Loch of Stenness) although the rest are much smaller and some may be less than 1 ha. Around the UK a large proportion of the national resource occurs in England and Scotland with 139 lagoon sites in Scotland, 12 in Wales and 177 in England (Bamber *et al*. 2001). Coastal lagoons are also listed as a priority habitat on Annex 1 of the EC Habitats Directive.	The processes which lead to the natural development of some types of lagoons are generally inhibited by human coastal activities. It is probable that the formation of new lagoons will not keep pace with the process of lagoon loss. Many lagoons are often seen as candidates for infilling or land claim as part of coastal development. Some coastal defence works can prevent the movement of sediments along the shore and lead to a gradual loss of the natural coastal structures within which many coastal lagoons are located. The impact of coastal defences will be compounded by the effects of sea level rise. One study in 1992 (Smith & Laffoley 1992) estimated that about 120 ha of coastal lagoons in England (10% of the existing resource in England) would be lost over the subsequent 20 years, mainly as a consequence of sea level rise.	Unknown

BAP Priority Habitat	Summary of current resource[1]	Information on factors affecting (taken from UK biodiversity website http://www.ukbap.org.uk/habitats.aspx unless referenced otherwise)	Assigned current status[2]
Mud habitats in deep waters	Mud habitats in deep water (circalittoral muds) occur below 20-30 m in many areas of the UK's marine environment, including marine inlets such as sea lochs. The mud habitats in deep water can also support seapen populations and communities with *Amphiura* spp. Currently the three species of seapens and the sea squirt *S. gelatinosa* have no statutory protection under UK or EC legislation. Some deep mud habitats are covered by some of the marine Special Areas of Conservation (SAC) sites, selected for 'Large shallow inlets and bays' under the EC Habitats Directive. However, this Annex I habitat is generally limited to 30 m. Within the existing SAC network, mud habitats in deep water are represented within sites such as Strangford Lough, Loch Maddy and Lochs Duich, Long and Alsh. Some of the Scottish Marine Consultation Areas include areas of circalittoral mud. Seapens & burrowing megafauna communities are also on the OSPAR list.	The majority of deep mud habitats are subject to some demersal fishing effort, principally for *Nephrops norvegicus*. *Nephrops* is one of most important fisheries in Scotland and benthic trawls or pots/creels are the two methods of fishing employed. The use of benthic trawls can result in the removal of non-target species and disturbance to the seabed. Marine fish farms are often sited within Scottish sea lochs and may have direct effects on mud communities, including smothering and increasing the Biological Oxygen Demand of the mud. Nutrient enrichment leading to eutrophication can have significant detrimental effects. This can lead to changes in the structure and composition of deep mud communities. The construction of roads, bridges and barrages may affect the local hydrodynamic and sediment transport regimes of inshore enclosed areas and consequently affect the deep mud substratum. Anchoring can cause physical damage to static megafaunal species such as seapens and *S. gelatinosa*. Offshore oil rigs and other oil installations can cause a variety of disturbance effects such as smothering due to disposal of drill cuttings, localised disturbance of sediments due to anchors and rig feet implacement and trench digging for pipelines.	Unknown
Serpulid reefs	The species has a worldwide distribution (except for polar seas) in sheltered sites, but the reef form has been reported from very few locations. In the UK, reefs have only been found in Loch Creran, and the Linne Mhuirich arm of Loch Sween, both sea lochs on the west mainland coast of Scotland. The reefs in Loch Sween are now reported to be dead. Small *Serpula vermicularis reefs* have also been found in two loughs on the west coast of Ireland, but the best developed reefs in the world are in Loch Creran. The reefs at Loch Creran, at least in the sublittoral fringe, have declined over the last 100 years (together with eelgrass *Zostera marina* beds) Moore 1996, while those in Loch Sween apparently died between 1982 and the mid 1990s.	Serpulid reefs are fragile and easily damaged by mechanical disturbance, such as from mobile fishing gear, which would seriously damage the reefs. Anchors and mooring chains could cause considerable damage to serpulid reefs. Severe damage, albeit on a very local scale, caused by movement of mooring blocks and chains has been seen in parts of Loch Creran. One mooring had reduced colonies to rubble within a radius of about 10 m, while further extensive damage was caused within about 50 m of salmon cages (Moore 1996).	Unknown

[1] Information on the current status and factors affecting these habitats has been taken from the UK biodiversity website http://www.ukbap.org.uk/habitats.aspx
[2] Taken from 2002 report http://www.ukbap.org.uk/2002OnlineReport/2002Report.htm

OSPAR Convention: Species and habitats in need of protection
The OSPAR Commission has agreed an international programme of work to implement the OSPAR Convention long-term strategy for the protection of ecosystems and biological diversity (Annex V). A set of criteria (the Texel-Faial criteria) were developed by OSPAR Contracting Parties to help identify species, habitats and ecological processes that are in need of protection in the OSPAR area. The criteria have been used to develop an initial list of species and habitats that are considered to be under immediate threat or subject to rapid decline. An initial list of ten threatened habitats was proposed to the OSPAR Biodiversity Committee (BDC) in February 2003 and was approved at the ministerial meeting in June 2003. A further four habitats were proposed and agreed by the BDC in February 2004 and added to the original list at the ministerial meeting in June 2004 (Table 1.3).

Table 1.3. Approved and Proposed habitats in need of protection in the OSPAR area

Approved habitats
Carbonate mounds
Deep-sea sponge aggregations
Oceanic ridges with hydrothermal vents/fields
Lophelia pertusa reefs
Ostrea edulis beds
Seamounts
Seapens and burrowing megafauna communities
Zostera beds
Intertidal mudflats
Littoral chalk communities
Maerl beds
Modiolus modiolus reefs
Sabellaria spinulosa reefs
Intertidal *Mytilus edulis* beds on sediment

Further information supporting these listings is in the form of 'Case Reports for the Initial List of Threatened and/or Declining Species and Habitats in the OSPAR Maritime Area' and is available for download on the OSPAR web site (see the publication section at http://www.ospar.org/eng/html/welcome.html).

The OSPAR Commission is currently considering appropriate management measures to protect these habitats and species, of which OSPAR MPAs are one possible management solution (see section on OSPAR Marine Protected Areas (OMPAs) earlier).

EC Habitats Directive in the wider environment
Favourable Conservation Status (FCS) is one of the most important concepts in the EC Habitats Directive. Ensuring that the habitats (and species) listed in the Annexes attain FCS is the key objective of the whole directive. Whilst the initial implementation has focussed on identifying and designating Special Areas of Conservation (SACs) for the habitats (and species), Member States are expected to report on the status of the habitats against the FCS criteria in 2006/7. An assessment of whether a habitat is at FCS must consider its status in both Special Areas of Conservation (SACs) and the wider environment. Such an assessment will prove challenging in the marine environment where the current lack of habitat distribution maps precludes an estimation of the full extent of habitat in UK waters, and the lack of a wider environment surveillance programme does not allow an assessment of their current status. The Joint Nature Conservation Committee is currently undertaking a pilot study to consider how the UK might assess FCS: the initial conclusions particularly highlight the need to identify all sources of data and for data owners to make that material available to support these assessments (see the *Marine Benthos* section for a discussion on data availability).

EU Water Framework Directive
Whilst the assessment of *ecological status* required by the EU Water Framework Directive (WFD) is predominantly based on biological quality elements, the status of habitats will clearly affect these quality elements and be directly assessed under 'hydromorphological quality elements'. *High status* requires that the 'depth variation, structure and substrate of the coastal bed… correspond totally or nearly totally to the

undisturbed condition'; good status requires the morphological conditions to be 'consistent with the achievement of the values… for the biological quality elements'.

Implementation of the WFD is at an early stage, so there is no current assessment of the status of quality elements. Habitat quality will form part of the assessment of the effects of pressures and impacts currently (December 2004) being finalised by the competent authorities for the WFD.

Key points on the status of the wider marine environment

- There are no systematic surveys, surveillance or monitoring programmes at a UK level to enable an assessment of the status of habitats at this time (December 2004).

- The UK has identified and drafted Biodiversity Action Plan s (BAP) for 14 priority marine habitats as part of its implementation of the Convention on Biological Diversity (CBD).

- The status of nine of these BAP priority marine habitats is unknown, three are declining, one is stable and the other is fluctuating with no trend. There is no systematic surveillance programme for these habitats and therefore these assessments are based on an 'informed view'.

- The full distribution of priority habitats in UK waters is unknown at the present time (December 2004).

MEETING THE NEEDS OF THE POLICY DRIVERS

One of the most important aspects of these policy drivers described above is that they provide a commitment to manage the UK's most important marine habitats and species.

To achieve this, such management needs knowledge of the distribution of habitats and species, as well as an understanding of their sensitivity to the effects of human activities in order to manage habitats and species on a sustainable basis. Work which can feed into meeting the objectives of this report is ongoing. The marine environment is a complex system and in order to be able to come up with an assessment of status, the UK nature conservation agencies (EN, SNH, CCW, EHS) have undertaken a considerable amount of work relating to habitat definitions, species and habitat inventories and monitoring procedures for marine sites. There has been a considerable amount of work undertaken by a variety of other organisations, both governmental and non-governmental. Progress to date has focussed on commissioning research on the habitat features and the development of guidance to assist the assessment process.

This section has been structured to highlight some of the work undertaken to expand our knowledge of marine habitats and work on assessing the quality of the marine environment.

Knowledge of the distribution of habitats and species

Our knowledge of habitat and species distribution (mostly within the 12 nm limit) is now well advanced, due to the commissioning of many marine survey programmes and reviews to gain an overview of the marine resources around the UK partly to help support the selection and designation of marine protected areas (i.e. SACs).

These include two large UK-wide systematic surveys:

- the intertidal survey of Great Britain and Ireland (Bishop and Holme, 1980; Harvey *et al*., 1980), plus a series of regional surveys including the South West Britain Sublittoral Survey (Hiscock, 1981) and the Northern Ireland intertidal and subtidal surveys (Wilkinson *et al*., 1988; Erwin *et al*., 1986). and;

- the JNCC Marine Nature Conservation Review (MNCR, Hiscock, 1996); a programme of survey undertaken between 1987 and 1998 to provide a comprehensive baseline of information on marine habitats and species, to aid coastal zone and sea-use management and to contribute to the identification of areas of marine natural heritage importance throughout Great Britain. Seasearch was initiated in the 1980s by the Marine Conservation Society and Nature Conservancy Council, then run in the 1990s in conjunction with the MNCR. Since 1999 it has developed into a national project using volunteer divers to gather information on UK seabed habitats and associated wildlife which will lead to increased knowledge of the marine environment around the UK and contribute towards its conservation.

The focus of MNCR work was on benthic habitats and their associated communities and provides information on these around the UK, although with varying amounts in different areas (see Chapter 3 for a map showing the location of biological data identified by the MNCR). With these gaps in information, producing an accurate habitat distribution map at a UK seas level is not possible. There have been a number of recent mapping initiatives to address this however (see later).

The products of the MNCR are disseminated through:

- a series of area summary reports (available for download from the JNCC website);

- Marine Recorder which enables rapid access, manipulation and dissemination of data collected through the MNCR and further surveys (This database is held by each of the country nature conservation agency marine teams) and also;

- the national marine habitat classification for Britain and Ireland, developed through the analysis of empirical datasets, the review of other classifications and scientific literature, and provides a tool to aid the management and conservation of marine habitats. It was originally developed by the Marine Nature Conservation Review (MNCR) and published in two paper volumes in 1997 (Connor *et al*., 1997a,b) and has been subsequently revised (version 04.05) and is now available for download from the JNCC website (http://www.jncc.gov.uk/page-1584)

Reviews include:

- A *Coastal Directory for Marine Nature Conservation* (Gubbay, 1988), published by the Marine Conservation Society. This included a review of the status and species features of a range of coastal and marine habitats, communities and species, as well as an inventory of sites considered to be of marine nature conservation interest. The inventory was based on a review of survey reports, publications, a questionnaire survey and interviews with individuals who had specialist knowledge of particular areas.

- The Coastal Directories project in the 1990s, coordinated by JNCC on behalf of a wide-ranging funding consortium, collated extensive baseline environmental and human use information, including fisheries, for the coastal and nearshore marine zone of the whole of the UK. They were published as a series of 17 regional reports. Each report has a description of the marine and estuarine environments of the region, including important locations and communities (available from the JNCC website).

The UK marine SACs Project
The UK marine SACs Project (http://www.ukmarinesac.org.uk) was an EC LIFE-funded project which ran from May 1996 to October 2001 and aimed to develop approaches and techniques to the management and monitoring of marine SACs. Specifically it aimed to

i) Establish operational management schemes on a selection of 12 marine SACs around the UK, through working with relevant authorities and other local partners

ii) Share best practice on developing appropriate management schemes

iii) Gather existing knowledge and improve understanding of the dynamics and sensitivity of marine features, the impact of human activities on marine features, and practical techniques for monitoring and accessing the condition of these features.

iv) Raise awareness in the UK and Europe for the value of marine SACs and the means by which they can be safeguarded.

Outputs from this project included:

- Reports on the on the ecology, sensitivity and management of subtidal brittlestar beds (Hughes, 1998a), maerl (Birkett *et al*., 1998), *Zostera* (Davison and Hughes, 1998), intertidal reef biotopes (Hill *et al*., 1998), biogenic reefs (Holt *et al*., 1998), circalittoral faunal turfs (Hartnoll, 1998), infralittoral reefs with kelp (Birkett *et al*., 1998), intertidal sand and mudflats and subtidal mobile sands (Elliott *et al*., 1998), sea pens and burrowing megafauna (Hughes, 1998b) are all published on the UK marine Special Areas of Conservation (SACs) Project website detailed above. Some key conclusions are summarised elsewhere in this report.

- ecological requirements and sensitivity characteristics for the conservation and management of marine SACs (the Marine Habitat Reviews)
- information and good practice guidelines for activities which may impact on European marine sites
- The *Marine Monitoring Handbook*, which provides guidance on the different options and their relative costs and benefits and describes best practice through a series of procedural guidelines for the common survey/monitoring techniques. The handbook can be downloaded at http://www.jncc.gov.uk/page-2430.

Common standards monitoring guidance
Specific guidance for assessing the status of each marine interest feature is provided on the Joint Nature Conservation Committee website at http://www.jncc.gov.uk/page-2236

A statement on common standards for monitoring designated sites was published by JNCC in 1998 (http://www.jncc.gov.uk/page-2198). The common standards cover, amongst other things, features to be monitored and conservation objectives. The features to be monitored are known as the *interest feature(s)* for which the site has been notified (i.e. Annex I habitats and Annex II species). Conservation objectives should define what constitutes favourable condition for each feature by describing broad aspirations which should be met if the feature is to be judged favourable. It is difficult to come up with a generic way of constituting favourable condition for a feature as a whole and across the whole of the UK, as there is a need to take into account differing characteristics of the area which may support a feature. Marine ecosystems and the specific communities that occur vary according to a number of factors, including substrata type, topographical features, and environmental parameters, such as depths, salinity, temperature changes and turbidity. The judgement of what constitutes favourable condition will need to bear in mind the wide variation in types of site and their interest features, and knowledge of natural changes which occur. Once site and feature-specific conservation objectives have been set, the next step will be to determine the attributes (measurable characteristics) that can be used to help define favourable condition. For each habitat feature, attributes have been chosen based on answering the question of Favourable Conservation Status. Thus the Article 1 definition that '*its natural range and areas it covers within that range are stable or increasing*' is addressed through setting attributes based on the total extent of the feature and the distribution of the feature within the site; '*the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future*' is addressed through setting attributes which address the physical structure of the habitat, fundamental physiochemical processes, biotic assemblages and overall ecological integrity of the feature and; '*the conservation status of its typical species*' is addressed through attributes which relate to species which typify (characterise) the habitat, either generally (i.e. form part of its definition), or specifically on this site (i.e. those that contribute to local distinctiveness of the habitat). Although for each interest feature the list of possible attributes that could be selected are generic across all sites, the interpretation of the generic attributes is modified and tailored according to the local area. While the possible attributes that could be selected are generic across all features on all sites, the targets are not generic, and therefore should be site-specific to highlight local distinctiveness. Hence for each attribute specifically selected for the feature, a range of acceptable target values bounded by upper and lower threshold values needs to be identified which reflects the desired condition. These values can be based on past historical data. However, for many marine attributes, there are insufficient data to establish certain, unambiguous target conditions. In particular, there are insufficient time series studies to assess fully the extent of the underlying background variation (due to environmental and/or biological factors) against which the magnitude of an impact from a known anthropogenic pressure may be judged. Therefore in order to assess the status (condition) of features on protected sites and make correct judgements about change there is a need to separate out natural fluctuations from anthropogenic impacts. Monitoring[1] is carried out to collect information to determine the current 'value' and to see whether at this particular point in time the recorded value equates to the target value. It is anticipated that the certainty of target conditions will increase over future monitoring cycles, and with additional data gathered from surveillance programmes.

[1] A survey undertaken to ensure that formulated standards are being maintained.

Review of time series studies

A first step in this process was to commission a review of current and historical seabed biological time-series studies in the UK and near Europe (Hiscock and Kimmance, 2004: see http://www.marlin.ac.uk/time_series_metadata for report and interactive access to the database).

If monitoring is to be effective in providing information on the success or failure of site management measures then it is imperative that it is assessed in the context of long-term trends over a broad spatial scale, and from this a coordinated network of long-term reference monitoring sites can be established. In order to do this we need to identify organisations that are carrying out time-series studies to identify the sufficiency of time-series monitoring and gaps in coverage. For many marine habitats and species, there are few published UK-wide surveillance programmes that can contribute to the Common Standards Monitoring (CSM) programme. Therefore there is a need to compile an inventory of more local, small-scale programmes with a view to building a more widespread programme. The review highlighted 92 seabed biological surveys that include time-series data which identified some changes in species abundances that could be interpreted as related to changes in environmental factors, including as a result of human activities. It should be noted that it is inevitable that existing time-series studies will not provide the full network of sites that might be appropriate to monitoring change and obtaining contextual information to interpret change in SACs, and at present the survey of time-series studies is not complete and continued input of information to the database is needed.

Further work from this report has been carried out in order to identify seabed indicator species from time-series and other studies (Hiscock *et al*., 2004). This report aimed to match information sources to different pressures (environmental factors) as part of the EU Water Framework Directive drive to identify biological (as well as physical and chemical) data that will inform the development of measures of quality. The measures need to relate to a range of 'Pressures' so that cause and effect can be assessed. Ninety-eight papers or reports have been identified that list species which increase or decrease or that are considered intolerant or tolerant in relation to different pressures/environmental factors, and the results summarised in the report and/or included in spreadsheets for each of the main pressures identified by the Environment Agency[2]. Those pressures have been matched to 'Environmental factors' used in the Marine Life Information Network (MarLIN) programme (see earlier) to assess the sensitivity of species to perturbation and the MarLIN database has been queried to provide tabulated information on intolerance and sensitivity (sensitivity = intolerance and recovery potential) for species that have been researched by MarLIN. The information located in the literature has been brought together into one summary table identifying the response of 482 taxa to seven pressures, 15 environmental factors and a general category for industrial effluents, including sewage and metals.

Assessing the status of the seas

The country nature conservation agencies have produced their own reports based around presenting an analysis of the state of the environment (focussed to varying extents on the sea) and are currently undertaking monitoring programmes to assess the status of marine (and terrestrial) SAC features to meet the reporting deadline at the end of 2006.

The Welsh Government agencies have produced a report entitled *The State of the Welsh Environment 2003* (Anon, 2003). The reports cover all habitats – land and water – and there is limited information on marine habitats, re-emphasising the message on the lack of available data to undertake assessments at this stage. This report is more widely covered in Chapter 3.

In response to being able to undertake assessments CCW has initiated a range of projects to develop monitoring methods and establish baselines for the assessment and management of the eight Special Areas of Conservation (SACs) which occupy more than half of the Welsh coastal waters. Further monitoring trials have tested methods and deployment strategies for important invertebrate and algal communities at Bardsey Island/Ynys Enlli and Sarn Badrig in the Pen Llyn a'r Sarnau SAC (Lindenbaum *et al*., 2003; Howson *et al*., in press). Elsewhere monitoring strategies have

[2] Under Article 5 of the WFD there is a requirement to carry out a River Basin Characterisation assessment to identify the significant pressures and review the impacts of human activity on the water environment. Water bodies have been categorised into 5 categories, the ones of most relevance here being transitional waters and coastal waters.

been developed for lagoonal features across Wales (Bamber, in press). these and other studies provide the basis from which adequate assessment of the condition of features can be developed for the 2006 reporting schedule. A wide variety of other monitoring trials, predominantly within reefs and estuaries is described by Sanderson *et al.* (2001). In order to provide adequate information to judge the favourable conservation status of SAC features, surveillance of other factors is also required within designated sites. Turbidity data being generated in the Menai Strait and Conwy Bay SAC in partnership with the University of Wales, Bangor, and temperature data gathered in Pen Llyn a'r Sarnau are two examples of such data.

English Nature has produced their *State of Nature: Maritime – getting onto an even keel report* (Covey and Laffoley, 2002) This report considered the anthropogenic pressures on the major marine habitats highlighting the key issues of concern, and reviewed the wider impact of coastal development, marine pollution and fisheries. Key issues were the loss of existing lagoons, estuaries, and sandy and muddy seashore habitats through coastal squeeze against sea defences; the loss of estuary habitats due to inappropriate development and land claim, and cumulative rocky shore habitat loss from development or coastal defences. This is more widely covered in Chapter 3. English Nature also published a *Strategy for Conserving England's Marine Heritage* in 1993.This included the identification of nationally important subtidal marine areas around England (Sensitive Marine Areas). These are non-statutory marine areas, e.g. the Poole Bay and Isle of Purbeck Sensitive Marine Area, which are notable for their marine animal and plant communities or which provide ecological support to adjacent statutory sites. A further aim is to raise awareness and disseminate information to be taken into account in estuarine and coastal management planning. These areas rely on the cooperation of users and local communities for sustainable management.

English Nature has undertaken a rolling marine monitoring programme which is intended to generate data for site condition assessment and consequently improve site management. Data collection is centred upon the notified interest features at each site, and assessment of individual attributes for each interest feature is carried out according to the Joint Nature Conservation Committee's Common Standards Monitoring techniques. Attributes are frequently investigated on a hierarchy of biological spatial scales comprising:

- ranging from extent of a feature;
- variety of biotopes (marine communities) present;
- species composition of notable communities; and
- presence of regionally important or rare species at the site.

The hierarchical approach allows the effects, risks or impacts at the site to be assessed at the appropriate scale, and provides meaningful information on the long-term stability of the habitats, communities and species present at the site. In 2004-5 a range of projects is under way to record condition of features at Natura 2000 sites. A nationally led contract is being undertaken to describe the condition of SAC reef interest features at Lundy Island, Isle of Wight, Thanet Coast, Falmouth, Plymouth and Berwickshire. Assessment of subtidal sandbanks is in progress in partnership with Scottish Natural Heritage in the Solway Estuary, and numerous smaller intertidal surveys are under way on other parts of the English coast (especially at Morecombe Bay, Duddon Estuary, South Wight and Severn Estuary). Finally, a programme of habitat study is under way at Special Protection Areas (SPAs) in the Solent, Swale and Medway, Northumbrian Estuaries and Humber Estuary to described bird invertebrate prey abundance to improve site management.

Scottish Natural Heritage (SNH) has produced a *Natural Heritage Trends: The Seas around Scotland* report (Saunders *et al*., 2004). This highlighted a relative lack of information for much of Scotland's marine waters (assessing the status of the Scottish marine waters, particularly those off the north and west coast, is probably one of the biggest challenges due to their remote and relatively inaccessible nature), although there has been significant marine survey activity in recent years aimed at generating baseline data for site condition assessment. This report brings together details based on the best information available on natural heritage trends in the Scottish marine environment, and a list of organisations, institutions, laboratories and companies that hold information relating to the

Scottish marine environment is included in the report. The conclusion to the report discussed that despite Scotland's seas supporting a wide range of marine habitats and species (i.e. seven of the nine marine Annex I habitats (EC Habitats Directive), and 13 marine habitats described in the UK Biodiversity Action Plans), these have been subject to a multitude of pressures and without improved knowledge, care and long-term commitment to their protection, they could be irreparably damaged. In general, the overall level of coastal development is low and in many areas has declined steadily over a period of perhaps 30 years. A comparison of North Sea coastal development in 1988 with that of 1999 revealed little change, apart from an increase in the relative importance of leisure and recreational uses. In the West, fish farming has raised various issues concerning release of therapeutic medicines and on the extent of organic deposition. Growth of the industry has prompted concern about the effects of nutrients over wider areas and, although there is little relevant hard evidence, this will receive more attention in the future. Overall, the report states that current data suggest that Scotland's seas are reasonably healthy adjacent to the vast sparsely inhabited areas and are improving where anthropogenic discharges previously displaced natural marine or estuarine communities. Despite the survey coverage being dispersed and incomplete, it continues to reveal new discoveries such as cold water corals and the sublittoral St Kilda plateau and one of the SNH future objectives is to improve the management, stewardship, awareness and understanding of marine ecosystems.

SNH has drawn together a monitoring programme which has involved undertaking surveys incorporating features such as the Berwickshire caves, Papa Stour reefs and caves, Vadills lagoons, intertidal and subtidal sandbanks and maerl within the Sound of Arisaig and Kentrick Bay, surveys of estuarine environments in the Dornoch Firth SAC, survey of biogenic and rocky reefs in the lochs Duich, Long and Alsh SAC, and the littoral and sublittoral features of Loch Nam Madadh SAC. Details on the status of these features are not available at this present time (December 2004), but assessments on determining the condition of SAC interest features is being carried out to report in 2006.

The Environment and Heritage Service Northern Ireland (EHSNI) has drawn together a monitoring programme for Rathlin Island SAC and Murlough Bay SAC utilising a CSM approach. This work is expected to commence in 2005. EHSNI have now published the final report of the Strangford Lough Ecological Change Investigation http://www.ehsni.gov.uk/natural/conservation/SLECI/sleci.shtml which has clearly demonstrated that the Horse Mussel reefs are in unfavourable condition. Efforts in Strangford Lough will now concentrate on the options for restoration back to favourable condition.

Habitat classification and mapping initiatives

There is a real need to understand and define the distribution of habitats, particularly to provide a baseline for a monitoring programme and a framework or context within which to understand the results of the monitoring effort. In recent years there has been a substantial increase in habitat mapping studies to meet the demands from industry, fisheries, coastal developers and conservation managers.

National level

<u>Marine landscapes</u>

One of the key recommendations in the interim report of the Review of Marine Nature Conservation (RMNC) Working Group, submitted to Ministers in March 2001, was to set up the Irish Sea Pilot project (Vincent *et al*., 2004) with the aim of trialling a 'framework for marine conservation' (Laffoley *et al*., 2000), addressing the ecological requirements of marine wildlife at an appropriate range of spatial scales to test the potential for an ecosystem approach to managing the marine environment at a regional sea scale.

The 'framework for marine conservation' proposed the use of marine landscapes as part of an ecosystem-based approach to marine conservation. This marine landscape level represents an intermediate scale between regional seas and habitats, which have consistent physical and ecological character and provide a sensible scale to relate to the management of certain human activities such as fishing. Conservation action will be aimed at regulating such human activities in a way which is tailored to the relative sensitivity to damage of the seabed substratum, and also to the relative sensitivity to alteration or disturbance of particular water column characteristics (such as frontal systems).

The concept of a marine landscapes classification of the sea and seabed was developed with the aim of enabling action to be taken to benefit nature conservation in circumstances where marine biological data are limited. The classification is based on the assumption that geophysical and hydrographical information (for which there is generally better broad-scale coverage than biological information) can be used in lieu of biological information to classify medium scale marine habitats and to set marine nature conservation priorities. In total, 18 coastal and seabed marine landscape types were identified for the Irish Sea. The Irish Sea Pilot project has demonstrated that the identification and mapping of a comprehensive series of marine landscape types using geophysical and hydrographical data is fully practicable at the Regional Sea scale. This marine landscape classification developed under the Irish Sea Pilot project is now being extended to cover the UK continental shelf under the CMap (Countryside map of the sea) project. This is likely to be invaluable for strategic planning, spatial planning policy development and management decision making for the sea (Golding *et al*., 2004).

National marine habitat classification

The UK nature conservation agencies have put considerable effort into mapping habitats around the UK coast. The national marine habitat classification for Britain and Ireland (http://www.jncc.gov.uk/page-1584 – see earlier), has provided a tool to aid the management and conservation of marine habitats and has aided the production of habitat maps such as through the CCW intertidal habitat survey. Started in 1996, this project aims, for the first time, to map the intertidal communities between the high and low water marks of the whole Welsh coastline by 2005. Developing a marine habitat classification for the UK has been a significant achievement, especially as the UK system now forms the basis for the marine section of the European Environment Agency's EUNIS habitat classification, thus providing consistency at a European level. The classification needs to be adopted more widely by UK government agencies to help integrate data for marine surveillance and assessment. The classification will also need to be extended to cover offshore habitats, particularly those in deeper waters, and will have important benefits for marine environmental management.

Marine Natural Areas

English Nature has identified and described, together with the Joint Nature Conservation Committee and in consultation with other organisations, six Marine Natural Areas encompassing the seas around England; these are the Southern North Sea (Jones *et al*., 2004a), the Mid North Sea (Jones *et al*., 2004b), the Eastern Channel (Jones *et al*., 2004c), the South Western Peninsula (Jones *et al*., 2004d), the Western Approaches (Jones *et al*., 2004e), and the Irish Sea (Jones *et al*., 2004f). These Marine Natural Areas (MNAs) have been identified using oceanographic processes, bathymetry and biogeographic characteristics to define broad natural divisions in the marine environment and provide a series of 'profiles': documents which provide a thumbnail sketch of each Area including its physico-chemical characteristics, key habitats and species, and, in brief, relevant human activities relevant to these from the Mean Low Water Mark out to the 200 nautical mile limit or the limit of the UK continental shelf. In addition to producing the profiles, English Nature has used a Geographic Information System (GIS) to hold and display the data referred to in this document, and a series of maps are produced in the report showing the locations of specific habitats.

Wider environment level

OSPAR habitat classification

The OSPAR Biodiversity Committee (BDC) has been developing a habitat classification system for the OSPAR area (as part of the European Environment Agency's (EEA) European Nature Information System (EUNIS) habitat classification) and initiated a habitat mapping programme to underpin its work on the protection and management of ecosystems and habitats. This work is being led by the United Kingdom. The development of a habitat classification system for the North-East Atlantic was progressed through two workshops, held in Oban (1999)[3] and Southampton (2000)[4] under the joint auspices of OSPAR, the International Council for the Exploration of the Sea (ICES)

[3] IMPACT 99/4/Info.2
[4] BDC 00/6/Info.1

and the European Environment Agency (EEA), building upon a preliminary classification of marine habitats developed for the EUNIS system. The recommendations for additions and amendments to EUNIS arising from these workshops are reflected in the current version of EUNIS, available at http://eunis.eea.eu.int/eunis/habitats.jsp.

The Biodiversity Committee agreed at its November 2000 meeting[5] to continue development of the classification so that further detail could be added, sufficient to meet the needs of OSPAR for assessment, comparison and mapping. It was envisaged that there were short-term needs in relation to threatened habitats and the development of Ecological Quality Objectives (EcoQOs), coupled with a longer-term need to facilitate Quality Status Reporting including through mapping.

This further classification development has been assisted by a review of literature describing marine habitats in the OSPAR maritime area. Contracting Parties have undertaken the review for literature relating to marine habitats in their own national territory and Exclusive Economic Zones (EEZs). In parallel with the literature reviews by the Contracting Parties, the United Kingdom has been undertaking detailed analysis of some 30,000 benthic samples (intertidal and subtidal) held on the JNCC's national marine database, together with a review of literature relating particularly to offshore sediment habitats. This has led to a major revision of the UK's marine habitat classification, which was originally published in 1997 and which also covers inshore habitats around Ireland. The first phase of this work, for intertidal rock and sediment habitats and for circalittoral (animal-dominated) subtidal habitats, was released in April 2003 (see http://www.jncc.gov.uk/page-1584). Revision of the remaining sections (infralittoral or algal-dominated subtidal rock habitats and subtidal sediment habitats) is now complete and is being prepared for Internet release. A revised classification of habitats for the OSPAR area was adopted by BDC in February 2004 (BDC 04/14/1-E, Annex 8) and is currently being used to update the EUNIS classification.

At the Biodiversity Committee (BDC) 2003, proposals[6] were put forward for two types of habitat mapping programme, namely to produce point distribution maps for the whole OSPAR area and a more detailed holistic habitat mapping programme, initially for data-rich areas such as the North Sea. The BDC recognised both the need and the relatively low cost of the point distribution mapping programme, and agreed that the UK should lead the coordination of such a programme, which should be directed towards the 14 priority habitats on the OSPAR list. Development of this programme is described below. In contrast, the BDC recognised the potentially high cost of the second programme and agreed that the development of holistic maps for the whole OSPAR area should be considered as a long-term product.

For the point distribution mapping programme each Contracting Party will be responsible for supplying simple datasets on the distribution of each (of 14) priority habitats within their own marine waters (out to 200 nm or EEZ limits). The UK will collate these datasets and prepare compiled maps showing the distribution of each habitat across the OSPAR area. The resultant maps will be reported to BDC and made available via the Internet. A work programme has been developed to lead up to the presentation of a completed set of habitat maps to the BDC meeting due in early 2005.

Mapping **E**uropean **S**eabed **H**abitats (**MESH**)

To initiate delivery of a holistic mapping programme, the Joint Nature Conservation Committee has led the development of an EU funding proposal under the Interreg framework international marine habitat mapping programme entitled 'Development of a framework for **M**apping **E**uropean **S**eabed **H**abitats' (**MESH** for short), which started in spring 2004 and lasts for three years, MESH has 12 partners across the UK, Ireland, the Netherlands, Belgium and France and aims to produce seabed habitat maps covering the marine waters of north-west Europe, together with the development of international standards for seabed mapping. The outputs from the MESH project will contribute to the longer-term OSPAR objective for holistic habitat maps of the OSPAR area. The more fine-scale mapping within the MESH project is being integrated with the development of a broad-scale marine landscapes map for the entire UK shelf in the CMap project (see earlier).

[5] BDC 00/15/1, Annex 7
[6] BDC 03/3/6

The two projects aim to deliver much needed habitat mapping information at a variety of scales to give regional, national and international perspectives on the seabed resource, which will be important for developing monitoring strategies and informing strategic marine resource use and will feed into spatial planning needs.

Assessing the quality of the marine environment
Much discussion recently has focussed on particular pressures and the effects of human activities on habitats and their associated benthic communities. The effects of certain activities on benthic communities are further discussed in Chapter 3.

Specific impacts affecting the physical structure of habitats are:

- Physical loss, e.g. by removal such as land claim, coastal development or smothering, and coastal squeeze.

All habitats are sensitive to some degree to removal and smothering. For example, kelp forest, subtidal faunal turf and rocky shore communities are highly sensitive to physical loss by removal and moderately sensitive to smothering. Activities that may influence the hydrodynamic regime, such as coastal defence and coastal development, can lead to changes in sediment deposition rates, which may subsequently result in smothering.

- Physical damage, e.g. by dredging, mobile benthic fishing (such as bottom trawling), extraction (such as aggregate extraction), recreational activity (for example yacht moorings) and bait digging.

There have been a number of studies documenting the effects of mobile benthic fishing gear on the seabed. These are covered in more detail in chapter 3. Extensive physical damage may ultimately lead to loss of habitat: for example reef communities are sensitive to physical damage (Hill *et al*., 1998). Damage caused by selective extraction can occur when particular elements of the habitat are physically removed, which also has the potential to alter the condition of the habitat. Activities that result in abrasion, such as bait digging, may cause the destabilisation of sediment and an increase in its erosion. This can alter the structure and function (both physically and biologically) of the sub-features of intertidal flat habitats and ultimately could lead to loss of the feature of interest.

Fishing is the most significant human activity causing change in the UK's marine environment. Most of the data on the impact of fishing gear, however, comes from comparatively shallow waters. Damage to the seabed and to seabed communities is widespread, which will adversely affect other species, including fish, that depend on these habitats and communities. Changes caused by trawling on the seabed and its habitats in the North and Irish Seas are widespread. Some habitats may be more resilient and recover faster than others. Direct damage is not the only physical effect of trawling. The stirring of seabed sediments can alter the seabed habitat, as can the moving or removal of seabed features such as stones and boulders (Laffoley and Tasker, 2004).

- Non-toxic contamination, e.g. nutrient enrichment or organic enrichment.

Intertidal mudflat and sandflat communities are sensitive to nutrient and organic enrichment. Such inputs can locally lower oxygen levels, making the flats anoxic. Eutrophication caused by a nutrient increase can result in increased coverage of ephemeral algae and algal mats such as *Entermorpha* spp. Eelgrass beds are therefore also highly sensitive to smothering in areas where algal mats that grow due to nutrient enrichment cover them.

Physical disturbance by fishing causes changes in nutrient cycling in marine ecosystems (Duplisea *et al*., 2001). This is important in avoiding eutrophication or
anoxia in or near the seabed.

- Biological disturbance, e.g. introduction of non-native species.

The selective extraction of part of an interest feature such as the removal of worms for bait from intertidal mudflats and sandflats may alter its structural composition as well as its ecology.
There are already 53 non-native species recorded in British waters, with the Chinese mitten crab, the slipper limpet and the Japanese seaweed *Sargassum muticum*, also known as Strangle weed, among the most damaging examples (Clover, 2002).

The introduction of non-native species such as the Chinese mitten crab, thought to have arrived from China as larvae in ballast water, is causing concern in the Thames, Medway and Humber estuaries. It is thought that as populations increase, flood defences could be affected. The mitten crabs live in fresh water as juveniles, but then move down to the estuaries. They are known to burrow into sediment banks in estuaries, therefore causing a threat to the stabilisation of the sediment.

- Climate change

Climate change presents a series of important and immediate challenges to nature conservation. There is already clear evidence to show that plants and animals, including those characteristic of the UK's seas, are being affected by climate change. This includes changes in the populations, ranges, migration patterns, and seasonal and reproductive behaviour of certain species. It is only in recent years that the potential effects of climate change (whether natural or accelerated by anthropogenic influences) on the natural environment have been considered in depth, partly due to the great advances in technology required for modelling studies. Most research effort has been directed towards the effects of anthropogenic climate change. Implications of climate change include habitat loss of estuaries, particularly where these are backed by coastal defences preventing natural retreat. MarClim (http://www.mba.ac.uk/marclim/) – Marine Biodiversity and Climate Change (a multi-partner project, with research led by the Marine Biological Association, Plymouth). is currently the only government-funded project addressing climate change in the marine environment in the UK. The aim of MarClim is to assess and forecast the influence of climatic change on marine biodiversity in Britain and Ireland using long-term and current data on intertidal rocky shore indicator species.

There are well-known documented effects of some these activities on habitats within marine SACs. These are described under the advice on operations within Regulation 33 (from the Habitat Regulations 1994) advice packages. The aim of this advice is to enable all relevant authorities to direct and prioritise their work on the management of activities that pose the greatest potential threat to the favourable condition of interest features on the European marine site and to help provide the basis for them to be addressed within the management scheme.

Site characterisation studies

The operations advice can also help inform on Regulation 50, which requires a competent authority to undertake a review of any existing consent or permission to which Regulation 48(1) (requirement for an appropriate assessment of the implications of proposed projects and plans on the European marine site) would apply if that consent was being reconsidered as of the date on which the site became a European site. The Environment Agency has been working closely with English Nature and the Countryside Council for Wales to review discharge consents affecting existing designated sites and to adjust the operational standards as necessary. An important stage of this process has been to undertake investigative work in the form of site characterisation studies. Competent authorities must make an assessment of existing permissions/consents/other authorisation in combination with each other and take into account cumulative influences on the site to ascertain whether it can be concluded that they are not having an adverse effect on site integrity, i.e. are not affecting the structure and function of the site which directly or indirectly would affect the conservation objectives for any of the interest features. This is based by looking at exceedence of the Environmental Quality Standards (EQSs) set for the water quality parameters (EQSs are addressed further within the Marine Environment Quality sector assessment.)

The principles of site characterisation are based on collating, integrating and critically evaluating available information for European marine sites to identify the risks to the site, as addressed through the Regulation 33 advice packages (see above), followed by a desk-based assessment of existing site knowledge to refine understanding of impacts and risks and to characterise pollution sources. Finally, there is a phase of further investigation through modelling predictions, laboratory studies, field sampling and re-analysis of existing data. Various studies are being carried out, for example on Plymouth Sound and Estuaries SAC (Langston *et al*., 2003a), the Stour and Orwell estuaries (Johnson *et al*., 2004), the Humber estuary (Thomson *et al*., 2004), the Exe estuary (Langston *et al*., 2003b) and Chesil and the Fleet (Langston *et al*., 2003c).

These summarise potential issues affecting water quality and highlight effects mostly on the biota of toxic and non-toxic contaminants rather than direct effects on habitats, so they will not be discussed further within this chapter. Key findings of note are within the Plymouth Sound and Estuaries SAC, principally the Tamar and Tavy estuaries where there is evidence of influence by past mining activities which continue to affect the area via mine drainage discharges, run-off from spoil heaps and remobilisation of metals from sediments. Specifically mentioned are hydrocarbons (PAHS) found in high concentrations in Tamar (Hamaoaze and upper) and Plymouth Sound sediments which pose a threat to the vulnerable seagrass features and nutrients within the upper estuaries especially Tamar, Yealm and Lynher which also pose a threat to *Zostera* beds and associated diverse fauna (i.e. due to increased algal smothering of seagrass beds and intertidal flats). Many of the studies, however, are over 10 years old and were typically of short duration and covered limited geographical areas and ranges of contaminants, and so will need improvements to facilitate the understanding of the system and assist authorities in ensuring favourable condition of the sites and features (Langston *et al*., 2003a). Within the Exe Estuary report it was noted that there are signs that *Zostera* (eelgrass beds) is declining in the estuary, although it also notes that this is based on sparse evidence (Langston *et al*., 2003b).

Assessing estuary quality

Estuary quality is assessed by the environmental protection agencies in the UK (Environment Agency (England and Wales); Scottish Environmental Protection Agency (Scotland); Environment and Heritage Service (Northern Ireland)). Information about the quality of estuaries in the UK is available on the Department for Environment, Food and Rural Affairs (Defra) website http://www.defra.gov.uk/environment/water/quality.

In England, Wales and Northern Ireland, (and in Scotland up until 1995) estuaries are categorised into four quality classes, ‘good’, ‘fair’, ‘poor’ and ‘bad’, based on the biological, aesthetic and chemical quality of the water. A points system is used to classify waters, where points are awarded if certain criteria are met and the total number of points for the estuary determines its quality class. In Scotland a new classification system was introduced in 1995, called the Association of Directors and River Inspectors for Scotland (ADRIS) estuary scheme. As with the previous scheme, ADRIS is based on the biological, aesthetic and chemical quality of water, but the criteria are more comprehensive and more precisely defined. In order to achieve a particular classification under the ADRIS scheme waters must satisfy all the quality criteria appropriate to the class. In this scheme, estuaries are also divided into four quality classes, categorised as ‘excellent’, ‘good’, ‘fair/poor’ and ‘seriously polluted’. Northern Ireland is changing over to the ADRIS scheme and will present results in future years based on this new classification. The Environment Agency is also considering changing the classification system in England and Wales to a more objective and comprehensive General Quality Assessment.

Between 1980 and 1995 estuarial quality remained fairly consistent. The latest information for 2000 shows an improvement in England and Wales, with an increase in the proportion of estuaries classified as good or fair. In Northern Ireland, quality remained the same in each of the classes between 1985 and 1993, after taking into account the inclusion of sea loughs from 1991. Eighty-eight per cent of estuarial length was classed as good in 1993 (no estuarial lengths fell into the ‘fair’ category). In Scotland, estuarial quality improved between 1990 and 1995, and has remained fairly consistent since then, where 95% of Scottish estuaries are currently classified as excellent or good.

Documenting the long-term effects of activities is less well known; however, there is a continuing effort to address this through various initiatives and programmes which ultimately can feed into an assessment of status.

Assessing the sensitivity of habitats to the effects of human activities

Information on relative sensitivity and links to the effects of human activity are, however, less well developed and are only now receiving the attention they deserve for the role they will play in future management of these waters.

MarLIN Biology and Sensitivity Key Information Reviews

These reviews target the information required to assess the sensitivity of species or biotopes to environmental perturbation. Reviews are also undertaken for species that are important to the structure and functioning of marine habitats. Further information can be found at http://www.marlin.ac.uk/index.htm.

The sensitivity assessments of the interest features or their component sub-features are based upon a series of scientific review documents. These include reports produced for the UK marine SACs project (see earlier), the Countryside Council for Wales Science Report (Holt *et al.*, 1995) and the Marine Habitats Reviews (Jones *et al.*, 2000). The MarLIN approach to assessing sensitivity built on a review of the strengths and weaknesses of existing and prior approaches to sensitivity assessment, especially the earlier work by Holt *et al*. (1995, 1996), which thought through many of the concepts of vulnerability, sensitivity and recoverability. Studies commissioned or undertaken by the nature conservation agencies in the UK, the ICES Benthos Working Group workshops and meetings of the OSPAR IMPACT group, the Review of Marine Nature Conservation (RMNC) (Laffoley *et al*., 2000), together with subsequent development by MarLIN, have all contributed. The sensitivity assessments are based on current information, but may develop with improvements in scientific knowledge and understanding.

An evaluation of the marine landscapes in relation to their susceptibility to harm as a result of human activities is under the Irish Sea Pilot study (see earlier). Golding *et al*. (2004) also reports on the work undertaken to collate and analyse geophysical information and identify marine landscapes for the Irish Sea, and to identify their characteristic biological communities. Work to evaluate the susceptibility of marine landscapes to human activities (Tyler-Walters et al., 2003), and to 'score' each coastal (physiographic) and seabed marine landscape using a simple measure of relative biological diversity, is also reported in this paper.

PROGRESS TOWARDS ENVIRONMENTAL OBJECTIVES

At present, the concept of establishing environmental objectives in relation to marine habitats is an emerging process and there are few formalised objectives established. The following table summarises the progress against the known objectives:

Source	Objective	Progress
DEFRA Marine Stewardship Report	"Clean, healthy, safe, *productive and biologically diverse* oceans and seas"	Insufficient information or appropriate tools to make an assessment at the level of UK Seas.
EC Habitats Directive	Habitat feature should achieve favourable condition at each SAC; Habitat feature should attain Favourable Conservation Status in UK	Monitoring the status of Special Areas of Conservation (SACs) started in 2000 and is an on-going activity. Monitoring must be complete by the end of 2006 and the first report on status at each SAC is due in early 2007. It is not yet clear how to the assessment will be completed for the marine environment.

Source	Objective	Progress
OSPAR Biodiversity Strategy	Designate OSPAR Marine Protected Areas	Implementation of this strategy is still at an early stage and none of the Contracting Parties have yet submitted proposed MPAs to the OSPAR Commission.
	Identify species, habitats and ecological processes that are in need of protection in the OSPAR area	Ten Habitats were agreed in 2003, a further 4 will be proposed in 2004. UK is leading on a data collection exercise to map the distribution of these habitats in the OSPAR area.
OSPAR Joint Assessment and Monitoring Programme (JAMP)	Objectives for habitats (and species): BA-2 An assessment in 2006 of the status of the species and types of habitats that have been placed on the OSPAR List of threatened and/or declining species and habitats; BA-4 A further assessment in 2009 of the status of the species and habitats that have been placed on the OSPAR List of threatened and/or declining species and habitats	The JAMP was agreed in 2003 but it is not clear how the assessments will proceed. UK does not currently have surveillance or monitoring programmes in the wider environment to provide data to make these assessments.
Convention on Biological Diversity	Develop national action plans (known as Biodiversity Action Plans or BAPs) to halt the worldwide loss of animal and plant species	UK has identified 14 priority habitats and prepared BAPs. The full distribution of these priority habitats in unknown, There are no surveillance programmes to assess any trend in status of the priority habitats.
EU Water Framework Directive	Good ecological status for all water bodies by 2015; the status of quality elements should not decline: a water body at high status that declines to good status will not meet the objective	The WFD was transposed into national legislation in December 2003. The first broad assessment of status is due in 2006.

CONCLUSION

Overall, the UK is starting to take appropriate measures to undertake assessments against the objectives of the European Directives, although it is not yet clear how the wider environment component of these directives will be tackled. It is not clear at present how the UK will contribute to the broader targets agreed through International Conventions and Agreements, particularly in areas away from the coast in the offshore parts of UK seas.

From the information presented in this chapter, it is clear that there is a lot of ongoing work that, when complete, will feed into a future assessment of the state of marine habitats. It is also clear that there are a lot of gaps in information, and many studies are relatively 'local' and thus not appropriate as an indication of the state of the seas at a UK level. It is not easy to determine the direct causes of the biological changes seen outside those expected through natural hydro-climatic variability around the UK, and the impacts of these changes.

To have a means of assessing the appropriateness of measures designed to protect marine ecosystems from anthropogenic impact, more investment is needed to identify or initiate and then maintain long-term datasets at both a local and wider spatial scale to address this gap. In order to understand how much habitat has been, and continues to be, changed through various pressures listed previously, it is necessary to have relatively fine-scale maps of habitat occurrence and pressures of, for instance, trawling, which are not yet available. Considerable effort has already gone into habitat mapping, although most of this effort has been concentrated on UK coasts, with less information available for offshore habitats.

Finally, we also urgently need to identify the full UK distribution of habitats of conservation interest, such as OSPAR rare and threatened habitats and BAP priority habitats, in order to fully assess the risks to their status from anthropogenic impacts.

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2. State of plankton

KEY MESSAGES

- **Natural atmospheric and hydrographic variability appears to be the major contributor to ecosystem change in the shelf seas of North-West Europe. This overriding natural variability, possibly forced by global warming, needs to be considered in any assessment of the ecological state of UK coastal waters.**

- **On the basis of the evidence from plankton the seas around the British Isles that are sampled by the Continuous Plankton Recorder (CPR) are relatively pristine. However, data from the CPR survey (Thompson *et al*., 2004) have shown a clear increase in the abundance of plastic particles in seawater, including in oceanic waters.**

- **However, nearshore estuarine and coastal waters have not been sampled as systematically and impacts from contaminants and eutrophication in these areas will thus be more difficult to assess.**

- **Since 1946 there have been considerable changes in many ecosystems around the UK with a pronounced regime shift around 1982–1988.**

- **In addition to the regime shift there has been a northerly biogeographic movement of warm water plankton of 10° of latitude in forty years and a parallel retreat of cold water plankton to the north.**

- **Some plankton species are occurring earlier in the season (including dinoflagellates), which has important implications for the monitoring and study of Harmful Algal Blooms.**

- **After the mid-1980s the planktonic ecosystem moved from a cold temperate to a warmer dynamic regime around the UK.**

- **The regime shift is evident in chlorophyll, phytoplankton and zooplankton, fish, birds, benthos, oxygen and hydrographic variables and is also reflected in changes in nutrient concentrations of relevance to the understanding and development of policy on eutrophication.**

- **The regime shift coincides with a sharp increase in Northern Hemisphere Temperature (NHT), Sea Surface Temperature (SST) and the North Atlantic Oscillation (NAO).**

- **It is likely that the high temperatures experienced in the North Sea and British waters in recent years, after the regime shift, are generated by the combined effect of a generally highly positive NAO and high and increasing NHT.**

- **The evidence for a stepwise increase in chlorophyll levels in the North Sea in the late 1980s could, at face value, be taken as due to eutrophication. However, the exact same pattern and increase was also seen in oceanic waters to the west of the British Isles. Therefore, it must be assumed that a strong overriding climatic signal is apparent in the phytoplankton data recorded by the Continuous Plankton Recorder (CPR) survey.**

KEY MESSAGES

- **The changes in chlorophyll observed in regional areas of the North-East Atlantic are also likely to have affected coastal areas around the British Isles and in the North Sea.**
- **The effects of eutrophication on European regional seas cannot be assessed without taking into account wider hydro-climatic influences on phytoplankton populations.**
- **The above changes have had marked effects on fish stocks, e.g. cod and salmon. If the International Panel on Climate Change (IPCC) predictions of a continuing rise in global temperatures prevail then it can be expected that the returns of salmon to home waters will continue to decline especially at the southern edge of its distribution in Spain and France and possibly in the UK.**
- **There is clear evidence for forcing by global warming in the signals seen in the plankton and the observed changes are likely to have a major impact on biogeochemical cycles and living marine resources and might ameliorate or exacerbate any contaminant or eutrophication impacts.**
- **It is unlikely that any changes in UK policy will make any difference to the climatic forcing parameters or to the plankton within one decade. A longer term view needs to be taken.**
- **The long time series of data and wide coverage of the CPR survey makes it possible to determine baseline conditions for a range of planktonic species and indices in terms of abundance, biomass and biodiversity.**
- **There are considerable spatial differences in the plankton communities around the UK as we are at a biogeographic node between warm temperate and boreal faunas. On the basis of this variability it is difficult to develop a target of what might be considered as a mean planktonic state for UK waters.**
- **Good information exists on most mesoplankton. In contrast, limited knowledge exists on gelatinous plankton and micro and ultraplankton.**
- **No time series of plankton production exist in UK waters. However, new methods and use of satellite data may make this possible in the near future.**

EXECUTIVE SUMMARY

Plankton are at the base of the food chain and are the source of food for all other marine organisms. The carrying capacity of ecosystems in terms of the size of fish resources and recruitment to individual stocks is highly dependent on variations in the abundance, timing and composition of the plankton. These organisms also play a crucial role in climate change through the export of the important greenhouse gas CO_2 to the deep ocean by carbon sequestration in what is known as the 'biological pump'. Without this process concentrations of CO_2 would be much higher in the atmosphere and the climate of the world would be much warmer. Through the foresight of the UK government in maintaining funding for more than 70 years a comprehensive coverage of plankton variability has been obtained in the waters around the British Isles over this time by the Continuous Plankton Recorder (CPR) survey.

Assessment of the results from the CPR survey indicates that major biological changes have taken place in the plankton over the last few decades in the seas around the British Isles, apparently greater than at any time over the last 100 years. A pronounced stepwise change (regime shift) has occurred in marine ecosystems since the mid-

1980s that is reflected in all components of the ecosystem, e.g. plankton, benthos, fish, birds, nutrients and current fluxes. At about the same time there has been a northerly movement of warmer water plankton by 10° latitude in 40 years and a similar retreat of colder water plankton to the north. While direct causative mechanisms for these changes are at times not fully established, hydro-climatic variability appears to have played an important modulating role. This overriding natural variability, possibly forced by global climate change, needs to be considered in any assessment of the ecological state of UK coastal waters.

Against this background of 'natural' variability the plankton of the seas around the British Isles that are sampled by the CPR appear relatively pristine and apparently unaffected by anthropogenic inputs of contaminants or eutrophication. However, the CPR survey monitors in deeper water offshore. It is nearshore regions that are more likely to be affected by pollution and where there is a priority to distinguish between natural forcing and human impacts. At present there is in general no systematic sampling of plankton in nearshore waters, although this will be required in the future to comply with the EU Water Framework Directive and other international agreements. The evidence for the statement on eutrophication is provided by the similarity of the patterns of change seen in both coastal and offshore regions of the North Sea and areas to the west of Ireland in the ocean (Edwards *et al*., 2001). The changes in phytoplankton are primarily forced by physical factors. This does not mean that eutrophication does not occur in waters closer to the coast, where the CPR does not sample. Physical factors also clearly dominate the patterns of change in zooplankton. Overall there is no evidence for any impact from contaminants on the plankton at the regional scale. However, data from the CPR survey (Thompson *et al*., 2004) have shown a clear increase in the abundance of plastic particles in seawater, including in oceanic waters.

The seas around the British Isles are biologically diverse in terms of plankton, especially so as the UK is at the node of the limits of distribution of warm temperate and cold boreal faunas. This diversity is reflected in the productivity of the seas in terms of harvested resources. Our understanding of the diversity and ecology of certain members of the plankton, including coelenterates and other 'jellies' and the smaller components from micro to picoplankton is, however, far from complete. There have been clear changes in diversity in recent years as a consequence of the regime shift and the biogeographical shifts. The full consequences of these changes for biodiversity, biogeochemical cycles and living marine resources have still to be determined as have the potential impacts on the 'biological pump'. Ecosystems around the UK appear to have moved into a warmer dynamic regime that is possibly leading to a greater transport of material to the benthos with a faster turnover in the plankton involving the microbial loop. Temperature appears to be a major factor in the composition of communities and in the timing (phenology) of populations.

Highly significant relationships have been found between plankton, salmon returns to home waters, cod and other demersal species and three indices of hydrometeorological forcing (Northern Hemisphere temperature (NHT), Sea Surface Temperature (SST) in the eastern Atlantic and the North Atlantic Oscillation (NAO)). These relationships have been reinforced by a strong link with NHT from the 1980s onwards. As the rapid rise in NHT has been attributed to increasing levels of greenhouse gases it is possible that the recent observed changes in the plankton are a response to global warming. If the predictions of the International Panel on Climate Change (IPCC) of a continuing rise in global temperatures prevail then it can be expected that returns of salmon to home waters will continue to decline, especially at the southern edge of their distribution in Spain and France and possibly in the UK. In recent decades North Sea cod stocks have undergone a pronounced decline as a consequence of overfishing. The radical switch that occurred in the plankton environment of larval/juvenile cod since ~1987 has exacerbated the impact of overfishing on cod as conditions have been highly unfavourable for the survival of young cod. The planktonic copepods that form the principal food of larval cod when they hatch from their eggs have changed in composition, with a reduction in size and biomass and a mismatch in the timing of occurrence of the cod larvae and their favoured planktonic food. Stocks of the boreal cod, as for the salmon, are also likely to decline if Northern Hemisphere temperatures continue to rise, although it should be remembered that a single year with good recruitment could lead to a rapid improvement in cod stocks.

Part of the sequence of changes that have occurred since the mid-1980s has been an apparent alteration in the current patterns in the North Atlantic, with an increased inflow of oceanic water into the North Sea from a more southerly source. Higher flows in the slope current are implicated. Possibly through increased nutrient supply from the ocean and higher temperatures, phytoplankton biomass and almost certainly production has increased in most UK waters, especially in the North Sea and in an area off the shelf to the west of Northern Ireland. Some idea of the scale of the change can be seen in the 90% increase in winter levels of Phytoplankton Colour (a visual index of chlorophyll) post 1987. Good calibration has recently been achieved between this index and SeaWiFS measures of chlorophyll reinforcing the message of the change. As the changes occur in both the North Sea and off the shelf they clearly cannot be attributed to eutrophication.

Because of the data rich nature of the CPR archive and the long period over which samples have been taken and analysed, it is possible to determine baseline conditions for a range of planktonic species and indices in terms of abundance, biomass and biodiversity. These indices may be calculated from mean results or changes since the beginning of the time series or from when important changes took place in the methodology of analysis. Results are presented for a set of proposed indicators of the state of UK marine waters. Four general indices of plankton have been selected to summarise the main patterns of change (Total Copepods, abundance of the copepod *Calanus finmarchicus*, Ratios of the copepods *Calanus finmarchicus* and *Calanus helgolandicus* and Phytoplankton Colour). In addition, seven assemblages of copepod plankton are outlined that reflect changes in water masses around the UK. Patterns of change are also described for 'Harmful Algal Bloom' species and introduced 'non-native species'.

Observed planktonic variability emphasises the need to develop an ecological approach to monitoring human impacts and also for a multi-scale approach that quantifies some degree of natural variability from a regional scale down to a local scale. Confidence in any assessment of anthropogenic impacts on the biological systems found in UK coastal waters will only be possible if wider pan-Atlantic influences and 'natural' variability through time are taken into consideration.

INTRODUCTION

THE ROLE OF PLANKTON IN THE OCEAN

The free-floating plant life of the sea (phytoplankton), at the base of the food web, provides food for the animal plankton (zooplankton), and in turn the fish and their predators, e.g. birds and marine mammals. Many of these tiny organisms exhibit spectacular patterns of shape and colour. For example, diatoms, the dominant group in the phytoplankton, are enclosed in two glass-like cups like an old-fashioned pill box, often with attached spines, and under the microscope are often iridescent and very beautiful. Copepods are the dominant zooplankton group in the North Atlantic. They are small (generally between 0.5 mm and ~8 mm long) crustaceans with long antennae at the front of a muscular body that may be bright red due to oily storage products. The successful development (recruitment) of larval fish to adult stocks after they hatch from their eggs is highly dependent on the abundance, composition and timing of occurrence of the zooplankton.

Light, nutrients and the degree to which the water is mixed are the main agents governing the growth of phytoplankton. Many of these factors in turn are dependent for example on wind strength/direction/frequency, cloudiness and precipitation and exert a strong influence on the upper 100 m of the water column. Even in clear tropical waters light only penetrates down to 100 m so most phytoplankton are found in the upper 40 m. Most zooplankton are also found in the upper layer of the water column, although some show patterns of daily vertical migration over hundreds of metres, apparently as a predator avoidance mechanism.

As well as forming the base of the food chain in the ocean, phytoplankton also influence other processes in the sea by at times occurring in huge concentrations (blooms) that may in part be due to increased human inputs of nutrients to the sea (eutrophication). Some of the species are toxic to humans and other marine animals forming 'Harmful Algal Blooms' and phytoplankton also play a key role in modulating climate change through a range of interactions. A key process is the photosynthetic uptake of CO_2 in the surface ocean and export of this carbon to the deep ocean in what is known as the 'biological pump'. At the surface, concentrations of CO_2 are generally in equilibrium with the atmosphere. The deep bottom water of the oceans, because of their colder temperature, can hold much higher concentrations of CO_2 and dissolved organic matter from settling plankton. Without this deep reservoir, concentrations of CO_2 in the atmosphere would be much higher. Any substantial change on a global scale of the composition or functioning of phytoplankton thus has considerable implications for climate change.

PLANKTON SAMPLING AROUND THE BRITISH ISLES

Studies of the variability of plankton sampled by simple cone-shaped nets were initiated in British waters in the 1890s. A more extensive, but semi-quantitative, study of spatial, seasonal and interannual variability of the plankton in British waters took place as part of the international collaborative surveys of the International Council for the Exploration of the Seas (ICES) in 1902 to 1908. Since then systematic and long-term studies of the plankton in British waters have been few and far between, with a number of time-series studies at single locations or covering small areas offshore (e.g. MBA Station E1 (Southward *et al.*, in press) and the 'Flamborough Line' off the east coast (Cushing, 1975)). Many of these surveys were discontinued in the 1980s or earlier. Furthermore, many surveys took samples, but they have never been analysed. Exceptions to this generalisation are the time series of plankton measurements taken off Northumberland since 1968 (Clark and Frid, 2001), at Station L4 off Plymouth since 1988 (Rodriguez *et al.*, 2000) and the weekly samples taken off Stonehaven by the Fisheries Research Services – Marine Laboratory Aberdeen (FRS-MLA) since 1997 (Steve Hay, *pers. comm.*). Routine samples, but with no systematic sampling strategy, are also taken each year for phytoplankton analysis by, for example, the Environment Agency (EA) and the Scottish Environment Protection Agency (SEPA) for the assessment of toxic algal blooms. There has been no historical overview of planktonic research in UK nearshore waters that brings all this information together, other than the general information included on plankton in the Coastal Directories (Barne *et al.*, 1996). While the following plankton report is very much based on CPR data and is biased towards offshore waters, the patterns of change demonstrated by the CPR survey are widespread and regional at the scale of the whole of the British Isles. It is unlikely, therefore, that nearshore areas, including marine conservation sites, will not be affected by the hydro-climatic signals that are detected by the CPR survey.

The main information on plankton variability around the British Isles derives from the CPR survey (Reid *et al.*, 2003a). Since 1931 a monthly synoptic survey of the plankton has been carried out in UK waters and extending out into the Atlantic using the CPR machine. This survey is one of the longest running marine biological monitoring programmes in the world and the only one that operates on an ocean basin scale. The CPRs (Figure 2.1) are towed by ships of opportunity, at speeds of up to 25 knots, on standard routes, sampling the near surface plankton at a depth of about 5–10 m. The plankton is filtered by a continuously moving band of silk gauze, of 270 μm mesh, that moves through the instrument. Water enters the CPR through a small aperture at the front which expands to a rectangular cross-section (10 cm wide) across which passes the silk band that filters off the plankton (Figure 2.2). The silk slowly moves across the filtering area at a rate that is proportional to the speed of the towing ship so that six metres of silk is equivalent to 500 nautical miles of tow. In effect, the band of silk when unrolled is like a film roll of the changing plankton along the route of the towing ship. The silk is divided into sections representing 18 km (10 nautical miles) of tow for analysis under a microscope when the plankton are identified and counted. Over 450 different taxa of phytoplankton and zooplankton are identified and counted. Since the survey started in 1931, up to 2004, CPR machines have been towed for more than 5 million nautical miles (~8 million kilometres) and approximately 190,000 samples have been analysed.

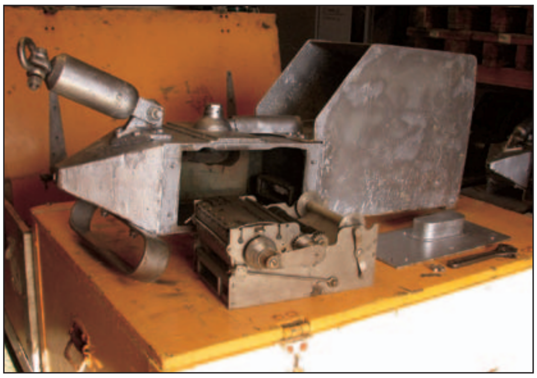

Figure 2.1. Photograph of a Continuous Plankton Recorder with the sampling cassette removed to show the silk spool and preservative storage tank. The cassette has been reversed to show the ingenious fusee tension mechanism on the side that takes up slack in the silk as it is wound on

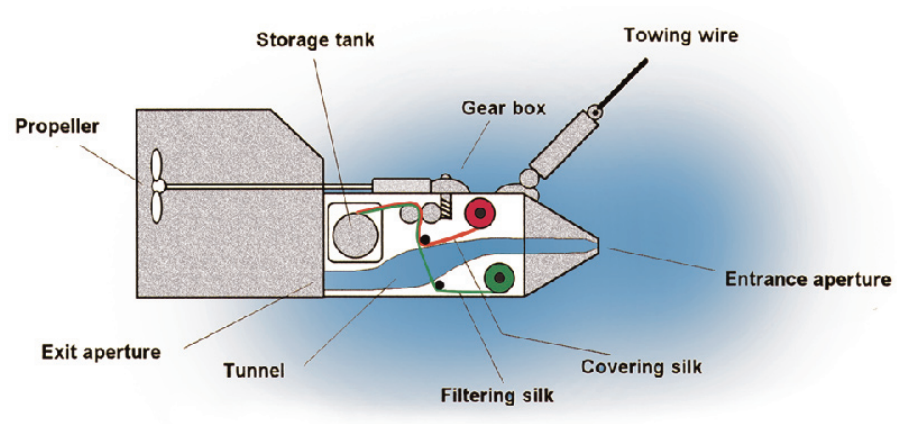

Figure 2.2. Schematic of the Continuous Plankton Recorder showing the water passing through the filtering silk (green) as it moves progressively through the machine at a rate that is proportional to the speed of the ship. The gearing mechanism is powered by an impeller that moves as the machine is dragged through the water. A second band of silk (red spool) covers the filtering mesh to form a sandwich that holds the plankton as it is wound onto a spool in a storage tank containing formaldehyde fixative and preservative

Sampling by the CPR in UK waters in every month of the year restarted after the Second World War in 1946. The route coverage has varied since then due to the changing vagaries of the shipping industry. Figure 2.3 gives representative coverage of routes in 1946, 1958, at the peak of the survey in 1970 and at the present day. A map of the sample coverage in the North Atlantic since January 1946 is given in Figure 2.4.

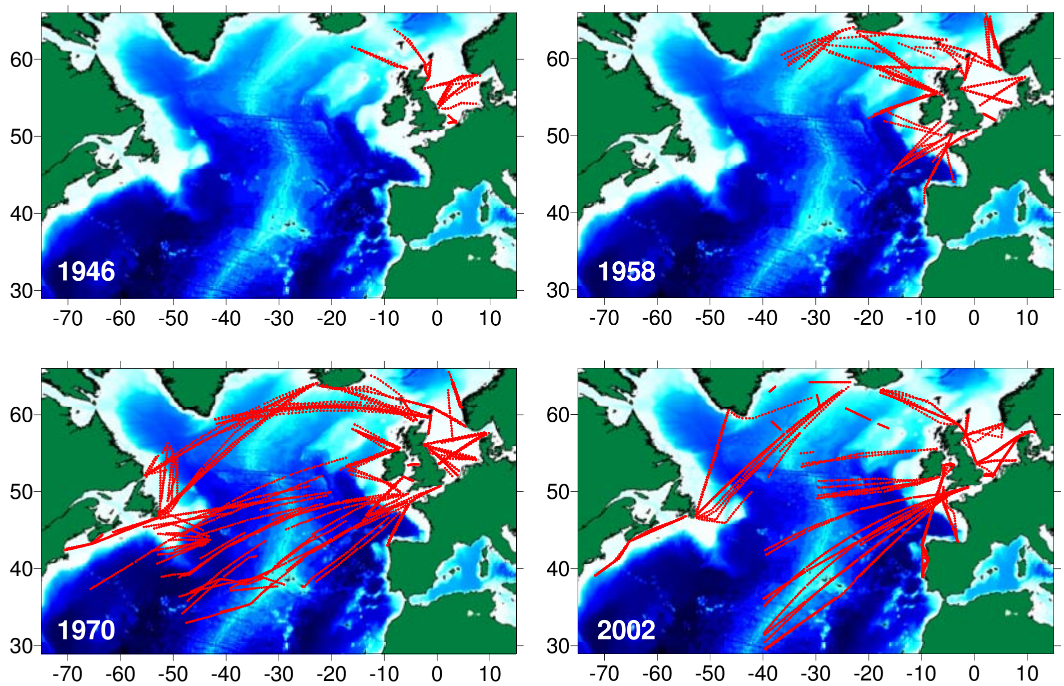

Figure 2.3. Coverage of routes in 1948, 1958, 1970 and 2002

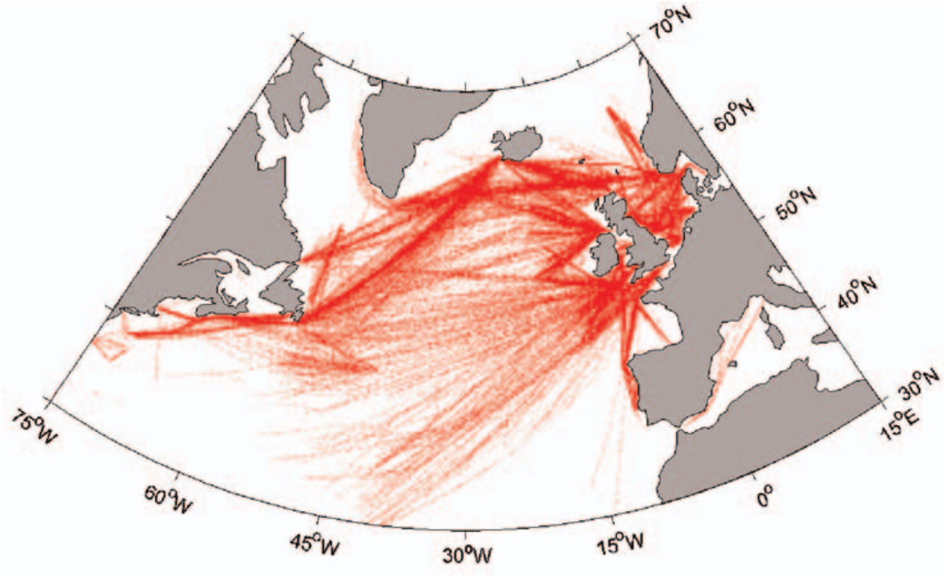

Figure 2.4. Map of the sample coverage in the North Atlantic January 1946 to December 2002. Each small red dot represents an analysed plankton sample

CURRENT STATE

The CPR survey is one of only a few long-term biological monitoring programmes and the only one at a spatial scale that gives a systematic coverage of the North-East Atlantic and UK shelf seas in space and time. Because this survey has a sufficient spatial extent to detect different regional responses to environmental variability it can be used to help to determine whether localised anthropogenic effects have a wider-scale impact and may help to separate anthropogenic and climatic signals from natural variability. New results from the CPR survey reinforce the message that natural atmospheric and hydrographic variability are the major contributors to ecosystem change in the shelf seas of North-West Europe. This overriding natural variability, possibly forced by global climate warming, needs to be considered in any assessment of the ecological state of UK coastal waters.

Because of the data-rich nature of the CPR archive and the long period over which samples have been taken and analysed it is possible to determine baseline conditions for a range of planktonic species and indices in terms of abundance, biomass and biodiversity. These indices may be calculated from mean results or changes since the beginning of the time series. Measurements of Phytoplankton Colour give a coarse visual assessment of phytoplankton biomass/chlorophyll. Preliminary studies have shown that the CPR Colour index compares well with satellite measurements of chlorophyll (Batten *et al*., 2003b). It is also possible to determine dominant patterns of change in the zooplankton and phytoplankton using multivariate statistics such as Principal Component Analysis. It was studies of this type that first showed that long-term trends in the plankton of the CPR were closely related to other measures of change in populations of seabird and fish across four trophic levels (Aebischer *et al*., 1990).

There has been increasing recognition of the uniqueness of the CPR time series as a 'barometer' against which climate change and the effects of pollution/eutrophication on the natural variability of marine populations can be assessed, and also as environmental input to interpretation of changes in fish stocks and fisheries assessments (Brander *et al*., 2003b). The results of the survey have been used to describe and analyse the biogeography, seasonal cycles and year-to-year variability of the plankton in relation to hydro- and meteorological change and fisheries. In a similar ecological vein, other recent applications of CPR data have provided information on harmful algal blooms, monitored and documented the spread of non-indigenous plankton species, and described changes in marine biodiversity. An overview of the last 70 years of work by the survey is presented in a special issue of *Progress in Oceanography* (Reid *et al*., 2003c).

The present chapter consists of two parts:

Firstly there is a series of case studies that provide a commentary on recent research based on CPR data that help understand and assess the current state of the marine environment in UK waters. A number of these studies have been focussed on the North Sea and further work is needed to extrapolate the findings to other areas around the UK. There is no equivalent sampling in nearshore waters that need to be monitored as part of the Water Framework Directive. It is these nearshore regions that are more likely to be affected by contaminants and eutrophication and where there is a priority to distinguish between natural forcing and human impacts. Urgent consideration should be given to establishing a similar extensive coastal plankton monitoring programme to the CPR survey further offshore. One possibility might be to tow CPRs at shallow depths behind the survey vessels of the public/government agencies when they are *en route* to or from their normal survey duties.

Secondly, we give an outline over time (when possible since 1946) and space (the seas around the British Isles) of a set of proposed indicators of the state of UK marine waters. Four general indices of plankton have been selected to summarise the main patterns of change (Total Copepods; abundance of the copepod *Calanus finmarchicus*; ratios of the copepods *Calanus finmarchicus* and *Calanus helgolandicus*; and Phytoplankton Colour, an index of phytoplankton biomass). In addition, seven assemblages of copepod plankton are outlined that reflect changes in water masses around the UK.

Results for the first four indicators are presented for six areas (Figure 2.5): two, the North Sea and Channel, covering Region II (the Greater North Sea) and three, the Malin, Irish and Celtic Seas, covering Region III (the Celtic Seas) as per the regional breakdown of OSPAR QSR 2000 (OSPAR Commission, 2000). To provide a comparison with oceanic conditions results for an area to the west of the British Isles are also presented.

Systematic monthly sampling in each of these regions started at different times ranging from January 1946 in the North Sea to October 1970 in the Irish Sea. As the methods of analysis for phytoplankton and for some zooplankton organisms changed in 1958 different periods of time are used in the presentation of results. The mean number of samples analysed per month for each of the six selected regions is plotted in Figure 2.6.

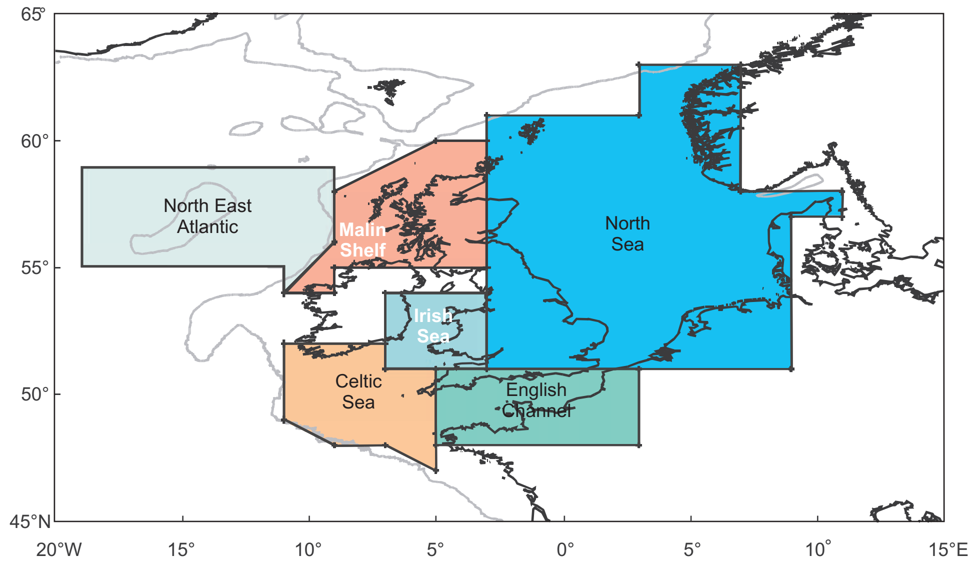

Figure 2.5. Map of the six areas for which plankton data has been averaged

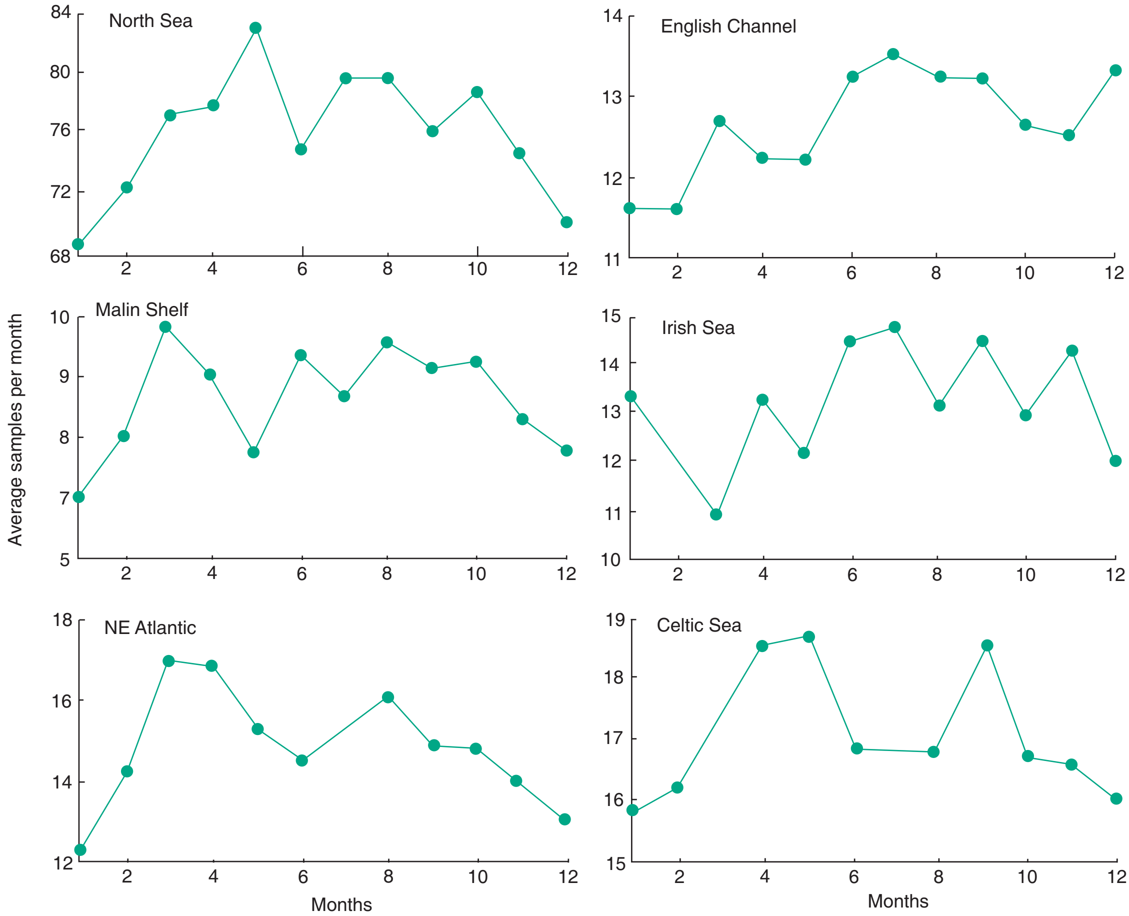

Figure 2.6. Mean number of samples analysed per month for each of the six regions

The number of samples available for the development of indicators in each of the six regions for two periods of time are given in Table 2.1. Maps of changes in the last group of indicators are provided for six associations of copepods over the period 1958 to 1999. Individual pixels in the maps give average information for a 50 × 50 nautical mile grid.

Table 2.1. Analysed samples available for indicator development

UK Regional Seas	Total number of samples 1946-2002	Number of samples 1958-2001
North Sea	51914	41629
Irish Sea	5460	5433
Malin Shelf	5546	4249
NE Atlantic	8570	6526
English Channel	6032	5896
Celtic Sea	9804	9004

QUESTIONS ON CURRENT STATE

Can 'a real difference be made to planktonic ecosystems within one generation'?
On the basis of the evidence provided in this report the plankton of the seas around the British Isles that are sampled by the CPR are relatively pristine and unaffected by anthropogenic inputs of contaminants or eutrophication. The primary

factor governing the changing seasonal and annual patterns appears to be hydroclimatic forcing. There is clear evidence for forcing by global climate change in the signals seen, and the changes observed are likely to have a major impact on biogeochemical cycles and living marine resources. They might also ameliorate or exacerbate any contaminant or eutrophication impacts. The observed environmental changes need to be taken into account when assessing potential policies that might be implemented 'to show a real difference in the marine environment within one generation'. It is unlikely that any changes in UK policy will make any difference to the climatic forcing parameters or to the plankton within one decade. A longer term view needs to be taken.

What is the measurement of performance against an overall target at a future date and research?

To a large extent only 70 years of measurement are available, primarily from the CPR survey. During this time there have been considerable changes with a pronounced regime shift in many ecosystems around the UK. There are also great spatial differences in the plankton communities around the UK, as it is at a biogeographic node between warm temperate and cold boreal faunas. On the basis of this large variability it is difficult to develop a target of what might be considered as a mean planktonic state for UK waters. Temperature variability seems to be a major factor in the composition of communities and it might be possible to determine an expected community structure for a given area in a given temperature band. There is a need for research in this area. Other research needs will be covered below.

Is the plankton around the UK productive and biologically diverse and can we measure it accurately?

It is clear from the evidence provided by the CPR that a rich and diverse fauna of plankton exists in UK waters, which is added to each year by varying inputs of different taxa from the Atlantic. The organisms identified by the CPR survey can be accurately quantified to include measures of diversity and can provide an index of productivity and of the state of health of pelagic ecosystems. The seas around the UK are some of the most productive in the world on the basis of harvested resources. The CPR gives an adequate overview of diversity in the larger components of the plankton with the exception of coelenterates, but we have very little understanding of this factor for most the vast majority of the micro-, nano- and picoplankton. Most measurements that are made on plankton are made at a single point in time. We also have little understanding of changes in production as there are no long-term measurements.

What is the description of the baseline productivity and diversity of marine life?

The results from the CPR survey identify more than 450 different taxa of phytoplankton and zooplankton in the North Atlantic, approximately half of which are identified to species. Baseline conditions can be accurately assessed using decadal means of the plankton species/communities/diversity in question. There are, however, some limitations to the available data because of the size of the filtering silk and the sampling methods (Batten *et al*., 2003a). There is limited information on the composition of the wider categories that are not identified to species and especially for the eggs and larvae of fish and the meroplanktonic larvae of benthic organisms. The CPR also only samples at ~5 to 10 m and does not therefore take into account many planktonic species that live at deeper depths. Gelatinous plankton may be important in the dynamics of marine systems, they are inadequately sampled by the CPR and we know very little about their variability. Finally, measurements of phytoplankton using inverted microscopy give a clearer picture of smaller components of the plankton. There has been no attempt to assess the variability of these organisms on a UK scale from the many analyses that have been made.

What is the evidence for current 'state' against a baseline condition?

There are no statutory monitoring programmes for marine plankton. In consequence, our present knowledge of plankton has been derived from a range of academic studies and from the few long-term studies that have fortuitously been maintained. The CPR survey provides the only long-term and wide spatial coverage of planktonic change in UK waters. After approximately 1986 the planktonic ecosystem moved from a cold temperate to a warmer dynamic regime around the UK. Natural variability is assumed to vary between ±2 standard deviations above or below the long-term mean. Large shifts greater than two standard deviations are used to assess anomalous periods and or anthropogenic influences within a multidecadal time series. If the high anomalies are sustained over a number of years this may signal a regime shift.

CASE STUDIES

NORTH SEA REGIME SHIFT

The planktonic ecosystem of the North Sea has undergone a sequence of changes over the last 50 years each represented by similar levels of plankton abundance and characteristic communities (Reid and Edwards, 2001). The most recent of these changes, around 1987, was sufficiently pronounced to be termed a regime shift (Reid *et al*., 2001a). In oceanography the term has been applied to pronounced stepwise changes in the abundance and composition of plankton and fish at decadal scales (e.g. Hare and Mantua, 2000). A theoretical basis for such changes in the dynamical equilibrium of plankton populations was proposed by Scheffer *et al*., (2001).

The change that took place around 1987 was first noticed in 'Phytoplankton Colour', a visual index of chlorophyll measured by eye on the CPR filtering silks. In the North Sea this index has shown a positive increasing trend with a convergence of the spring and autumn blooms until 1987 (Reid *et al*., 1998). After 1987 chlorophyll levels increased almost twofold throughout the year (Figure 2.7), especially in winter and summer months (Edwards *et al*., 2001a).

This pattern of change characterised a large area of the North Sea, other sea areas around the British Isles and oceanic waters out to approximately 20°W to the west of Ireland (Figure 2.8).

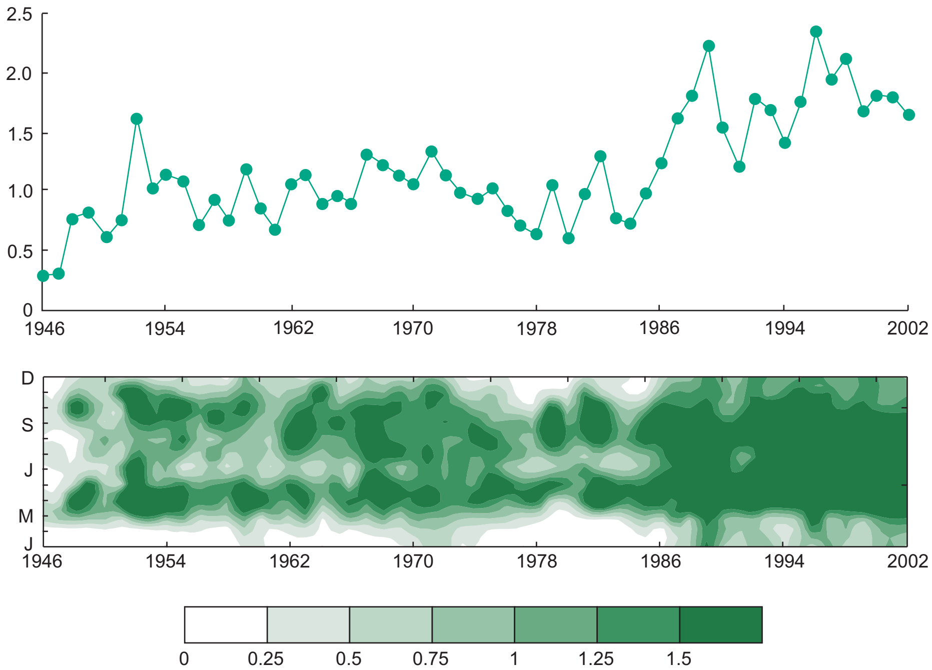

Figure 2.7. A contoured plot of monthly means of Phytoplankton Colour averaged for the North Sea (1946–2002) with above a graph of mean annual data. Updated from Reid *et al*. (1998)

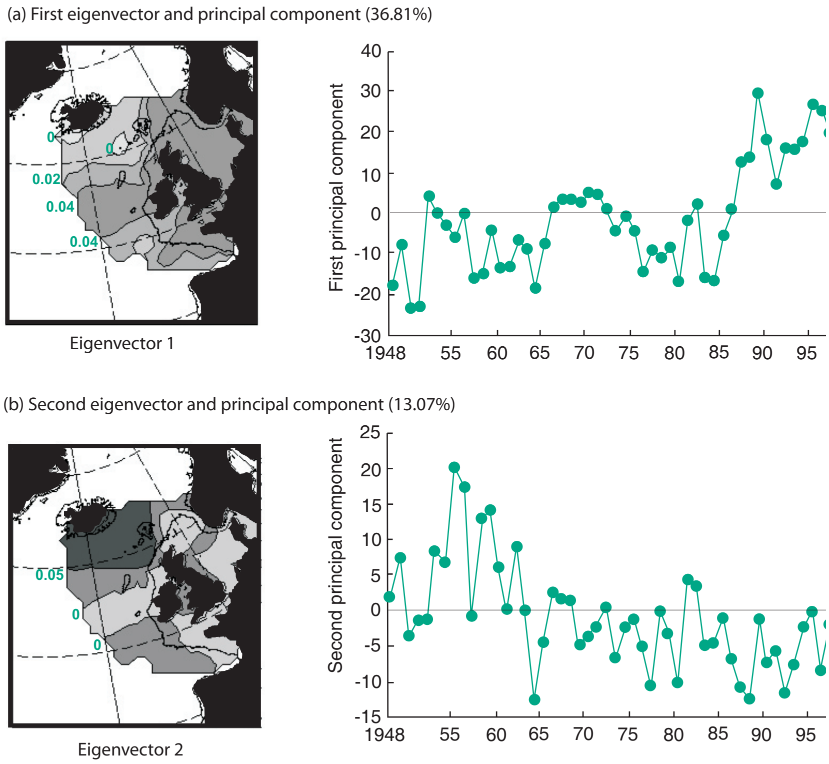

Figure 2.8. Long-term spatial changes in Phytoplankton Colour. Contoured map of the first and second eigenvector and graph of the first and second principal component from a principal component analysis of geographical variability over the period 1948 to 2000 (Beaugrand and Reid, 2003)

The composition of the dominant phytoplankton and zooplankton species sampled by the CPR and a range of other biological, physical and chemical variables showed changes approximately during the same period between the mid- and late 1980s (Beaugrand, 2004a) (Figure 2.9).

Benthic biomass doubled off the Friesian Islands (Krönke, *et al*., 1998) (Figure 2.10) and the benthos monitored by the former Imperial Chemical Industry for titanium dioxide discharges off the Northumberland coast showed a stepwise change in diversity around 1987 (Warwick *et al*., 2002).

Increases in oceanic inflow, in sea surface temperature and in the overall heat content of the North Sea occurred (Reid *et al*., 2001a; Reid and Edwards, 2001; Beaugrand, 2004a). A substantial change in approximately 1989 was observed by Dahl and Danielson (1992) in nutrients (nitrate, orthophosphate, silicate) and oxygen in the deep waters of the Skagerrak. As the levels of nutrients increased (Figure 2.11) the concentration of oxygen decreased. Similar changes in nutrients and oxygen (starting in 1987) have also been described from the Helgoland time series in the German Bight (Hickel *et al*., 1996).

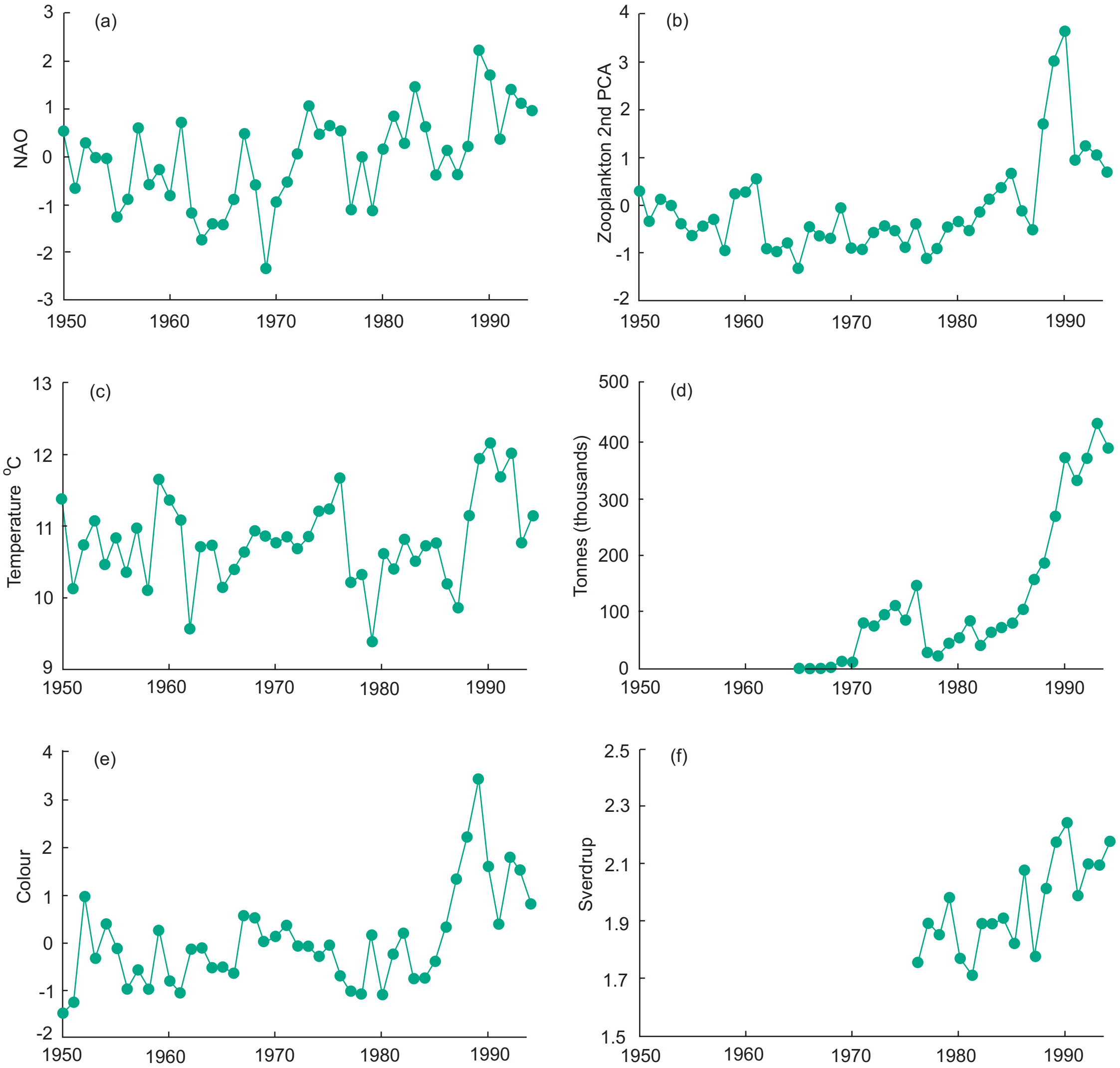

Figure 2.9. Annual mean graphs for: (a) A standardised plot of the North-Atlantic Oscillation, (b) Zooplankton (CPR, second principal component) for the North Sea, (c) Sea surface temperature for the North Sea (ICES data), (d) Horse mackerel landings from the North Atlantic between 45°N and 65°N (ICES data), (e) Phytoplankton Colour (CPR) for the North Sea and (f) Modelled inflow into the North Sea (IMS Bergen). Source: Reid and Edwards (2001)

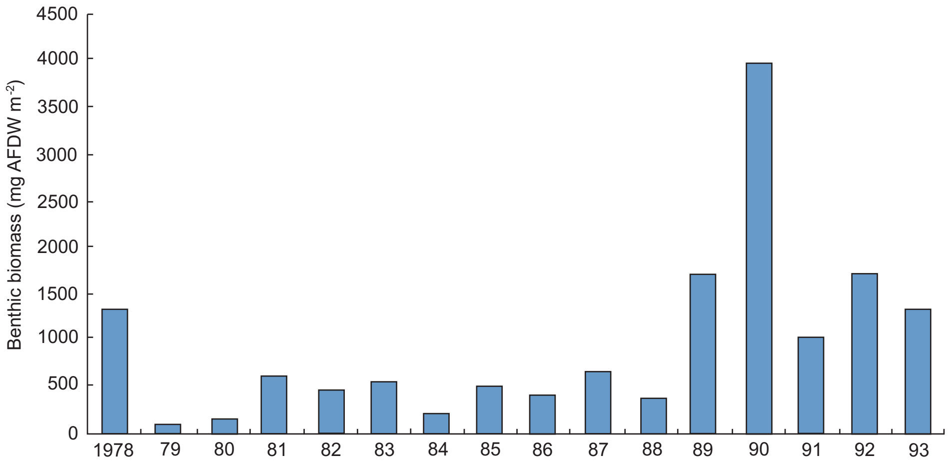

Figure 2.10. Second quarter means of benthic biomass from 1978–1993 recorded in the Norderney coastal zone (southern North Sea). Data from Kröncke, *pers. comm*.

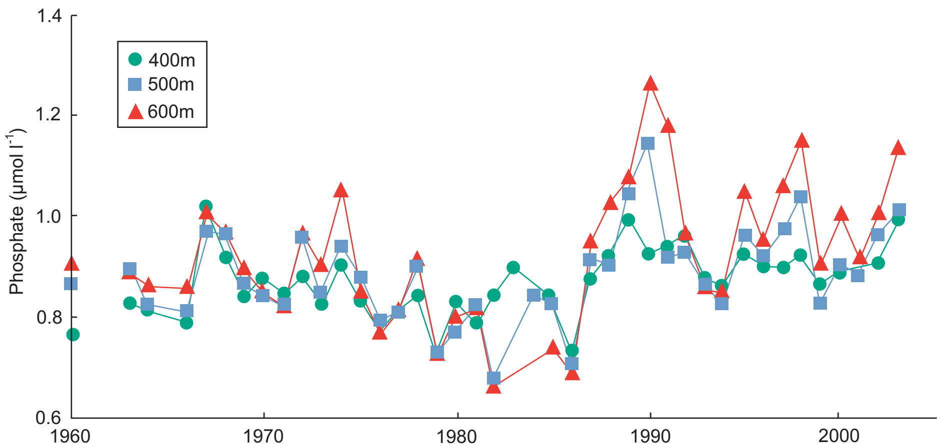

Figure 2.11. Time series of phosphate measurements averaged for three different depths in the Skagerrak. Source ICES database, courtesy of Dr H. Dooley

Observed changes in the abundance and distribution of some marine birds coincided with the regime shift, such as the appearance and expansion of the estuarine white egret (*Egretta garzetta*) in the UK from 1988. Some fish species have also shown marked changes in distribution and abundance, e.g. the horse mackerel (Reid *et al*., 2001a). The landings of horse mackerel by the Norwegian fishery were highly correlated with estimates of volume flux of oceanic water into the North Sea from a 3D mathematical model (Iversen *et al*., 1998; Reid *et al*., 2001a). Marked reductions circa 1987 are also seen in open ocean catches of salmon and in rates of return of salmon to home waters (Reid and Planque, 2000). Finally, the recruitment and biomass of cod dropped dramatically in the North Sea at the time of the regime shift (Beaugrand *et al*., 2003).

Evidence is accumulating to show that the regime shift is a much wider phenomenon characterising the North Sea and regions around and to the west of the British Isles out to ~20°W and that it started earlier in the Atlantic from ~1986 (Beaugrand and Reid, 2003). It also appears that this event is unique in the North Sea in at least the last 100 years (Reid *et al*., 2003b). In summary, post-1987 the North Sea appears to have become more productive and less of the plankton appears to be grazed, and instead there appears to have been an increase in the quantity of settling detritus helping to explain the higher biomass of the animals living on the bottom, lower oxygen levels and apparent recycling of nutrients in deeper waters of the Skagerrak. Levels of phosphate in seawater, instead of increasing, should have decreased as inputs of phosphate from rivers have reduced substantially. Measures to reduce phosphate levels by treatment in sewage plants and the introduction of phosphate-free detergents have led to substantial reductions in concentrations in rivers (Fourth North Sea Conference Progress Report, 1995).

NORTHERLY BIOGEOGRAPHICAL MOVEMENT

Recent research on the biodiversity of marine plankton has revealed a pronounced biogeographical shift in biodiversity, with a northward extension of more than 10° latitude of warm-water species in only 40 years (Figure 2.12) with a complementary reduction in the diversity of colder-water (cold-temperate, Subarctic and Arctic) species to the north (Beaugrand *et al*., 2002b).

An associated rapid rise, especially over the last decade, has occurred in the incidence of sub-tropical plankton species recorded around the British Isles. Of the nine species assemblages that characterise the northern North Atlantic, only six are found around the British Isles. The main shift in distribution took place from the early 1980s to the south-west of the British Isles and from the mid-1980s in the North Sea. All the biological assemblages show consistent long-term changes, including neritic species, which seem to have also moved slightly northwards. Examples of the changes in the distribution of the assemblages are given in the next section of this report on indicators. The changes in the plankton assemblages were correlated with Northern Hemisphere Temperature (NHT) anomalies and to a lesser extent with the winter NAO index (Beaugrand *et al*., 2002b), suggesting that global climate warming may be causally involved. There has been a similar northerly shift in the ranges, as yet poorly documented, of other marine organisms, e.g. the portunid crab and a number of marine fish species of southerly affinity, such as bass, horse mackerel, red mullet, pilchard sun fish and sardine (Brander *et al*., 2003a). New fisheries have started on some of these species in the North Sea. Combined together the evidence suggests that pelagic marine ecosystems have moved towards a warmer dynamic regime in the north-eastern North Atlantic. In terrestrial ecosystems of western Europe, similar changes in spatial distribution and phenology have been detected for many species of plants, butterflies, amphibians and birds and attributed to a warming climate.

There is some evidence that the slope current to the west of the British Isles has been more active since the 1980s with pulses of warmer water extending to the North in certain years (Holliday and Reid, 2001; Reid *et al*., 2001b). This current is used by fish such as the mackerel and horse mackerel as a migratory corridor and is also the primary route for the northerly expansion of some of the plankton assemblages in the above study. Variations in the water masses, temperature and volume flow of this current and its inflow onto the shelf and into the North Sea are likely to have a major impact on UK coastal waters. We have little understanding of this variability at the present time.

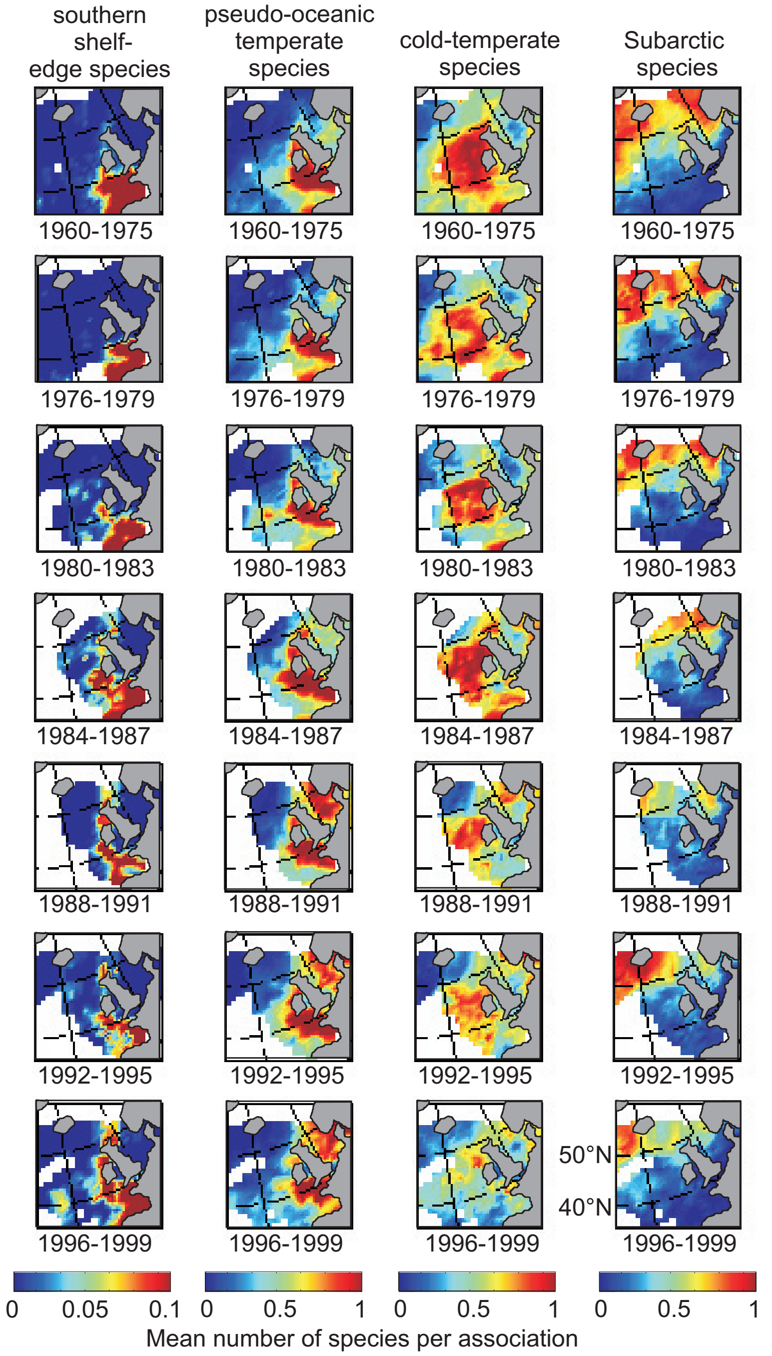

Figure 2.12. Long-term changes in the mean number of species for four planktonic copepod associations from 1960 to 1999. The mean of the four-year periods from 1960 to 1975 was calculated to reduce the number of maps. The spatial patterns seen in these two four-year periods were similar and consistent with the following period 1976–1979. Source Beaugrand *et al*. (2002a)

FISH, PLANKTON AND CLIMATE INTERACTIONS

Highly significant relationships (Figure 2.13) were found between Phytoplankton Colour (as an index of primary production), three measures of secondary zooplankton production (total small copepods, the large copepod *Calanus finmarchicus* and Euphausiids from the CPR),

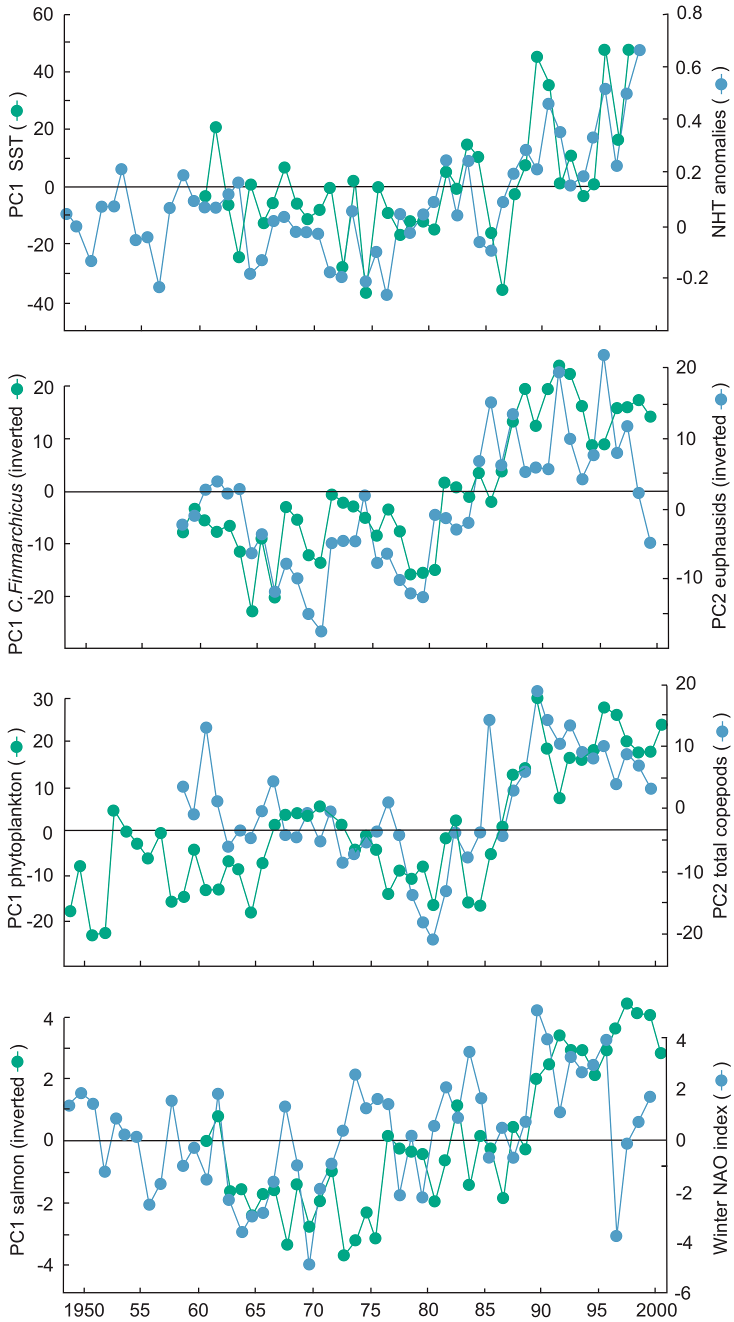

Figure 2.13. Long-term changes in CPR plankton, salmon returns to home waters, sea surface temperature and the large-scale hydro-climatic variables, Northern Hemisphere temperature (NHT) and the North Atlantic Oscillation (NAO). PC1: first principal component. PC2: second principal component. Areas related to the principal components correspond approximately to the area exhibited by eigenvector 1. Source: Beaugrand and Reid (2003)

salmon returns to home waters from 14 locations in the North-East Atlantic and three indices of hydro-meteorological forcing (Northern Hemisphere Temperatures (NHT), Sea Surface Temperature (SST) in the North Atlantic and the North Atlantic Oscillation (NAO)) in a study of long-term change by Beaugrand and Reid (2003). Superimposed on the linear relationships was a stepwise change that appears to have been initiated after an increase in Northern Hemisphere temperatures at the end of the 1970s, culminating in the regime shift of 1986/88, which again appears to be associated with a sharp increase in NHT, SST and the NAO. The biological variables responded in a cascade that started with Euphausiids (reduction) in 1982, Total Copepods (increase) in 1984 Phytoplankton Colour (increase) and *C. finmarchicus* (reduction) in 1986 and salmon returns to home waters (reduction) in 1989.

To understand the regional forcing behind the hydrometeorological change, correlations were made between two climatically contrasting periods: 1960–1978 and 1979–1997 (Figure 2.14). These analyses showed that the pattern of forcing on SST generated by the NAO remained very similar through both periods, especially in the winter and spring. The situation was very different for NHT, with no significant pattern of correlation in the first period, whereas the second period showed high correlation between SST and NHT in the eastern North Atlantic, around the British Isles and in the North Sea, especially in the autumn, winter and spring months of the year. It is likely that the high temperatures experienced in the North Sea and British waters in recent years, after the regime shift, are generated by the combined effect of a generally highly positive NAO and high and increasing NHT. If the IPCC predictions of a continuing rise in global temperatures prevail then it can be expected that the returns of salmon to home waters will continue to decline, especially at the southern edge of its distribution in Spain and France and possibly in the UK.

In recent decades cod stocks and recruitment have undergone a pronounced decline as a consequence of overfishing. Using data from the CPR survey Beaugrand *et al*. (2003) have shown that, in addition to the effects of overfishing, fluctuations in plankton have resulted in long-term changes in cod recruitment in the North Sea. Six quantitative parameters representative of the diet of cod larvae and juveniles were produced for the study, total biomass and mean size of calanoid copepods, abundance of the two dominant large copepods *Calanus finmarchicus* and *C. helgolandicus*, *Pseudocalanus* spp. and euphausiids. Long-term changes in cod recruitment were seen to covary significantly with the plankton indices (Figure 2.15).

The radical switch that occurred in the plankton environment of larval/juvenile cod after the regime shift has been highly unfavourable for the survival of young cod. Since ~1987 the planktonic copepods that form the principal food of the young larval cod when they hatch from their eggs have changed in composition, with a reduction in size and biomass. For example, the mean size of copepods decreased by a factor of two after the beginning of the 1980s. Euphausiids, which are an important food source for cod later in the year also declined in abundance. These organisms have a high-energy content and are an important source of vitamin A for cod, which cannot synthesize this vitamin. The timing of occurrence of the main peak in the abundance of the copepods has also changed to later in the year, a time when the fish larvae have grown and can no longer utilise these small prey organisms. This mismatch in the abundance and timing of their prey means that fewer cod larvae are developing into adult cod. In contrast, at a time between 1963 and 1983, known as the 'gadoid outburst' when cod stocks reached unprecedented high levels, the type, quantity and timing of planktonic food available to cod larvae precisely matched their requirements (Beaugrand *et al*., 2003).

The higher temperatures that are associated with the post regime shift period and which have contributed to the changes in plankton will also have a higher metabolic cost for cod growth. Cod are boreal animals and are at the southerly limits of their distribution in British waters. The warmer waters have caused a northerly retreat of their favourite food organisms and are almost certainly linked to the general changes in their planktonic food. Clearly, links between the temperatures in the North Sea and rising trends in the Northern Hemisphere attributed to global climate warming, suggest that North Sea cod stocks are unlikely to recover in the near future, even with a zero ban on fishing.

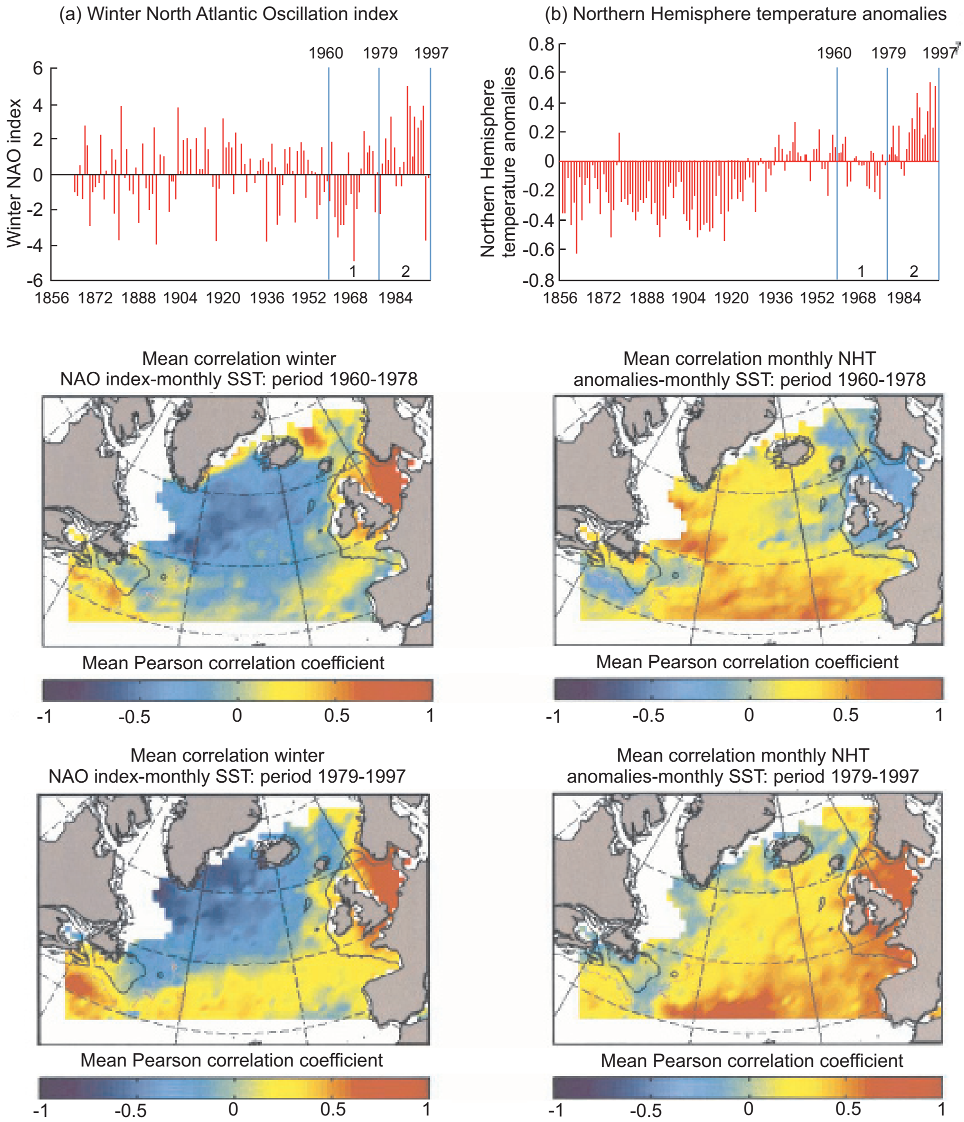

Figure 2.14. Long-term changes in the winter North Atlantic Oscillation (NAO) index (a) and monthly Northern Hemisphere Temperature (NHT) anomalies (b). Maps of correlations were produced for each between the winter NAO index and monthly SST (left map) and between monthly NHT anomalies and monthly SST (right map). The maps present the average of all monthly correlation maps for two 19-year periods: 1960–1978 and 1979–1978. From Beaugrand and Reid (2003)

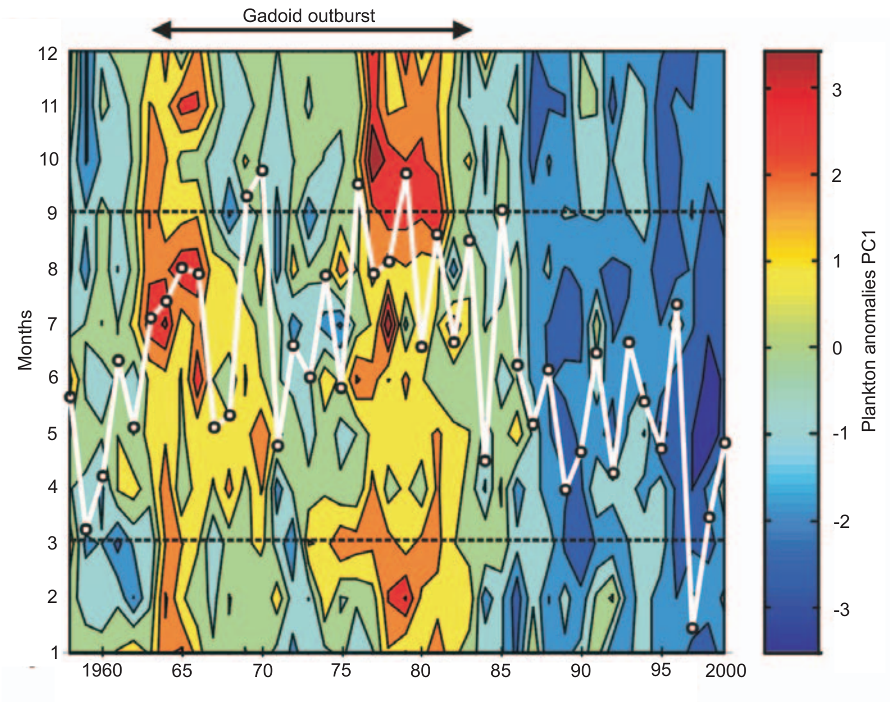

Figure 2.15. Long-term monthly changes (1958–1999) in the plankton (as the first principal component, 33.78% of the total variability), resulting from analysis of a year–month table of a set of biological indicators. The main variables related to this first principal component were, in order of importance, mean abundance (as mean number of individuals per CPR sample) of *Calanus finmarchicus* (normalised first eigenvector), euphausiids), mean size of calanoid copepods, *Calanus helgolandicus*, calanoid copepod biomass and the genus *Pseudocalanus* spp. A negative anomaly in the first principal component indicates a low value for all biological parameters with the exception of *C. helgolandicus* (opposite pattern) and *Pseudocalanus* spp. (no relationship). Cod recruitment (one-year-olds; in decimal logarithm) in the North Sea (curve in white) is superimposed with a lag of one year. The period of the 'gadoid outburst' is indicated at the top of the diagram. Horizontal dashed lines indicate the period (March–September) when larval cod occur most commonly in the North Sea. Source (Beaugrand *et al*., 2003)

EUTROPHICATION VERSUS NATURAL VARIABILITY

There has been a considerable increase in phytoplankton biomass (Phytoplankton Colour index) over the last decade in certain regions of the North-East Atlantic and North Sea. Particularly high stepwise increases were seen after the mid-1980s in the North Sea (Figure 2.7) and west of Ireland between 52°N and 58°N (Reid *et al.*, 1998). An inverse pattern of change (decreasing trend) in phytoplankton biomass occurred in the oceanic area north-west of the British Isles, but has increased again in the late 1990s (Reid and Beaugrand, 2002). The increase in phytoplankton biomass was in the region of 3–4 standard deviations above the long-term mean (1960–1995) which included a >90% rise in phytoplankton biomass over the winter months (Edwards *et al*., 2001a). The late 1980s/early 1990s also saw an increase in phytoplankton abundance, with many species occurring up to one to two months earlier than their normal seasonal cycle. This apparent stepwise increase in chlorophyll levels in the North Sea in the late 1980s could, at face value, be taken as evidence of eutrophication. However, the exact same pattern and increase was also seen in oceanic waters to the west of the British Isles. Therefore, it must be assumed that a strong overriding climatic signal is showing through in the phytoplankton data recorded by the CPR survey, which is not only evident in regional areas of the North-East Atlantic, but is also likely to have affected coastal areas around the British Isles and in the North Sea. Many published studies on decadal biological changes that have previously been ascribed to signs of eutrophication have later been found to be primarily driven by hydro-climatic changes (Edwards *et al*., 2002). It should also be noted that climate has an equally important role in modifying marine nutrient concentrations. Edwards and Reid (2001) concluded that the effects of eutrophication on European regional seas cannot be assessed without taking into account wider hydro-climatic influences on phytoplankton populations.

Long-term signals in phytoplankton biomass and phytoplankton community shifts are correlated with Sea Surface Temperatures (SST) in the eastern North Atlantic, Northern Hemisphere Temperature (NHT) and changes in the North Atlantic Oscillation (NAO) index (Edwards *et al*., 2001a; Beaugrand and Reid, 2003). It has been suggested that the ratio between diatoms and dinoflagellates may provide a good indicator for both regional environmental changes, such as eutrophication, and wider scale climatic changes, as these two groups show consistent patterns of ecological succession and distinct eutrophication responses. The CPR data has shown that there has been a general increase in dinoflagellates from the 1960s to the 1990s which is associated with an increase in temperature.

BIODIVERSITY

By monitoring the diversity of the pelagic ecosystem (Figure 2.16) the CPR survey contributes towards the commitments of the UK government under the 1992 *Convention on Biological Diversity*. Information and data are necessary for the development of policies for sustainable use of marine resources (Article 6), identifying and monitoring components of biodiversity (Article 7) and providing data relevant to management of biological resources (Articles 8 and 10).

Total species richness (γ-diversity) is higher in the northern North Sea than the southern North Sea (Lindley and Batten, 2002). However, diversity per sample (α-diversity) of copepods is higher in the southern North Sea (Beaugrand *et al*., 2000). This apparent contradiction is due to the different ecological characteristics of the areas. The composition of the community in the northern North Sea is much more seasonally variable (Beaugrand *et al*., 2001) being influenced by boreal and warmer oceanic waters coming from the shelf edge bringing diverse oceanic and shelf edge communities into the area.

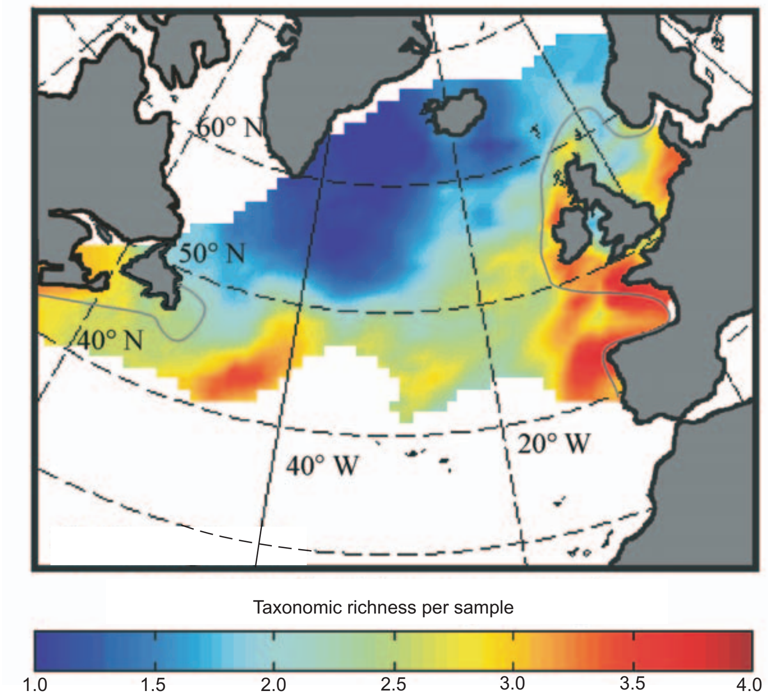

Figure 2.16. Biodiversity of marine copepods in the North Atlantic as measured by taxonomic richness. Source: Beaugrand *et al*. (2000)

Diversity, measured both as species richness and dominance, has increased in the northern North Sea (Lindley and Batten, 2002; Beaugrand, 2003), and this can be related to changes in the distributions of communities described by Beaugrand *et al*. (2002b). These distributional changes appear to be related to climatic variability on an ocean basin scale rather than localised phenomena. The changes have included an increase in the relative and absolute importance of the meroplankton (Lindley and Batten, 2002) and the replacement of the cold water copepod *Calanus finmarchicus* as a key species in the North Sea by its sibling *Calanus helgolandicus*. Also, the high diversity warmer water communities contain a larger proportion of small species than do the colder water communities. Although the most detailed work on the effects on biodiversity of long-term changes has been focussed in the North Sea, comparable patterns of change can be expected throughout the survey area.

NON-NATIVE SPECIES

One of the biggest threats to marine planktonic biodiversity is thought to be the introduction of non-native species and has only recently been recognised as being a serious problem in the oceans. There is now considerable concern about the inadvertent trans-oceanic transfer of planktonic organisms in the ballast water of ships. Many of these introductions can have important ecological and large economic consequences by out-competing native species and/or causing nuisance blooms. The effects of each new introduction are extremely unpredictable and efforts to assess and monitor invasive species are at best fragmented.

One case history, however, based on CPR data has provided a unique insight into the progressive expansion of an invasive plankton species (*Coscinodiscus wailesii*). The geographical expansion of this species has been followed from its initial introduction into European shelf seas to the present day (Figure 2.17), during which time it has become a persistent and significant member of the plankton community (Edwards *et al*., 2001b). When this species first appeared in the North Atlantic it had a detrimental effect on fishing operations and has subsequently become, at times, a dominant member of the phytoplankton community in competition with other indigenous species. This information has provided an invaluable model of how the pattern and rate of spread of an introduced species is

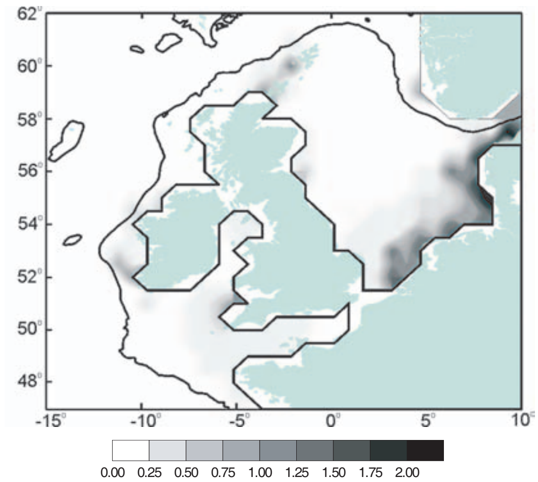

Figure 2.17. Geostatistical estimates of the mean log abundance of the diatom *Coscinodiscus wailesii* in the North-East Atlantic from 1985–1995. Source: Edwards *et al*. (2001b)

likely to evolve in European waters. This type of analysis is essential if we are to establish the effectiveness of any management strategy that may be deployed to limit such invasions, such as controls on ballast water exchange.

PHENOLOGICAL CHANGES

Figure 2.18 shows the annual peak in the seasonal abundance of decapod larvae from 1948–2000 in the central North Sea (Edwards *et al*. (2004) and Richardson submitted). There is

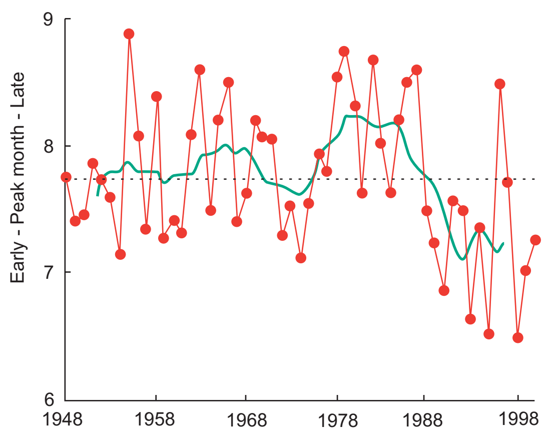

Figure 2.18. Inter-annual variability (light line) in the peak development of decapod larvae in the central North Sea from 1948–2000 (dark line: 3 year running mean; dashed line: baseline mean 1948–2000). Source Edwards *et al*. (2004)

a strong relationship between winter sea surface temperature and the early/late development of the decapod seasonal cycle ($r = 0.67$; $p < 0.01$). Although there is considerable inter-annual variability in the period 1948–2000, a major pattern has emerged over the last decade. Since 1988, with the exception of 1996, the seasonal development of decapod larvae has been much earlier than the long-term average (baseline mean: 1948–2000). The peak seasonal appearance of echinoderm larvae shows the same pattern and is correlated with the trend in decapod larvae. The pronounced trend towards an earlier seasonal appearance of meroplanktonic larvae during the 1990s parallels equivalent changes in the climate of the North Atlantic. The 1990s in the Northern Hemisphere, for example, were the warmest decade since records began in 1860, having 9 out of the 10 warmest years on record (Hadley Centre, UK climate database). Many other plankton species are occurring earlier in the season, including dinoflagellates, which has important implications for the monitoring and study of Harmful Algal Blooms.

Overall marine pelagic production is thought to be largely dependent on the temporal synchrony between primary, secondary and tertiary production (Cushing, 1990). The inter-annual variability in the timing and degree of overlap between trophic production curves is presumed to govern larval survival rates of meroplankton and fish during their early life stages and the eventual year-class strength of commercially important fish and shellfish species (Platt *et al*., 2003). In the marine environment, varying responses to climate change across functional groups and multiple trophic levels could lead, in theory, to a mismatch in timing and decoupling of phenological relationships. This in turn could have repercussions for trophic interactions, food web structure and eventually changes at an ecosystem-level (Beaugrand *et al*., 2003; Edwards and Richardson, 2004)).

HARMFUL ALGAL BLOOMS (HABS)

As well as providing an index of phytoplankton biomass (Phytoplankton Colour), the CPR survey identifies approximately 170 phytoplankton

Table 2.2. Known harmful and detrimental phytoplankton taxa recorded by the CPR survey in the North Atlantic and around UK coastal waters at a temporal resolution of one month

Species/genus	Associated harmful/detrimental effects	Time-series
Ceratium furca	Hypoxia/anoxia	1948 –
Coscinodiscus wailesii	Production of mucilage.	First recorded in 1977 (invasive)
Dinophysis spp	Diarrhectic shellfish poisoning (DSP).	1948 –
Gonyaulax spp	Unspecified toxicity.	1965 –
Noctiluca scintillans	Discolouration and hypoxia/anoxia.	1981 –
Phaeocystis spp	Production of foam and mucilage. Hypoxia/anoxia.	1946 – (presence/absence)
Prorocentrum micans	Diarrhectic shellfish poisoning (DSP). Discolouration and hypoxia/anoxia	1948 –
Pseudo-nitzschia spp	Amnesic shellfish poisoning (ASP)	1948 –
Nitzschia closterium (now *Cylindrotheca*)	Production of foam and mucilage.	1948 –
Chaetoceros spp	Gill clogging	1948 –
Skeletonema costatum	Gill clogging	1948 –

taxa. Within the database a number of taxa that have been identified as potentially harmful or detrimental have been recognised and are listed in Table 2.2. One of the most studied HABs in the North Sea is the foam alga *Phaeocystis*. Massive developments of this alga regularly occur in the southern North Sea. The long-term monthly variability of *Phaeocystis*, averaged for the North Sea, is shown in Figure 2.19.

Whereas it was particularly common in the 1950s it began a process of decline which lasted through the 1960s and 1970s. Since the mid-1980s, however, the occurrence of *Phaeocystis*

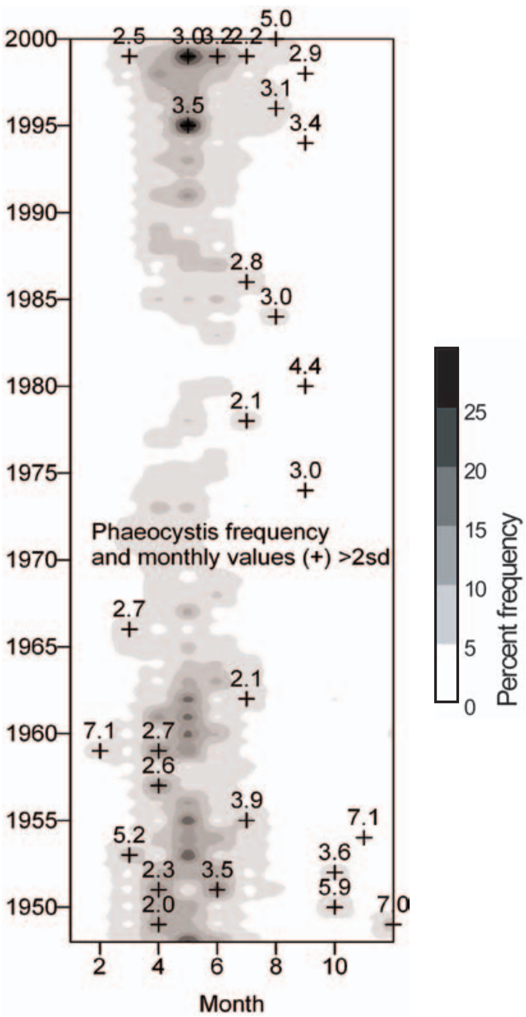

Figure 2.19. Long-term monthly variability of *Phaeocystis* from CPR records averaged for the North Sea. Source: Edwards (unpublished)

has increased in the North Sea and has been frequently recorded over the last few years. In particular, 1999 stands out as an exceptional year with a number of large blooms. It has been suggested that increases in *Phaeocystis* could be attributed to an increase in nitrogen and phosphorus inputs (Lancelot *et al*., 1987). However, similar patterns of occurrence are found in other non-eutrophic regions of the North-East Atlantic, suggesting that the patterns are climatically forced, mirroring what is seen for phytoplankton biomass. Remarkably similar decadal patterns of abundance have also been observed for *Noctiluca scintillans* from the Helgoland Roads, which have been related to winter SST (Heyen *et al*., 1999). At this site, water samples for plankton are taken five days in every week. Some of the most exceptional phytoplankton blooms recorded by the CPR survey have also been associated with ocean climate anomalies and oceanic incursions into the North Sea (Edwards *et al*., 2002). Bloom events recorded by the CPR survey also show strong similarities with other phytoplankton surveys (Kat, 1982; Zevenboom *et al*., 1990). Without the aid of inter-regional comparisons, many blooms in the past have been wrongly used as supporting evidence for eutrophication.

Shellfish for human consumption are monitored for algal toxins under the requirements of the EC Shellfish Hygiene Directive by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), the Fisheries Research Services and the Department of Agriculture and Rural Development, Northern Ireland. Some phytoplankton samples are taken to help identify the causative organisms. Records obtained are coordinated by CEFAS as part of a UK Toxic phytoplankton monitoring programme. Non-routine sampling of phytoplankton blooms or other algal/scum concentrations is also undertaken by the Environment Agency and Scottish Environmental Protection Agency.

GAPS IN KNOWLEDGE OF THE STATE OF THE MARINE PLANKTONIC ECOSYSTEM

- An historical overview of planktonic research in UK waters that brings all information on UK and international monitoring and research together is long overdue. Such an overview would help to clarify gaps in knowledge and prioritise issues for study in the future.

- There has been no attempt to integrate single point samples and small surveys using nets or water samples with the geographically more extensive CPR survey. Developing a web-based Geographical Information System that could include data from many different surveys would have considerable management uses.

- There are a number of geographical gaps in sampling in UK waters, especially on a synoptic monthly level. Sampling by the CPR is very limited or does not occur (for example in west Scotland and its sea lochs, in the northern Irish Sea and in the Clyde estuary) and is poor in the Atlantic to the west of the UK.

- Perhaps equally important are more distant waters such as the Labrador, Greenland and Norwegian Seas that may show early signs of changes that could later affect the ecosystems around the UK and which are highly sensitive to change in climate.

- At present there is no systematic monitoring of phytoplankton or other plankton in nearshore and estuarine regions out to 1 or 3 nautical miles. This is a very large linear band of water that will need to be sampled on a regular basis as part of the Water Framework Directive. Developing a shallow towed CPR survey in this region would enable comparisons with the long-term data that exists from further offshore.

- Given the large variability that is evident in plankton, our understanding of what is a baseline/normal ecosystem state is limited.

- Groups of plankton that are particularly poorly known and sampled are the coelenterates and other 'jellies' and the microplankton to picoplankton. Especially large changes in abundance of meroplankton have been evident in the North Sea in recent years. There is a poor understanding of the causes of these increases and of interactions between the benthos and pelagos.

- Only limited work has been undertaken on relationships between plankton and hydro-meteorological variables especially at the scale of the seas around the UK. A number of past studies have focussed on the North Sea and further work is needed to extrapolate the findings to other areas around the UK.

- The pronounced temperature increase that coincided with and has continued since the regime shift in the mid-1980s seems to be a key parameter governing the dynamic equilibrium of marine ecosystems over a wide region around the British Isles with likely, but at present largely unknown, consequences for biogeochemical processes, fisheries and the 'biological pump'.

- Variations in the water masses, temperature and volume flow of the slope current to the west of the British Isles and its inflow onto the shelf in the North and adjacent Seas are likely to have a major impact on UK coastal waters. We have little understanding of this variability at present.

- Until recently there has been minimal use of plankton data in ecosystem and climatic models. There is considerable scope for research in this area to examine the process behind recent changes. Future development of these studies holds the prospect of improving our knowledge of the mechanisms by which climate change and plankton productivity are linked and of working towards a truly predictive capacity.

- The same situation applies to understanding relationships between plankton and fish recruitment. A demonstrated clear linkage has only become evident in recent work on cod (Beaugrand *et al*., 2003). Options also exist for including CPR and other plankton and environmental data in future new approaches to fish stock management.

- Temperature variability seems to be a major factor in the composition of communities and it might be possible to determine an expected community structure (mean planktonic state) for a given area in a given temperature band. There is a need for research in this area.

- We are still far from understanding relationships and the relative importance of human impacts such as contamination and eutrophication on plankton against natural and climatic change. This applies especially to nearshore waters and to organic contaminants.

FUTURE CHANGES TO RESEARCH PROGRAMME

Data sources

- An overview of UK plankton research and assessment of available datasets should be initiated. Many datasets are still in paper form and inaccessible. They need to be digitised and placed in a national archive as part of a data archaeology project. Pre-Second World War studies are particularly important to provide a longer term perspective on recently observed planktonic changes.

Design of plankton monitoring programmes

- A study should be initiated to look at appropriate sampling regimes for plankton to establish true spatial and temporal variability. Such a study could provide useful information on the number of samples that needs to be analysed in a given area and could be used in the design of a UK plankton monitoring programme for the Water Framework Directive.

Indicator development

- Further work needs to be carried out on the development of phytoplankton indicators and other sensitive ecological indicators.

Target performance

- There is a need for further work to be undertaken on the relationship of plankton to basic physical factors such as temperature and salinity. The expected composition of plankton communities in a given area against temperature bands should be determined.

Introduced species

- Introductions of new species should be recorded and their spread recorded in a national data centre.

Plankton satellite comparisons

- Data from the CPR survey should be used to provide sea-truthing of satellite data and a calibration in return of the in situ plankton results.

Modelling

- A range of modelling initiatives could be envisaged from ecosystem modelling built on 3D hydrodynamic models, to use of CPR plankton data in climate models. Modelling to take into account oceanic inflow and the role of the slope current should be progressed.

Instrumentation

- Wherever possible, additional hydrographic information should be obtained at the same time as plankton sampling is undertaken. Where ships of opportunity are used in Ferry Box and CO_2 studies, CPR machines should be towed on the same vessel.

Genetics

- There is enormous potential to apply new genetic tools to studies of populations and their variability through time and space using archived samples.

Resting stages

- Many planktonic organisms include a dormant resting egg or cyst stage as part of their life cycle. The role that this stage plays in the ecology of plankton is poorly known. The resting cysts of some toxic phytoplankton are often concentrated in seed beds in fine sediments on the bottom. It is not known how the distribution of these beds will be affected by climate change.

Filling gaps in UK sampling

- New CPR type programmes should be established in near coastal waters using the traditional methodologies so that a comparison can be made with the long datasets that occur offshore.

INDICATORS OF STATE

The only established marine planktonic indicators used by the UK up to now have been the abundance of the boreal copepod *Calanus finmarchicus* and total small copepods in the North Sea. These indicators were chosen respectively because of the inverse relationship between C. finmarchicus and the North Atlantic Oscillation discovered by Fromentin and Planque (1996) and the correlation found by Taylor (Taylor, 1995) and the position of the North Wall of the Gulf Stream (Gulf Stream index). Since at least 1996 (Planque and Reid, 1998), and probably 1987, the relationship with the NAO has broken down and the species has become much less abundant in UK waters as a consequence of the changes described above in the Case Studies section.

In addition to the abundance of *Calanus finmarchicus* and Total Copepods two new indicators are proposed here, all four indicators are averaged for six areas around the British Isles (Figure 2.5). The first new indicator is Phytoplankton Colour to represent algal growth. Ratios between *Calanus finmarchicus* and its congeneric *Calanus helgolandicus* are used for the second new indicator of environmental change. A second series of seven indicators, based on assemblages of copepods after the methodology of Beaugrand *et al*., (2002a, 2003) and Beaugrand (2004b) is also included. Maps showing changes in four of these copepod species associations in the North Atlantic, east of 20°W (averaged for pixels of 50 × 50 nautical miles) were presented earlier in Figure 2.12. These results and three other assemblages (Arctic, Shelf Sea Neritic and Coastal Neritic) also found around the British Isles are summarised below for two time periods: 1958–1981 and 1982–1999. The assemblages were determined using three criteria: (1) the spatial distribution of species, (2) the similarity in the seasonal variability of species and (3) diel and ontogenetic variation.

Proposed indicators:

- Total Copepods: Measured total abundance of mostly small copepods
- Abundance of Calanus finmarchicus
- Ratios of *Calanus finmarchicus* and *Calanus helgolandicus*, showing changes in the relative importance of two of the main large copepods that represent respectively, boreal and warm temperate water in British waters
- Phytoplankton Colour, an index of phytoplankton biomass, and
- Seven species assemblage indicators based on calanoid copepods, showing variability in the abundance of groups of copepods that characterise different water masses (based on 108 species).

    1. Arctic
    2. Subarctic
    3. Cold-temperate mixed water
    4. Shelf Sea Neritic
    5. Coastal Neritic
    6. Temperate Pseudo-oceanic
    7. Warm-temperate Pseudo-oceanic

TOTAL COPEPODS

Specific indicator: Total copepod abundance is the sum of the number of copepods, identified during the traverse stage of analysis, sampled (per 3 m^3) by the CPR survey. Copepods numerically dominate the zooplankton community. The method of counting this category in the survey has remained unchanged since January 1946.

Objective: To provide a measure of the total abundance of copepods for areas around the UK.

Relevance: Marine copepods form an important part of the diet of commercially exploited fish species and are the link between the base of the food web and higher trophic levels. There is increasing evidence that patterns in the abundance of copepods integrate a great deal of hydro-climatic variability and are particularly sensitive to ocean currents and changes in sea temperatures. They are therefore useful for monitoring environmental change in the marine environment.

Sensitivity of the index: Copepods can multiply rapidly when environmental conditions are optimal for growth and reproduction and consequently populations fluctuate readily in response to changing conditions. Two commonly used climate indices have generally been used to examine the relationship between environmental change and copepods at a large scale and over decadal periods of time. the first being the Gulf Stream index (GSI) and the second the North Atlantic Oscillation index (NAO). The GSI (available only since 1966) measures the position of the North Wall of the Gulf Stream, such that high values indicate a northerly path. In the past, the total number of copepods was positively correlated with the Gulf Stream position in April and copepods tended to be more numerous when the Gulf Stream followed a northerly path (Taylor, 1995). The relationship between the northerly path of the Gulf Stream and copepod abundance is thought to be via downstream atmospheric changes that affect the timing of spring stratification and the formation of a warmer surface layer in the sea.

Change over time and space: Figure 2.20 shows the annual mean levels of total traverse copepods averaged for each of the six areas:

- North Sea
- Malin Shelf
- North-East Atlantic
- Irish Sea
- Celtic Sea
- English Channel

Apart from the decline in *Calanus finmarchicus*, which is discussed below, the most evident feature of total copepod abundance in the areas around the British Isles is a general long-term decline. The taxa that most strongly showed this decline were the small copepod species *Para-Pseudocalanus* spp., *Oithona* spp. and *Pseudocalanus* adults. In the North Sea, for example, the abundance has dropped by half during the last few years compared with the abundance in the 1940s and 1950s.

Interpretation: An adequate explanation for the general decline in total copepod abundance has not yet been formalised. As total copepod abundance is the sum of all the species observed in CPR traverse it is difficult to interpret the observed change. Apart from the decline in *Calanus finmarchicus*, which is discussed below, the most evident feature of total copepod abundance in the areas around the British Isles is a general long-term decline. In the North Sea the taxa that most strongly showed this decline were the small copepod species *Para-Pseudocalanus* spp., *Oithona* spp. and *Pseudocalanus* adults. Some of these species will have adapted to boreal conditions and others to temperate conditions. There is a need therefore, to examine inter-species patterns to ascertain how each species is responding to changing climatic conditions. Over the last few years the decline has begun to stabilise, at least for the North Sea, but the

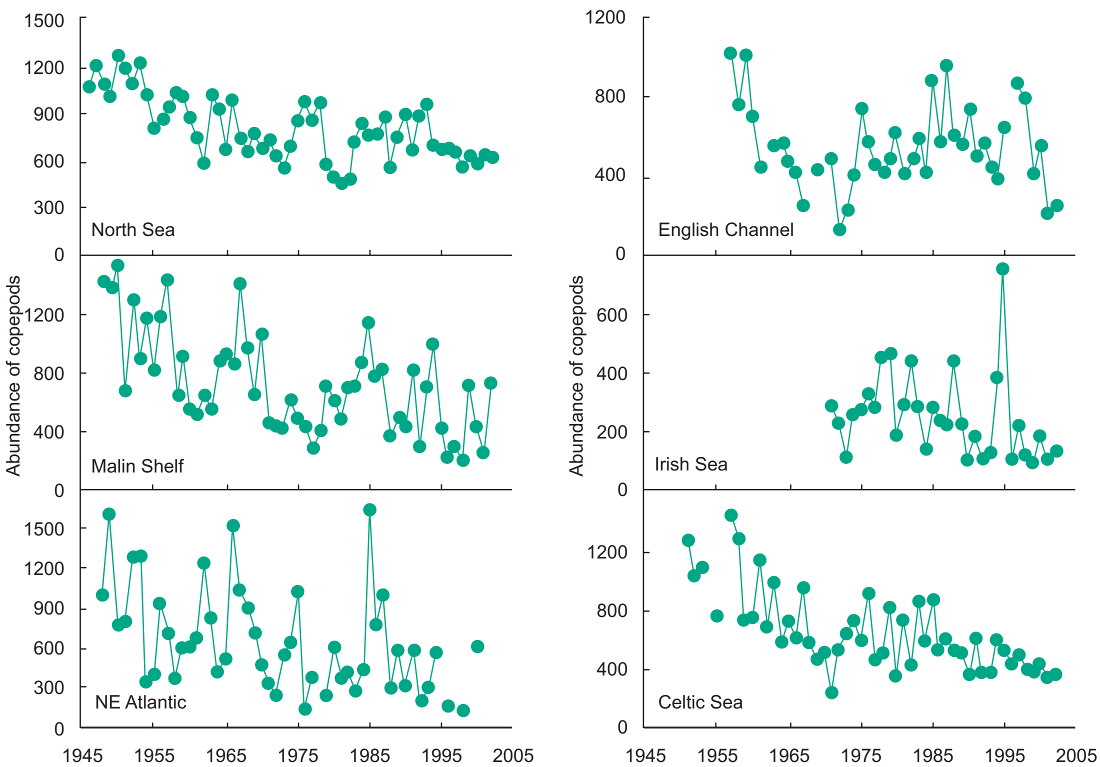

Figure 2.20. Plots of annual mean total traverse copepods averaged for the six areas defined in Figure 2.5

previously observed statistical relationship with the Gulf Stream is no longer evident. This is a similar pattern to the breakdown in the relationship between *Calanus finmarchicus* abundance and the North Atlantic Oscillation index since 1996 (see below). A general conclusion is that whatever is causing the decline in total copepods it is a large-scale phenomenon encompassing all the shelf seas around the UK, and is therefore likely to be modulated by large-scale hydro-climatic changes.

Further work: The decline in total copepod abundance needs to be examined in more detail as it has important consequences for higher trophic levels.

Data source: Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, Plymouth, PL1 2PB.

ABUNDANCE OF *CALANUS FINMARCHICUS*

Specific indicator: *Calanus finmarchicus* is an index of the abundance of boreal copepods determined from samples taken by the Continuous Plankton Recorder that represent a section along 10 nautical miles of sea. This species was not distinguished from the congeneric *C. helgolandicus* until January 1958. Results are only presented from this date, since when the methodology has remained unchanged.

Objective: To provide an index of the importance of boreal waters around the UK.

Relevance: Marine zooplankton are the food source of fish and many other marine organisms. Their abundance and timing are crucially important for the development of fish larvae, the recruitment of young fish and thus the size of fish stocks. *Calanus finmarchicus* is especially important as a food for fish larvae and for adult pelagic fish species such as the herring due to its size and its content of nutritious lipid oils. As a boreal organism they also provide an indication of the changing position of the boundary between boreal and temperate plankton. Since they diapause (hibernate) over the winter in the deep waters of the Norwegian Sea their abundance may also be an index of the volume of this water, which is an essential component of the 'global conveyor belt'.

Sensitivity of the index: The occurrence and abundance of this species in the shelf seas around the British Isles is dependent on yearly advection of seed populations from overwintering (diapause) populations in deep waters of the Norwegian Sea and possibly the Norwegian trench. In most years the species does not appear to be able to survive over the winter on the shelf. The highest concentrations of overwintering *Calanus* that are the source for North Sea populations appear to occur in the Faroe–Shetland Channel. Since the 1960s the volume of cold bottom water in this channel has decreased, possibly due to global climate change. In consequence, the annual supply of *Calanus* to restock the North Sea has dwindled, with important effects on recruitment of cod and other species. As a boreal organism *C. finmarchicus* prefers colder water; rising temperatures are likely to have reinforced its reduction in the North Sea. Until approximately 1987 this species was shown to be highly inversely correlated with the North Atlantic Oscillation (NAO) in waters around the British Isles (the NAO index measures the difference between the dominating atmospheric pressure systems in the North Atlantic: the Azores high and the Icelandic low). Many factors are likely to have contributed to this relationship, such as temperature, precipitation, strength of inflow from the ocean and wind strength, which are all known to be related to the NAO. The breakdown in the plankton NAO relationship shows the complexity of marine pelagic systems and the need to undertake more research on this sensitive species to environmental change to determine the key factors forcing changes in abundance and distribution.

Change over time and space: This species primarily occurs in the spring/summer months of the year (typically April, July) in the more northerly waters around the British Isles after the spring bloom of phytoplankton and normally declines to a low level in the autumn. It is found in much smaller numbers in the Channel and the Celtic and Irish Seas.

Figure 2.21 shows the annual mean levels of *Calanus finmarchicus* averaged for each of the six areas:

- North Sea
- Malin Shelf
- North-East Atlantic
- Irish Sea
- Celtic Sea
- English Channel

Interpretation: This species diapauses in deep water of the Norwegian Sea during the winter months of the year and re-invades UK shelf waters in the spring each year. Much research has been carried out on this process of invasion and it is believed that part of the reason for the decline in the species is attributable to the decrease in the volume of the cold deep water in the Norwegian Sea (Heath *et al*., 1999). Higher temperatures, and possible increased flows in the slope current may also have been unfavourable to the recolonisation of shelf seas like the North Sea. Interpretation of this species has been complicated by the breakdown in the clear statistical relationship with the NAO that existed until at least prior to 1988.

Further work: The breakdown in the *C. finmarchicus*: NAO relationship shows the complexity of marine pelagic systems and the need to undertake more research on this sensitive species to environmental change to determine the key factors forcing changes in abundance and distribution. Further work also needs to be undertaken on the invasion routes of the species onto the shelf and the forcing factors that promote different routes.

Data source: Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, Plymouth, PL1 2PB. North Atlantic Oscillation data can be obtained from http://tao.atmos.washington.edu/data_sets/nao/ and Northern Hemisphere temperatures from the Hadley Centre for Climate Research.

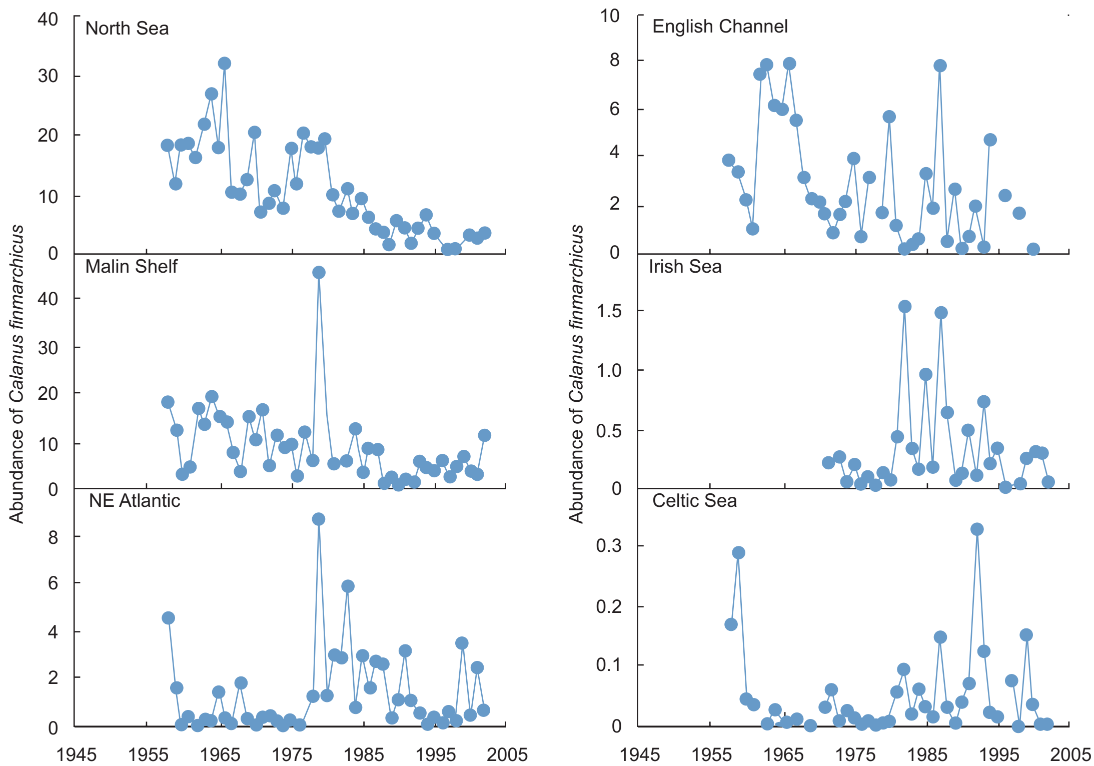

Figure 2.21. Plots of annual mean *Calanus finmarchicus* averaged for the six areas defined in Figure 2.5

RATIOS OF *CALANUS FINMARCHICUS* AND *CALANUS HELGOLANDICUS*

Specific indicator: There are no systematic or long-term current measurements of oceanic inflow into the North Sea so the only ways of estimating inflow are from modelling studies and by the use of indicator plankton. Changes seen in the plankton, and in particular *Calanus finmarchicus* and *Calanus helgolandicus* in the North Sea have been shown to be associated with variability in inflow and North Sea temperature. The patterns of change are especially clear when the relative abundance of these two copepods are expressed as ratios. Modelled monthly estimates of inflow for a section across the northern North Sea forced by monthly wind fields confirmed this relationship (Reid *et al*., 2003b). The main pattern of change in the inflows was also highly correlated with the North Atlantic Oscillation (NAO) reinforcing the dominant contribution that this mode of atmospheric variability has on the hydro-meteorological variability of the North Sea. While the ratios were originally determined for the North Sea they are presented here for six areas to reflect potential oceanic incursions on to the shelf with the eastern North Atlantic area as a possible control.

Objective: Development of a biological indicator of the relative importance and source of oceanic inflow onto the shelf around the UK and characterisation of cold/warm events.

Relevance: Oceanic inflow is estimated to contribute more than 90% of the nutrient input into the North Sea (NSTF, 1993). Temperature is also a key parameter influencing physiological processes and community composition of marine organisms. Together, variability in temperature and the volume, chemical properties, biological content and source of inflowing oceanic water are likely to have a considerable effect on all aspects of marine ecosystems around the British Isles, including the carrying capacity for fish resources and in turn the composition and tonnage of fish landings.

Sensitivity of the index: Appears to be a highly sensitive index to changing sources of oceanic water flowing into the North Sea and to the temperature conditions in the North Sea.

Change over time and space: Graphs of two different ratios between the large copepods *Calanus finmarchicus* and *Calanus helgolandicus* as annual means (Figure 2.22), are averaged for each of the six areas:

- North Sea
- Malin Shelf
- North-East Atlantic
- Irish Sea
- Celtic Sea
- English Channel

For the North Sea the different ratios of *C. helgolandicus* and *C. finmarchicus* distinguish three periods: a warm period subsequent to 1988 and two 'cold' biological events between ~1978 and 1982 and between ~1962 and 1967. However, it should be noted that the relative abundances of the two species in the North Sea are very different with *C. finmarchicus* being six times as abundant as its sister species. On the Malin shelf these two species again alternate in abundance in a similar way to the North Sea although numbers of *C. finmarchicus* are much lower. The major peaks in abundance appear to be delayed compared to the North Sea by one to two years.

In the other three more southerly areas the two species again alternate in relative abundance. The pattern of change is very different for the Celtic Sea compared to the North Sea with a warm period between 1973 and 1977 followed by a long period when *C. finmarchicus* dominates to 1993. What is of interest is that *C. finmarchicus* is also more abundant in 1999 and 2001, although numbers are much lower than in the North Sea. The Irish Sea shows a similar general pattern to the Celtic Sea, with one high peak in the *C. finmarchicus* to *C. helgolandicus* ratio in 1996. There is no clear pattern to the results from the English Channel other than a temperate phase between 1973 and 1980 in the general cold period in the North Sea and as for the Celtic Sea some higher peaks in the ratio *C. finmarchicus* to *C. helgolandicus* in recent years.

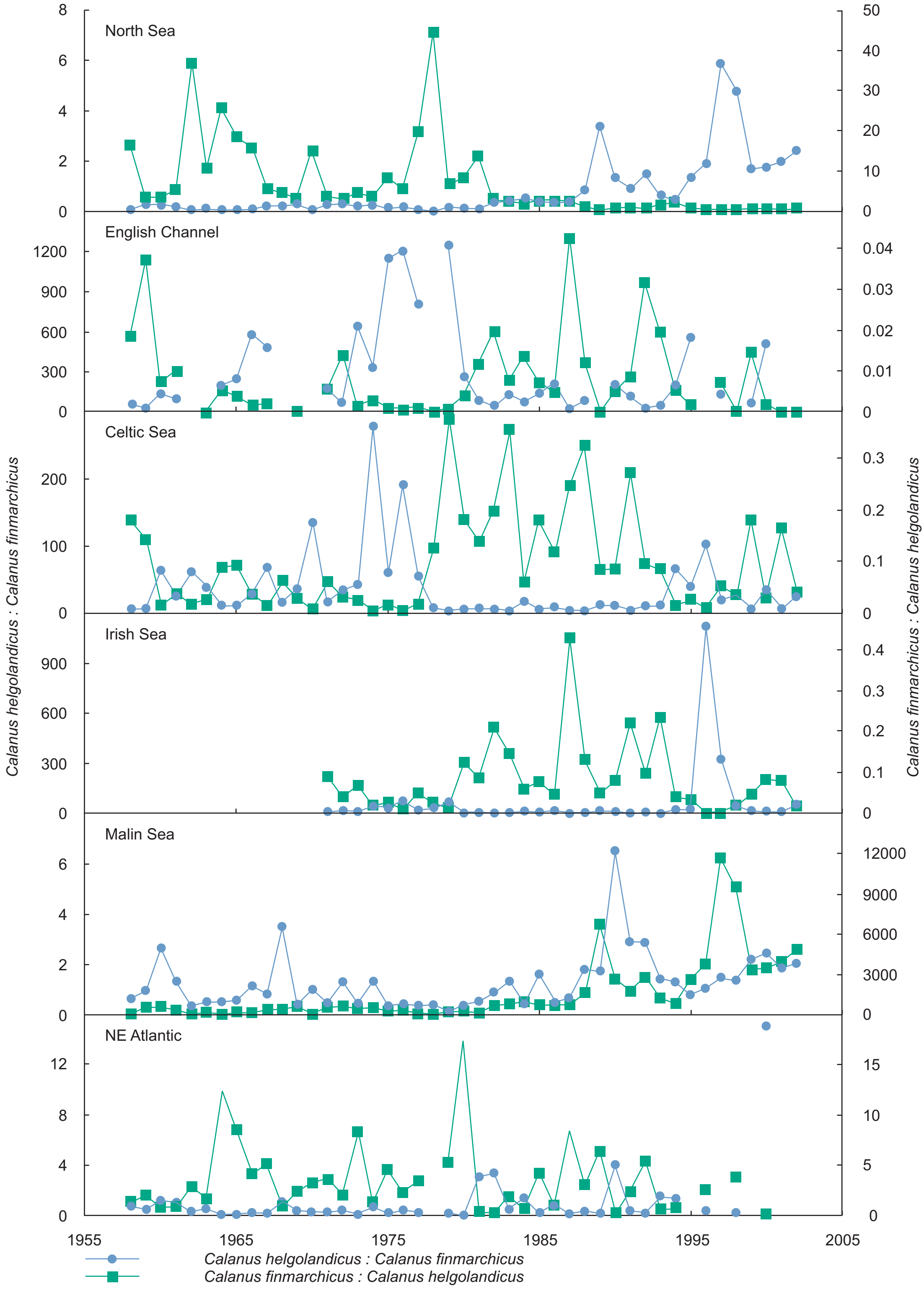

Figure 2.22. Plots of *Calanus finmarchicus*:*Calanus helgolandicus* ratios averaged for the six areas defined in Figure 2.5

Interpretation: In the North Sea abundance of the boreal copepod *C. finmarchicus* and warm temperate *C. helgolandicus* has shown a systematic alternation over the last 40 years (Reid *et al*., 2003b). In part, this reflects the inverse correlations that the two species show with the North Atlantic Oscillation (Fromentin and Planque, 1996), but also includes a temperature component as *C. helgolandicus* is strongly correlated with Sea Surface Temperature (Lindley and Reid, 2002). Varying inflows of oceanic water and the depth and seasonal timing of their occurrence, again related to the NAO, are a third important contributor bringing in seed populations. Inflows in the warmer periods appear to have a southerly source and be linked to higher flows in the slope current to the west of the British Isles (Holliday and Reid, 2001; Reid *et al*., 2001b). Inflows in the cold periods are important at lower depths, bringing in seed populations of *C. finmarchicus* from diapausing populations in deep water.

In the plot for the North Sea the 1988 regime shift identified by Reid *et al*. (2001a) is clearly distinguished. This event is shown, on the basis of 3D modelling, to be associated with an increased inflow of oceanic water. Peaks in the abundance of *C. helgolandicus* centred on 1989 and 1997 coincide with the two major oceanic incursions indicated by intrusion of southerly plankton into the North Sea (Edwards *et al*., 2001a; Holliday and Reid, 2001). The second of the cold events (~1978 to 1982) had a profound effect on North Sea ecosystems and fisheries with a marked reduction in the abundance of plankton and fish stocks (Edwards *et al*., 2002).

Further work: The breakdown in the *C. finmarchicus*:NAO relationship shows the complexity of marine pelagic systems and the need to undertake more research on this sensitive species to environmental change to determine the key factors forcing changes in abundance and distribution. The relationship between *C. helgolandicus* and the NAO was less clear. It is not known if this pattern has also broken down. Further work also needs to be undertaken on the invasion routes of the species onto the shelf and the forcing factors that promote different routes. In the past the two species were recorded in the Celtic Sea respectively above and below the thermocline. Vertical sampling in this area needs to be carried out to determine if a relict population of *C. finmarchicus* still exists in this area, and if so where it and its congeneric species overwinters.

Data source: Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, Plymouth, PL1 2PB. North Atlantic Oscillation data can be obtained from http://tao.atmos.washington.edu/data_sets/nao/.

PHYTOPLANKTON COLOUR

Specific indicator: CPRs have been towed behind merchant ships to monitor the plankton on a number of routes across the North Sea each month since January 1946. A six metre band of the filtering silk used in these instruments provides a 'film' of the plankton along a transect of ~500 nautical miles. Phytoplankton Colour is a simple index of chlorophyll (a basic measure of phytoplankton biomass) determined from a visual assessment, into four categories, of the colour of the CPR sampling silk. The methodology used has not changed since January 1946. Data for this index are available on the SAHFOS web site averaged for 41 Standard Areas covering the northern North Atlantic.

Objective: To provide an index of long-term variability in phytoplankton biomass and possibly production for sea areas around the UK.

Relevance: Phytoplankton forms the base of the food chain; variations in its composition, biomass and production are thus crucial for all other marine life. This variability also defines the carrying capacity of the living marine resources of an ecosystem/regional sea. Phytoplankton are sensitive indicators of environmental change and can be used to help distinguish anthropogenic from natural variability especially with respect to eutrophication and climate change. Measuring primary production is expensive and complicated; the Colour biomass index used here is a simple proxy for this production. The microscopic plants of the sea play a key role in climate change through the biological pump and in modulating gaseous exchanges with the atmosphere. Some of the species are toxic, causing Harmful Algal Blooms (HAB); information on natural change from the CPR helps to interpret the mechanisms behind HAB and develop management strategies. Finally the colour index provides sea-truthing for satellite measurements of phytoplankton biomass.

Sensitivity of the index: The spring bloom heralds the beginning of the growing year; its timing as well as subsequent successional changes in composition and abundance are known to be highly linked to meteorological (e.g. sunshine, wind) and hydrographic (e.g. currents, stability of the water column) variability as well as grazing from the zooplankton. Temperature is a key variable in phytoplankton growth and development as well as strongly influencing their physical environment through for example the development of water column stability. Evidence from the CPR has shown that Phytoplankton Colour is significantly correlated with both Sea Surface Temperature (SST) and Northern Hemisphere Temperature (NHT) in both the North Sea and much of the eastern North Atlantic. A weak relationship has also been found between Colour and the North Atlantic Oscillation (NAO).

Change over time and space: The predominant pattern of change for Phytoplankton Colour in a large area comprising the North Sea, sea areas around the British Isles and oceanic waters out to approximately 20°W to the west of Ireland over the last ~50 years has been an increasing linear trend, with a sharp stepwise increase after 1986 (Beaugrand and Reid, 2003; Edwards *et al*., 2001a; Reid *et al*., 1998). This pattern is most evident in the North Sea and less clear in some of the other five areas selected for this study. Pronounced changes have also occurred in the seasonal occurrence of the index.

Phytoplankton Colour in the North Sea (Figure 2.7) has shown pronounced changes over time with a stepwise increase in the index after about 1987, which reflects a much earlier and longer growing season as well as higher levels of Colour in the summer months of the year.

Graph Figure 2.23 shows the annual mean levels of Phytoplankton Colour averaged for each of the six areas:

- North Sea
- Malin Shelf
- North-East Atlantic
- Irish Sea
- Celtic Sea
- English Channel

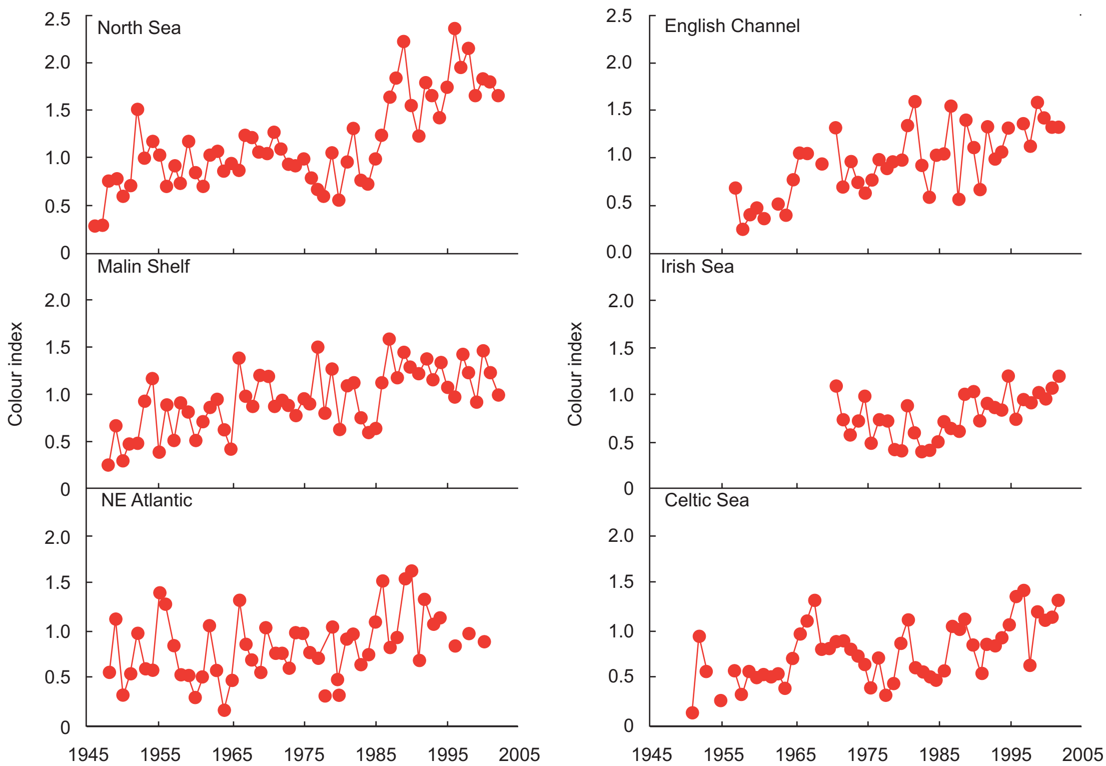

Figure 2.23. Plots of annual mean Phytoplankton Colour averaged for the six areas defined in Figure 2.5

In the North Sea, Phytoplankton Colour measurements were initiated in January 1946. At this time they were at a low level, especially considering that most of the routes were in the southern North Sea at this time. Levels increased, oscillating around a mean of 1 until 1988 when they jumped to a new mean level of ~1.7 units. Sampling in the Malin Sea started in a systematic way in January 1948; interannual changes and the mean level until 1987 were similar to the North Sea. An equivalent increase occurred in 1988 to the North Sea, but the mean level was much less. In the central eastern North Atlantic there has been a progressive upward trend since sampling started in 1948 with a general increase to higher levels from 1986. Sampling in this region has been more intermittent in the last decade.

Sampling in the Celtic Sea started from 1950, since when there has been a progressive rise in Colour to generally higher levels post 1987. Higher levels of Colour were also seen between 1968 and 1975. Systematic results were obtained in the Irish Sea from October 1970. Over this period the pattern of change is similar to the Celtic Sea, with the rise to higher levels occurring in 1989. In the English Channel the time series has been broken a number of times for short periods. The pattern is again one of a rising trend, with high levels of Colour occurring as early as 1982.

Interpretation: The changing patterns of Colour in the wider region that includes the six areas outlined here has been shown, after removal of temporal autocorrelation, to be significantly correlated with SST (averaged for the same area) and NHT (Beaugrand and Reid, 2003). Edwards *et al*. (2001a) also found a moderately significant correlation with the NAO. In the North Sea the changes in Colour as part of a regime shift are reflected in other trophic levels of the plankton in the biomass and diversity of the benthos (animals living in and on the bottom) in fish catches, recruitment and biomass, in nutrient concentrations, in inflow of oceanic water into the North Sea and even in the number of times that the Thames barrage has been closed to prevent tidal surges. Inflow of oceanic water has been shown to be highly related to the North Atlantic Oscillation and as the major source of nutrients to the North Sea has an important impact on productivity.

The similarity in pattern between the North Sea and the ocean to the west of Ireland indicates that the same processes are operating both on and off the shelf. These relationships suggest that the dominant factor contributing to the year-to-year variability in Phytoplankton Colour is physical hydroclimatic forcing, and that eutrophication in the areas sampled by the CPR, is a minor factor in the change. It is possible, however, that post regime shift changes may well have reinforced eutrophication symptoms in nearshore waters. Preliminary positive correlations between Phytoplankton Colour and satellite derived measurements of chlorophyll biomass help to reinforce the message that the observed changes are real and substantial. Colour in the North Sea at least appears to be responding to higher temperatures generated by the combined forcing of the NHT and NAO. The projected continuing rise in global temperatures by the International Panel on Climate Change (IPCC) implies that Colour levels may well continue to rise with a progressive change in the composition and seasonal occurrence of the species contributing to the index.

Further work: Some caution needs to be taken in the interpretation of the results for areas outside the North Sea where sampling has been less systematic through time. A statistical re-analysis of the data is needed that takes sampling into account.

Data source: Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, Plymouth, PL1 2PB. North Atlantic Oscillation data can be obtained from http://tao.atmos.washington.edu/data_sets/nao/ and Northern Hemisphere temperatures from the Hadley Centre for Climate Research.

COPEPOD INDICATOR ASSEMBLAGES

Specific indicator: Seven indicator assemblages of copepods have been produced based on the mean number of species in each assemblage (Beaugrand *et al*., 2002a,c). These associations determined from 108 species show variability in the abundance of groups of copepods that characterise different water masses. Here results have been averaged for two periods of years: 1958–1981 and 1982–1999.

Indicator associations

1. Arctic
2. Subarctic
3. Cold temperate mixed water
4. Shelf Sea Neritic
5. Coastal Neritic
6. Temperate Pseudo oceanic
7. Warm-temperate Pseudo-oceanic

Beaugrand *et al*., (2002a) decomposed the diversity of calanoid copepods, the most abundant taxonomic group in the plankton and best sampled by the CPR survey, into a number of species assemblages (Beaugrand *et al*., 2002b). At the scale of the North Atlantic basin and a spatial resolution approaching the meso-scale, nine species assemblages were identified using three criteria: (1) spatial distribution of species, (2) similarity in the seasonal variability of species and (3) their diel and ontogenic variations. The nine species assemblages were found to be closely related to geographical location and water mass. The indicator maps presented here (Figure 2.24) have been recalculated for two periods: 1958–1981 and 1982–1999. Only the seven associations that occur in waters adjacent to the UK are shown.

Objective: To produce a set of indicators that can be used to monitor modifications in the structural organisation of North Atlantic marine ecosystems linked to climate change.

Relevance: Provides an easily visualised and measured dataset of planktonic change at a scale of 50 × 50 nautical mile pixels. It enables the rates of biogeographic movement in planktonic assemblages to be measured.

Sensitivity of the index: These indices are constructed from time series of 108 species of copepods from the whole CPR database. The large amount of information included makes them especially sensitive to change.

Change over time and space: In the north-eastern North Atlantic and European seas, maps of the mean number of species for all associations in the area demonstrate that major biogeographical shifts have occurred in all seven species assemblages. This change has occurred since the early 1980s to the south-west of the British Isles and from the mid 1980s in the North Sea. The number of warm-water species has increased northwards by 10° of latitude, while the diversity of colder-temperate and subarctic species has decreased. All biological assemblages show consistent patterns of change, which may reflect a movement of marine ecosystems towards a warmer dynamical equilibrium.

Interpretation: Changes in these indices have been shown to be highly correlated with Northern Hemisphere Temperature (NHT) change and the North Atlantic Oscillation (NAO).

Further work: There is considerable scope to expand the use of these indicators to the examination of variability along particular stretches of the UK coast. The processes that are contributing to the distinction of the different associations and their change through time need to be examined.

Data source: Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, Plymouth, PL1 2PB. North Atlantic Oscillation (NAO) data can be obtained from http://tao.atmos.washington.edu/data_sets/nao/ and Northern Hemisphere temperatures from the Hadley Centre for Climate Research.

FUTURE RECOMMENDATIONS

- The environmental changes reported here need to be taken into account when assessing potential policies that might be implemented 'to show a real difference in the marine environment within one generation'.

- Consideration should be given to establishing a similar extensive inshore plankton survey to the Continuous Plankton Recorder (CPR) survey. One possibility might be to tow CPRs at shallow depths behind the survey vessels of the EA and SEPA when they are en route to complete other surveys.

- Temperature variability seems to be a major factor in the composition of communities and it might be possible to determine an expected community structure for a given area in a given temperature band. There is a need for research in this area.

- Some biological monitoring for plankton should be included in statutory monitoring programmes.

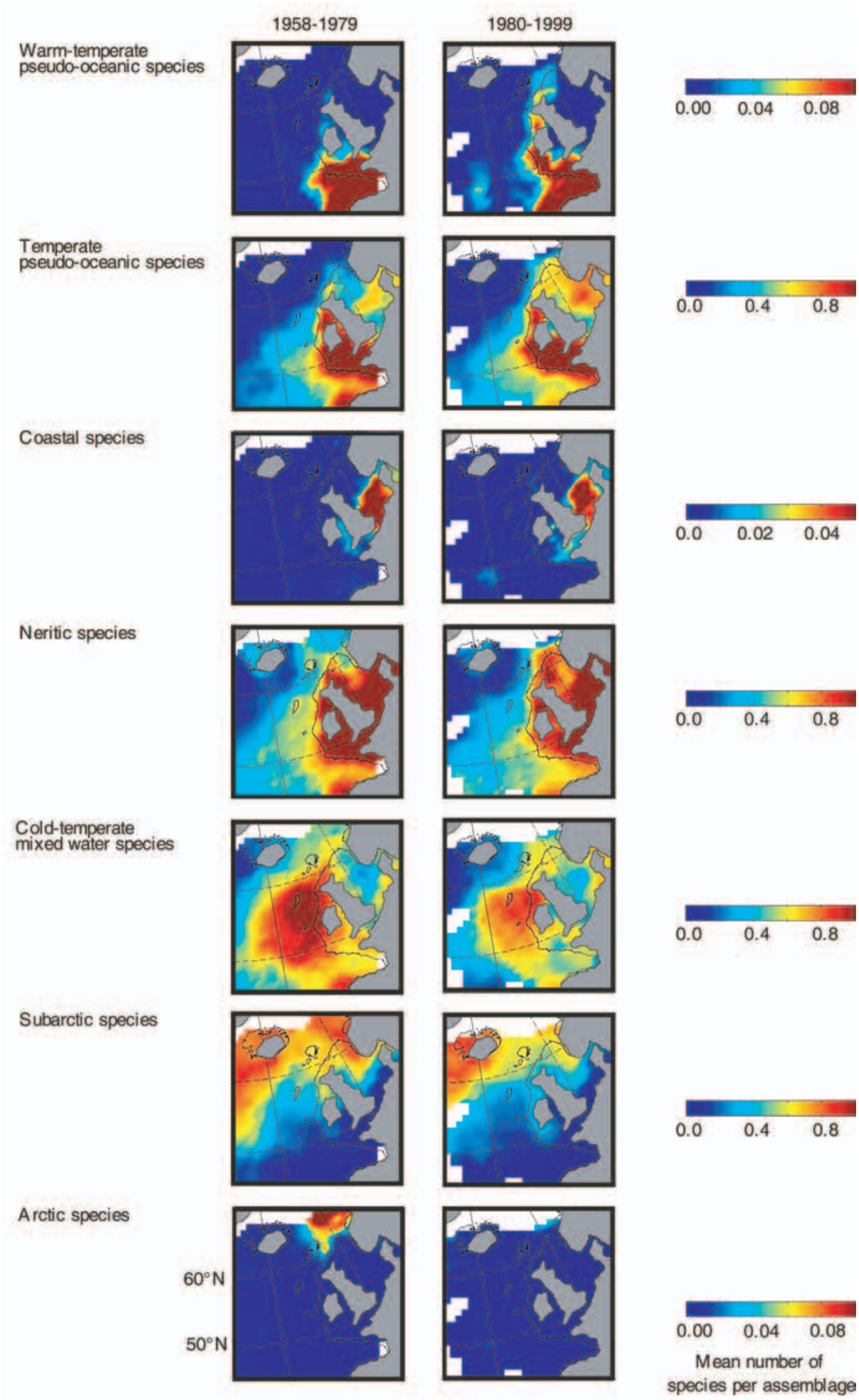

Figure 2.24. Maps of the Indicator Associations: Arctic, Subarctic, Cold temperate mixed water, Shelf Sea Neritic, Coastal Neritic, Temperate pseudo-oceanic and Warm temperate pseudo-oceanic averaged for the periods 1958–1979 and 1980–1999. Legend otherwise as per Figure 2.12 from Beaugrand *et al*. (2002a)

- Methods used in long-term plankton surveys should be standardised and maintained over long periods.

- An historical overview should be undertaken of past planktonic research in UK waters that brings together information from single point time series, one off surveys and the results of the Continuous Plankton Recorder (CPR) programme.

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3. State of marine benthos

KEY MESSAGES

The diversity of the animals and plants which live within or on our sea floor is ranked amongst the highest in Europe. The benthos is important in its own right to provide food for humans, but it is also a vital component of the marine food web providing habitat and food for other marine species.

The key messages to emerge from the sections considering the different aspects of the status of the benthos in UK seas are:

Marine survey programmes:

- **Assessing the status of marine benthic communities requires spatial and temporal survey data. Survey effort has declined in the past 10 years, but recent survey effort has increased the spatial 'baseline' for many regions of the UK's seas; early historical surveys of adequate scale or data quality are generally lacking, particularly in offshore areas. In our current data holdings we have only recorded about 40% of the taxa on the UK's national checklist. Data on temporal changes in marine benthic communities are only available for a limited number of locations.**

- **There are no agreed tools (indices) to assess the state of benthic communities at a UK level. However, a number of developments, including those arising from the Water Framework Directive programme, will help resolve this issue.**

- **On available evidence, there is no indication of significant structural or distributional changes to benthic communities arising from recent human activities on a regional or UK-wide sea scale. However, there is evidence that benthic communities are severely affected by certain fishing activities in some areas, particularly those in more stable environments. On the basis of the widespread but patchy distribution of fishing in our seas it is likely that the benthos remains modified in areas where fishing intensity prevents recovery.**

- **The health of benthic communities as assessed by the National Marine Monitoring Programme and various research projects shows that they are affected by a number of different activities and their response can be used as an indicator of change.**

- **Overall there is no evidence of broad scale impacts of nutrients or hazardous substances on benthic communities but they do show signs of stress in local areas often close to the source of the pollution.**

Progress against objectives:

- **The UK is taking appropriate measures to undertake the assessments against the objectives of the European Directives. It is not clear at present how the UK will contribute to the broader targets agreed through International Conventions and Agreements, particularly in areas away from the coast in the wider offshore parts of UK seas.**

KEY MESSAGES

Recommendations:

- **The UK needs to establish an appropriate surveillance programme to meet its international and national commitments to assess the status of benthic communities in UK seas. There is an urgent need to establish a process to gather data for the wider marine environment – both existing data and new data – and to develop nationally agreed indicators or assessment measures to properly assess the status of benthic communities.**

- **Human activities should be considered in an integrated manner to assess the overall anthropogenic impact on marine benthic ecosystems, and to contribute to a more holistic, ecosystem-based approach to management.**

- **There is a need to address the problems which exist on a local level from known human impacts such as polluting discharges or physical disturbance arising from dredging/disposal, and to consider further the potential for wider-scale damage incurred from fishing activities.**

INTRODUCTION

Marine benthic ecosystems are complex, dynamic, multi-dimensional entities. Some species, such as scallops, mussels and cockles, are valued directly for human consumption, while others provide food for fish and are a vital and integral part of the marine ecosystem.

The UK benthic communities are conspicuous for their variety and frequently high biodiversity. They may be ranked among the most important in any contemporary Europe-wide assessment.

An assessment of the 'state' of benthic communities should consider the physical environmental parameters that create the fabric of systems (tides, substrata), the composition of the flora and fauna, the functional relationships within the biota (such as predator–prey relationships), or the energy flows through the system from primary producers to consumers. All parameters will also vary over space and time. Perhaps more fundamentally, it is necessary to have a clear objective against which it is possible to plan a data-gathering campaign; this might be compared to the setting of a hypothesis as the basis for the 'scientific method'. Whilst it is desirable to consider a whole ecosystem approach, realistically it is difficult to gather comprehensive data from sufficient stations over space and time to assess the state of marine benthos for key stations, let alone the UK seas. A more achievable objective will continue to be an assessment of selected components of the system as proxies for the whole system.

One of the main objectives of the State of the Seas report is an assessment of our performance against the vision in the first marine stewardship report – that of clean, healthy, safe, *productive and biologically diverse* oceans and seas. The *productive* and *biologically diverse* aspects of the macro-invertebrate biological community component of the benthos are potentially achievable measures of state. There is, however, a further important aspect to an assessment of state in that it is necessary to assign values to measurements of state if such measurements are to assess our 'performance' in maintaining (or restoring) the marine system to match our 'vision'. Clearly it is necessary to define the 'acceptable' state against which the current state can be compared and then subsequently assigned a qualitative descriptor. Such an approach of establishing an 'environmental objective' is the basis of the assessments required under the EC Habitats Directive and the EU Water Framework Directive (WFD), and the concept behind the Ecological Quality Objectives (EcoQOs) that are being developed by the OSPAR Commission.

Defining 'acceptable' state' is not straightforward in an environment that is already subject to anthropogenic pressures and activities. It is tempting to consider the state at a pre-determined point in history (often the situation prior to the establishment of a management regime) as 'unacceptable', and then compare the current state with this 'standard' as a measure of performance. Whilst such an approach will demonstrate the hopefully positive benefit of management away from the 'unacceptable', it remains difficult to establish when the 'acceptable' state is attained. Frid *et al*. (2000) compared benthic communities in the North Sea from the 1920s to the 1980s to assess the impact of fishing, but concluded that the system may have already been affected in the 1920s. Benthic ecosystems are dynamic systems and change is the norm rather than the exception. Benthic community composition will often display large natural variability and it is unlikely there will be a single 'acceptable' state. Any attempt to incorporate all such variability into a definition of 'acceptable' will most likely result in a rather loose definition against which it will be extremely difficult to assess any unacceptable changes through adverse anthropogenic activities. An alternative approach could define the ecological objective in relation to the level of adverse anthropogenic activity on a system: this is the basis of the concept of 'ecological status' in the WFD.

'High ecological status' in the WFD is defined as:

> *There are no, or only very minor, anthropogenic alterations to the values of the physico-chemical and hydromorphological quality elements for the surface water body type from those normally associated with that type under undisturbed conditions.*
>
> *The values of the biological quality elements for the surface water body reflect those normally associated with that type under undisturbed conditions, and show no, or only very minor, evidence of distortion.*

'Very minor' is not quantified and consequently there has been considerable discussion over its actual interpretation in relation to the current level of anthropogenic activities. The key environmental objective of the WFD is that all water bodies achieve 'good ecological status' by 2015. For benthic communities in coastal waters this is defined as:

Although the WFD seems simple in concept, and uses the measurement 'diversity and abundance' as a proxy for the state of the ecosystem, there remain significant concerns over this approach, since benthic diversity can increase with intermediate levels of disturbance. It will be important to identify appropriate 'sensitive taxa' to support measures of diversity and abundance in order to assess the level of anthropogenic disturbance on benthic communities.

It is important to note that the WFD only applies to coastal waters out to 1 nautical mile (in England and Wales) and 3 nautical miles (in Scotland) beyond baseline; the baseline cuts across the entrances to bays and estuaries, and extends to the west of the Hebrides. Coastal waters under the jurisdiction of the WFD therefore include areas such as the Minch, the Wash, and the outer Thames and Severn Estuaries. There are proposals in the emerging *European Marine Strategy* to extend the WFD to cover all waters of the EU, but this is mostly likely to be based on the 'WFD concept' [of establishing ecological objectives] rather than its current definition. Establishing ecological objectives for ecosystem state based on anthropogenic pressures and activities would facilitate an assessment of the status of marine benthos for UK seas. Most importantly, it would provide the 'hypothesis' to underpin the development of appropriate data gathering campaigns. Unfortunately, such objectives are only just emerging from the various policy drivers, so we are not in a position to make an assessment of the state of benthos against ecological objectives.

Macroinvertebrates	Macroalgae and angiosperms
The level of diversity and abundance of invertebrate taxa is slightly outside the range associated with the type-specific conditions. Most of the sensitive taxa of the type-specific communities are present.	Most disturbance sensitive macroalgal and angiosperm taxa associated with undisturbed conditions are present. The level of macroalgal cover and angiosperm abundance shows slight signs of disturbance.

Key messages:

- It is necessary to establish an ecological objective that defines the desired 'state' of benthic communities.
- Ecological objectives are currently being developed through policy drivers: EC Habitats Directive, EU Water Framework Directive, OSPAR EcoQOs and the EU Marine Strategy.
- A direct assessment of the state of benthos in UK waters as a whole is not possible at this time.

Policy drivers

Survey, surveillance and monitoring undertaken by, or on behalf of, the government agencies provides information to assess the quality status of habitats and species in UK waters as required by national legislation. Furthermore, such information when considered with appropriate data from other sectors should contribute to an assessment of government policies to deliver targets on sustainable development and biodiversity agreed under international agreements and conventions.

Assessing the status of marine biodiversity is an essential component of:

International agreements and conventions: OSPAR, Ramsar, Convention on Biological Diversity (CBD), particularly the Jakarta Mandate, Göteborg Target set by the EU[1], World Summit on Sustainable Development (WSSD) in 2002[2], Bergen Declaration from the North Sea Ministerial Conference, ASCOBANS, Bonn Convention, Bern Convention, and the Straddling and Highly Migratory Fish Stocks Convention 1995

European legislation: EC Habitats Directive, EC Birds Directive and the EU Water Framework Directive.

National legislation and/or programmes: Wildlife and Countryside Act 1981 (as amended); Biodiversity Action Plans (BAP)

These policy drivers operate at two spatial scales: some require the designation of protected areas (for example Special Areas of Conservation (SAC) are required by the EC Habitats Directive); others relate to the wider/entire marine environment (Bergen Declaration). In general, the legislative approach is based on site protection and the broader agreements relate to the wider environment. Traditionally, the government agencies have focussed on meeting legislative drivers, although it is now generally recognised that a site-based approach to conservation will not necessarily deliver the target for marine biodiversity in the wider environment alone. Furthermore, many of the international agreements relate to higher vertebrates – seals, cetaceans, birds, and reptiles for which there are few comprehensive monitoring programmes due to their wide-ranging life strategy[3]. Any assessment of the 'quality status of the marine environment' must take such species into account and therefore it will be necessary to develop alternative survey strategies to meet all these policy drivers.

MARINE SURVEY PROGRAMMES

BASELINE SURVEY

Broad scale assessments of the state of marine biodiversity depend on spatial surveys to give a true representation of the entire marine environment. Such surveys have been undertaken either directly by government agencies, in collaboration with other agencies and organisations, or through commissioned contracts. These surveys provide vital baseline information and, for many parts of the UK, the only information available, on the composition of marine benthic communities. At present, there are few funds available to continue, let alone repeat, such surveys. It will, however, be essential to develop a programme where public organisations and private industry can collaborate to contribute appropriate data recorded to a central pool whilst undertaking their normal functions. These data should be made accessible to enable broad scale quality assessments in future years.

The UK has a long history of surveying marine benthic habitats and species in its waters. During the past 30 years, the nature conservation agencies have commissioned many surveys to support the selection and designation of marine protected areas (e.g. SACs). There have been two large UK-wide systematic surveys: the intertidal survey of Great Britain and Ireland (Bishop and Holme,

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1 The Göteborg Target states 'biodiversity decline should be halted [in the EU] with the aim of reaching this objective by 2010'
2 The WSSD agreed targets relating to biodiversity, marine protected areas and fisheries.
3 The UK has comprehensive seal and seabird monitoring programmes – at appropriate stages when species are not ranging.

1980; Harvey *et al.*, 1980) and the Marine Nature Conservation Review (Hiscock, 1996); plus a series of regional surveys including the South West Britain Sublittoral Survey (Hiscock, 1981) and the Northern Ireland intertidal and subtidal surveys (Wilkinson *et al.*,1988; Erwin *et al.*,1986). These surveys all contributed to the development of standardised recording methods that were published by the Marine Nature Conservation Review (Hiscock, 1996). More recent surveys have continued to use these standard techniques, with some local adaptation where appropriate. In addition, the conservation agencies have collaborated with many other organisations to support similar work.

Following the selection of Special Areas of Conservation (SACs) in inshore waters, the conservation agencies have invested significant resources into mapping the spatial distribution of benthic habitats and communities, primarily but not exclusively within SAC boundaries.

Publicly funded research and development programmes undertaken by academic institutions, government research institutes and public agencies have undertaken marine benthic surveys throughout many regions of the UK's waters. Their results are published through scientific journals and 'grey' technical reports. In the late 1980s and early 1990s, the Marine Nature Conservation Review completed a large collation exercise to extract and summarise material relevant to the description of UK benthic habitats and species (Hiscock, 1998); a summary of the locations of these data are shown in Figure 3.1. Unfortunately many of these data are not available at the present time to contribute to an assessment of the state of UK benthic communities. It would be timely to update this review to include studies undertaken in the past 10 years, particularly focussing on data available further offshore.

'COMPLIANCE' MONITORING

'Compliance' monitoring is undertaken to ensure environmental standards are being met and/or to assess the impact of licensed activities in the marine environment. Such monitoring is clearly targeted to specific locations and its spatial and temporal resolution linked to the activity or input under investigation. The findings from these studies are regularly reported in the scientific literature. Data from these activities are held by the regulatory agencies and private organisations that hold licences.

QUALITY STATUS MONITORING

In UK, there is a single national pollution monitoring programme – the National Marine Monitoring Programme (NMMP), which provides quality status data to comply with the OSPAR Joint Assessment Monitoring Programme. The NMMP undertakes a comprehensive assessment of the chemical, biological and physical characteristics of the environment at a selection of sites around the UK. The advantage of this approach is that it provides a means of conducting integrated analyses, which helps determine the causality of change at the community level and therefore allows the 'health' and function of an ecosystem to be estimated. It also improves our understanding of how ecosystems work and respond to pollution events. In addition, the results of the NMMP provide valuable data for the parameterisation and validation of ecosystem models presently being researched and developed. However, the NMMP concentrates on depositional environments. Relatively few offshore sites, i.e. those remote from anthropogenic contamination, are sampled. Therefore this programme would need to be expanded to encompass a wider variety of habitats, especially coarse sediments.

Summary

Key messages:

- Assessing the status of marine benthic communities requires spatial and temporal data.
- Baseline data are available for many regions of the UK's coastal seas.
- Data on temporal changes in marine benthic communities are only available for a limited number of locations.

AVAILABILITY OF DATA TO ASSESS THE STATE OF BENTHOS IN UK WATERS

Assessing the status of benthic communities in UK waters requires data to be available in an accessible format. Whilst there have been many benthic surveys over the past 100 years or so, many of the data are not readily accessible for holistic assessments. Crucially, it also requires data to be of adequate quality. The conservation agencies have invested significant resources into developing data management systems to support their core functions and to meet key policy drivers. In addition, the Marine Life Information Network (MarLIN) is actively sourcing and collating marine benthic data. The Joint

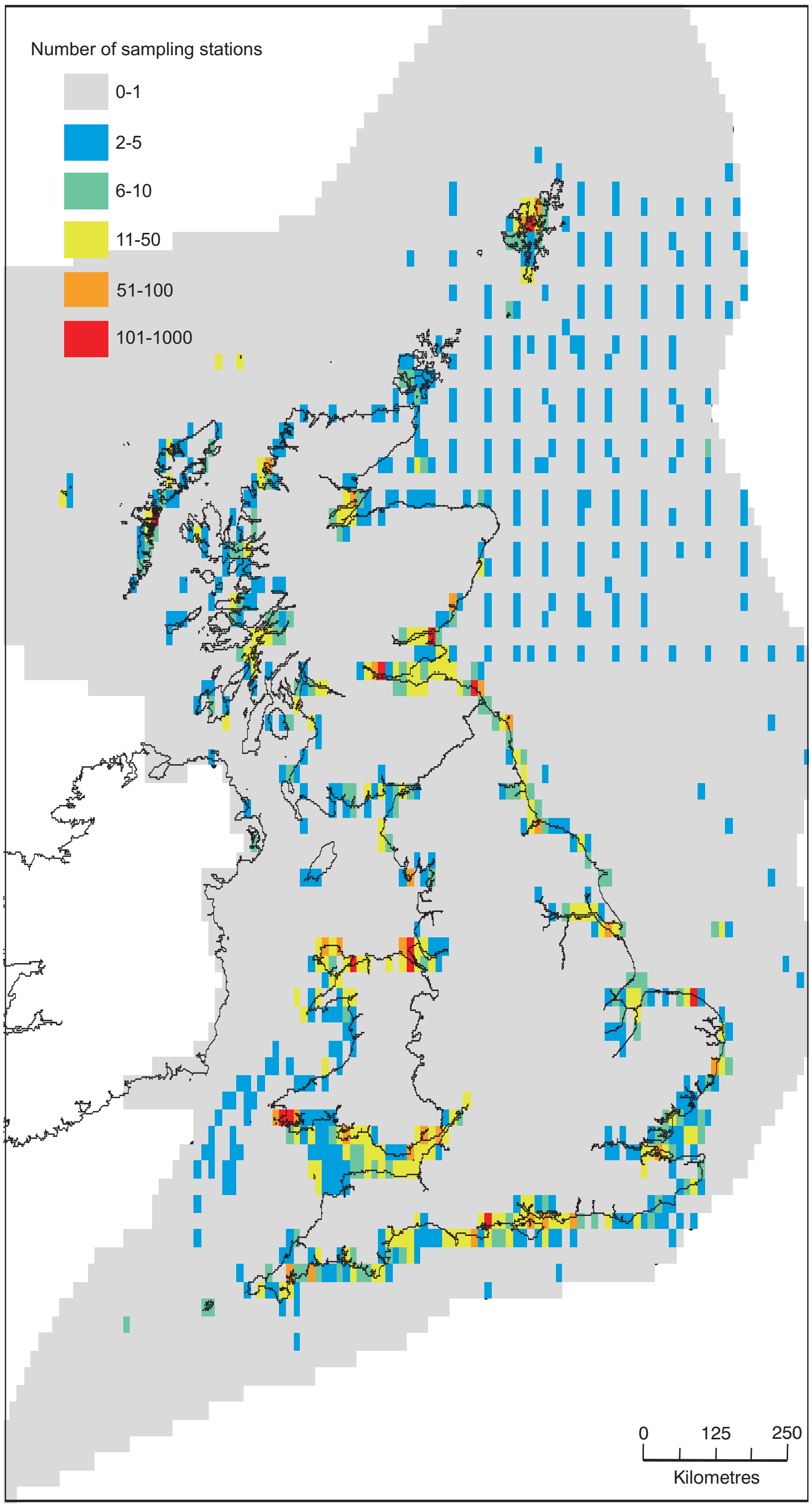

Figure 3.1. A summary of the location of biological data identified by the Marine Nature Conservation Review. Data are summarised by 12 × 12 km grid squares for UK waters. Additional stations beyond UK waters are also shown where other stations from that investigation fall within UK waters

Nature Conservation Committee (JNCC) has led on the development of the National Biodiversity Network (NBN) to make more data available for biodiversity assessment and other major data holders (e.g. the Environment Agency) are actively collating their data holdings.

NATIONAL BIODIVERSITY NETWORK

One of JNCC's key roles is the maintenance of UK wide datasets. In recent years, it has focussed on the delivery of data across the Internet and developing applications for data capture.

The National Biodiversity Network (NBN) is a union of like-minded organisations that are collaborating to create an information network of biodiversity data that is accessible through the Internet. To this end, a number of projects, such as the NBN Gateway have been undertaken and led by various partners within the NBN.

JNCC have developed Marine Recorder, a database tool to encourage the collection, collation and sharing of good marine biological data, which has been built on a variety of standards that facilitate the storage and exchange of information between organisations and individuals for the National Biodiversity Network. These standards include the NBN data model, which shows how biological data can be managed within relational databases, an electronic transfer format and the NBN species dictionary and biotope dictionary. The conservation agencies use *Marine Recorder* to capture and store their marine benthic data. These data are then made available to the wider community via the NBN Gateway.

The NBN Gateway is a web site that shows how multiple sources of biodiversity information can be accessed and used over the Internet. The site now contains over 10 million species records, as well as various sources of habitat records and the boundaries of the protected sites in the UK. The NBN Gateway provides controlled online access (the data owner remains in control of who can do what with the data) to a managed source of Biodiversity information (In other words it provides a service that continually updates the data that are available). The JNCC is actively encouraging organisations to make their marine data available via the NBN Gateway; the MarLIN project is also contributing appropriate data to the NBN Gateway. In summer 2004, a new version of the website was released and the JNCC is currently extending its capabilities to include a marine version that will take in all UK waters (out to territorial limits) as the current software (based on the UK National Grid) only covers inshore waters.

DATA AVAILABLE IN NBN

The JNCC has contacted the main government agencies involved in marine benthic sampling, together with a number of organisations known to hold marine benthic data as part of the State of the Seas Project, to request that they make their data available to the NBN. At the time of report preparation (December 2004), 15 datasets comprising 2042 surveys with 49,092 stations giving rise to 1,418,173 taxon records were available (Table 3.1). Nevertheless, there remain some significant sets of public data that have yet to be made available to the NBN, particularly from the fisheries agencies and the academic sector. There are also some collated datasets in the private sector that JNCC have not yet had an opportunity to request from the data managers; for example there is a large dataset from surveys undertaken by the aggregate extraction industry in the southern North Sea and eastern Channel.

The location of the data in the NBN throughout the UK's waters is shown in Figure 3.2, with a more detailed view of the UK coastal waters in Figure 3.3. These data were summarised by creating a grid equivalent to the grid used for ocean modelling (* × *) that approximates to 12 km × 12 km. All data falling within each grid cell were labelled with a code unique to the cell, enabling the data to be aggregated on the basis of grid cell. Despite the volume of data currently collated, there are significant areas of the UK's waters for which there are no data available at present and thus it is impossible to assess its status.

These data represent more than a hundred years of cumulative survey effort in UK waters. This survey can be summarised to demonstrate the effort over time, by year (Figure 3.4). It is apparent from Figure 3.4 that the level of survey effort has declined over the past 10 years despite the gaps in survey coverage in Figure 3.2 and concerns over the increased intensity of anthropogenic pressures on the marine environment (Covey and Laffoley, 2003; ICES, 2003).

Table 3.1. A summary of the data made available to the National Biodiversity Network (NBN) by March 2004. *Number of stations* refers to the number of geographic locations where one or more taxa were recorded. *Number of taxon records* refers to the number of individual records of species or higher taxa – the NBN data structure focuses on individual records to allow the user to plot the distribution of taxa in their chosen area

Name of data set	Number of stations	Number of taxon records
Countryside Council for Wales dataset supplied in January 2004	3052	84330
Centre fpr Environment, Fisheries and Aquaculture Science (Burnham)	159	
Dataset collated by the Joint Nature Conservation Committee for Irish Sea Pilot project in Spring 2003	506	24802
Dataset supplied by Environment and Heritage Service, Lisburn, Northern Ireland[1]	338	283500
Environment Agency, National Marine Service, Peterborough dataset	3384	414004
English Nature data supplied in February 2004	60	3347
ICES North Sea Benthos Survey, 1986 supplied by Flanders Marine Institute, Belgium	506	16846
The Joint Nature Conservation Committee data in February 2004[2]	34535	774682
MarLin data supplied to the Joint Nature Conservation Committee in Spring 2003	2521	97509
National Marine Monitoring Programme Dataset, December 2003	209	133500
pre-NMMP spatial dataset, supplied by the Environment Agency in December 2003	133	60739
Scottish Environmental Protection Agency dataset supplied to the Benthic Task Team for the Water Framework Directive in December 2003	333	73081
Scottish Natural Heritage data supplied in February 2004	522	6365
UKBenthos dataset supplied by UK Offshore Oil Industry Association	2834	218225

[1] The EHS data set includes some data from the Department of Agriculture and Rural Development (DARD), Northern Ireland.
[2] The Joint Nature Conservation Committee dataset includes data from the Conservation Agencies (Countryside Council for Wales, English Nature, Environment and Heritage Service Northern Ireland, and Scottish Natural Heritage supplied before 2001, plus data made available

NORTH SEA BENTHOS SURVEY, 2000

In 1986, ICES undertook a systematic survey of the North Sea (Künitzer et al., 1992). These data are now made available via the internet by the Flanders Marine Institute, VLIZ (http://www.vliz.be/).

Many of these stations were revisited by opportunistic surveys around 2000 (data were collected from 1999 to 2001); the stations corresponding to the UK contribution to this exercise are shown in Figure 3.5. These and other North Sea/E Channel data are presently being analysed by the ICES Study Group on the North Sea Benthos Project 2000 (SGNSBP) under the chair of Hubert Rees (CEFAS, Burnham). Progress and preliminary outcomes are available in reports of the Study Group (http://www.ices.dk/). Work-up of the UK dataset, commissioned by Defra, will be completed in December 2004. Draft findings have been made available for use in the SoS assessment and a full report of this project will be available for the State of the Seas website on completion.

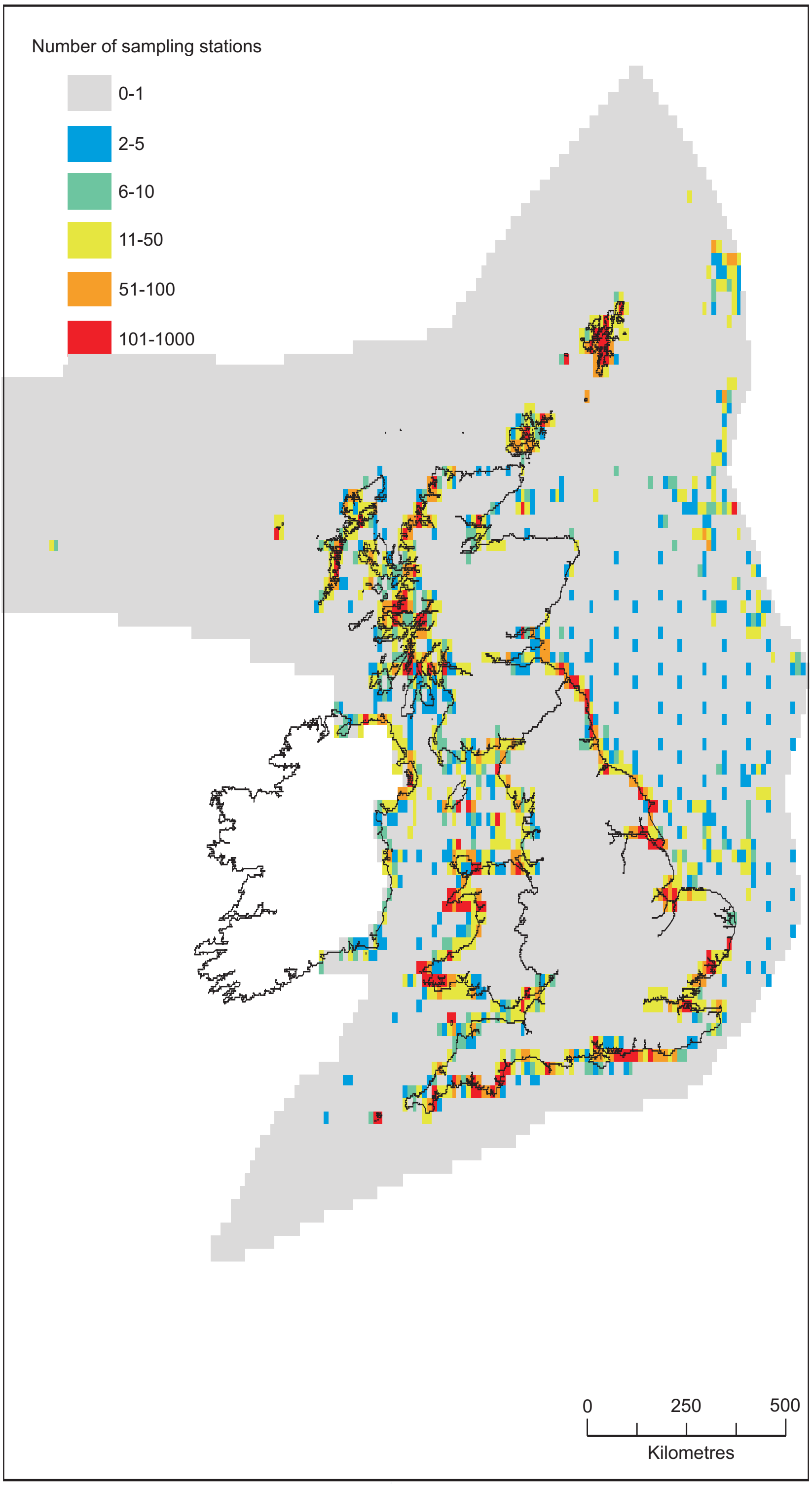

Figure 3.2. A map of UK waters showing the density of biological sample data that has been made available to the National Biodiversity Network in January 2004

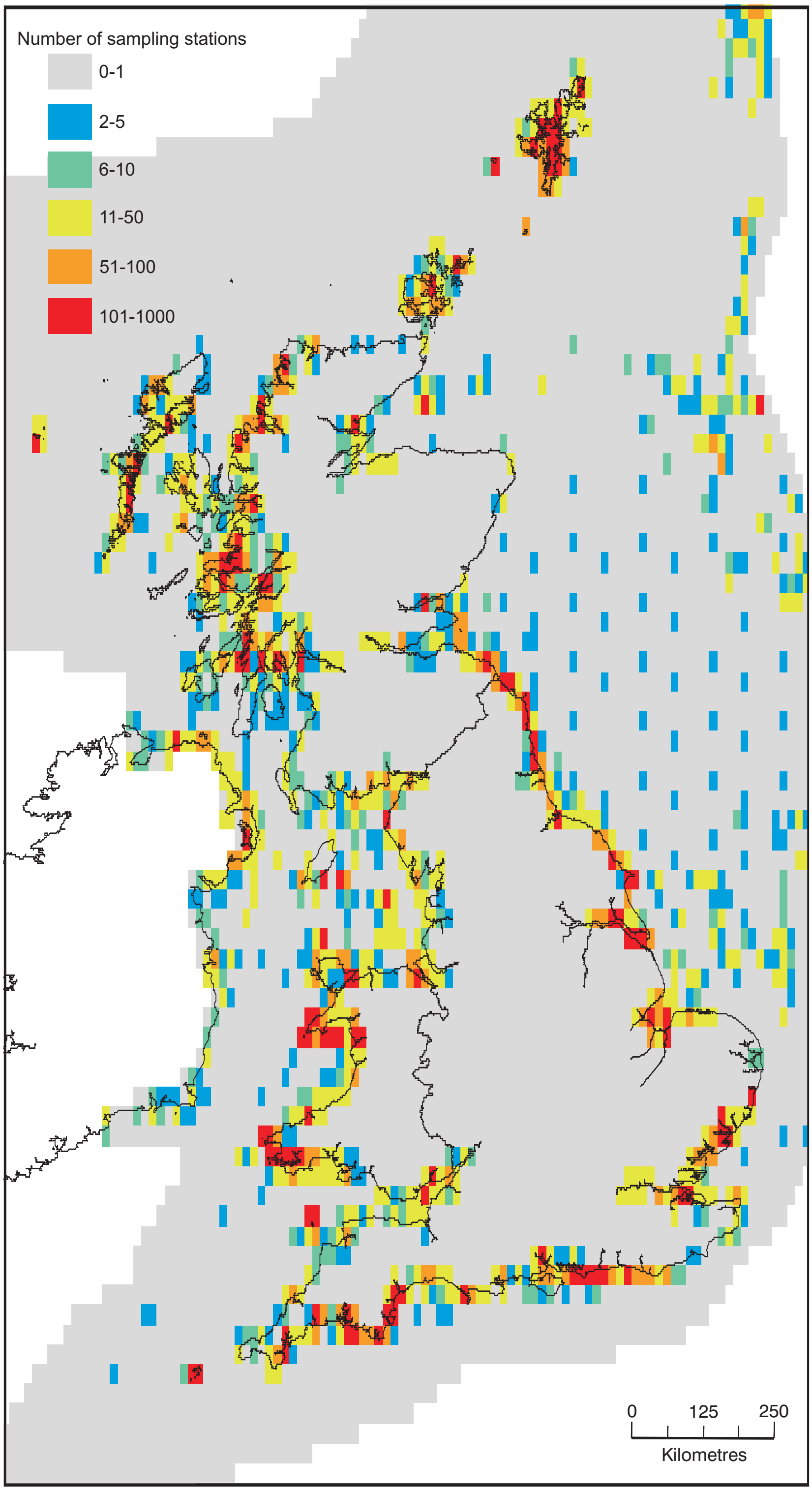

Figure 3.3. A view of the UK coastline showing the density of biological sample data available to the National Biodiversity Network in January 2004

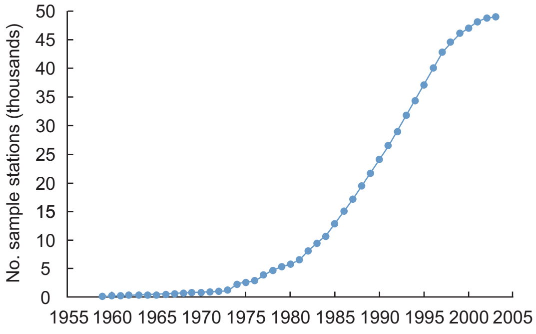

Figure 3.4. The cumulative total of sample stations available to the National Biodiversity Network in January 2004 that have associated taxon data

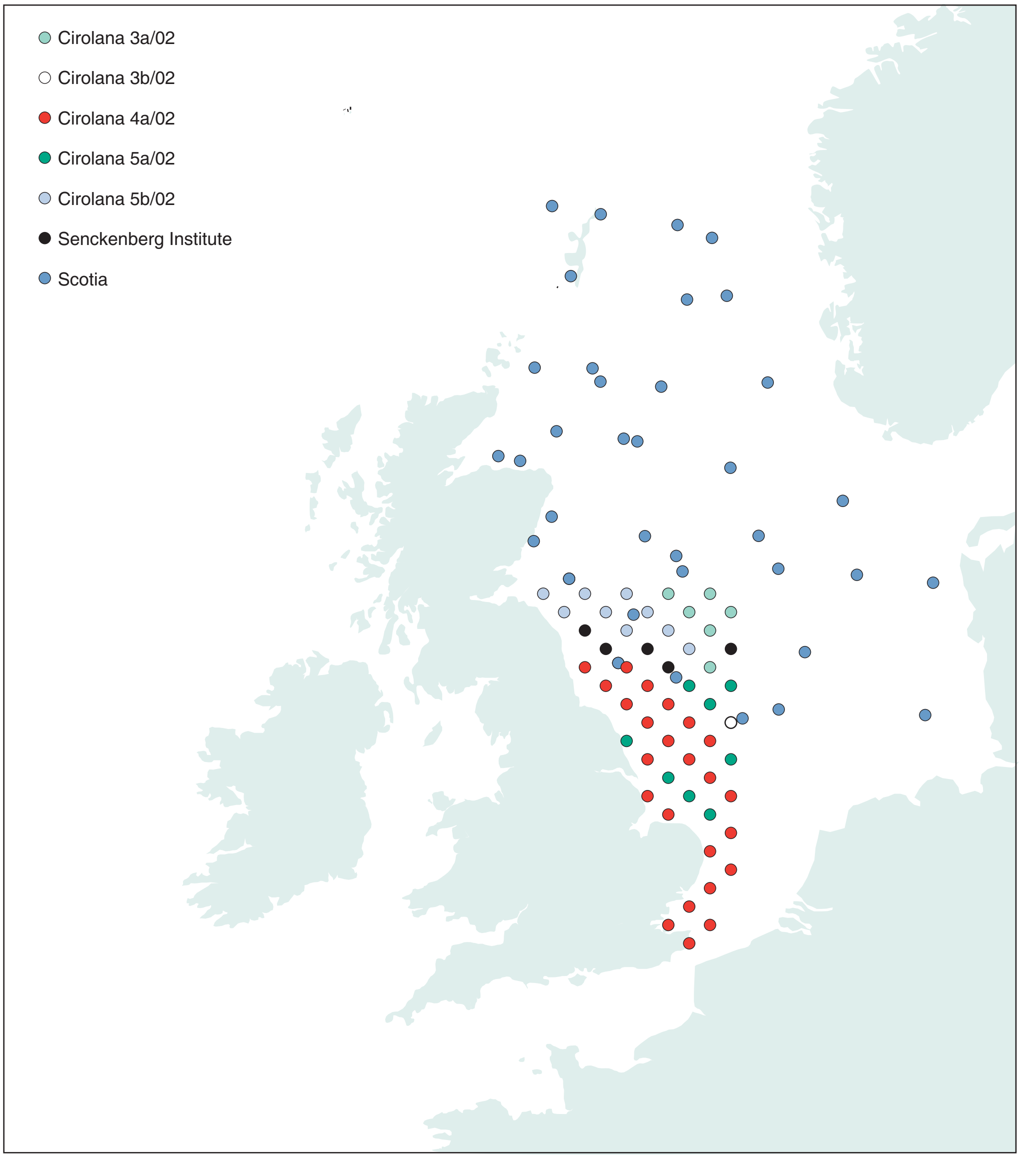

Figure 3.5. The location of the sampling stations for the North Sea Benthos Survey, 2000. The cruises were undertaken by CEFAS (Cirolana), FRS (Scotia) and the Senckenberg Institute, Germany (Hinz). Data supplied by Hubert Rees, CEFAS Burnham

HOW MUCH DO WE KNOW ABOUT OUR MARINE BENTHIC COMMUNITIES?

A summary of the marine biological taxon data made available to the National Biodiversity Network in January 2004 is shown in Table 3.2. These data are based on ~49,000 stations, amounting to ~932,000 taxon records that are assigned to a species; there are a further ~486,000 taxon records assigned to higher taxonomic groups. There are a further 18,000 out of 73,500 taxon records assigned to a species that are not included in these figures because the location of the sample stations could not be verified at this time. The *UK list* used for comparison was based on the *The Species Directory of the Marine Fauna and flora of the British Isles and surrounding seas* (Howson and Picton, 1997).

Table 3.2. A summary of the number of species recorded from the main benthic phyla based on the data available to the National Biodiversity Network in March 2004

Group	No. of taxa in NBN	No. of taxa in UK list	% recorded
Porifera	154	381	40.4
Cnidaria	137	417	32.9
Annelida	689	1054	65.4
Crustacea (lower)	294	1943	15.1
Crustacea (higher)	572	937	61.0
Mollusca	577	1429	40.4
Bryozoa	184	300	61.3
Echinodermata	84	148	56.8
Tunicata	70	134	52.2
Rhodophycota	301	503	59.8
Chrysophycota	2	2	100.0
Chromophycota	131	257	51.0
Chlorophycota	89	198	44.9
Angiospermae	6	6	100.0
Lichens	24	25	96.0
Others[1]	405	1449	28.0
Total	3719	9183	40.5

[1] Others do not include Reptiles, Birds or Mammals.

Summary
Key points:
- Lots of data are available for the coastal zone, little for offshore waters.
- Major data holders have still to make their data available.
- Survey effort has declined in the past 10 years.
- Only about 40% of taxa are recorded on UK list.

A DIRECT ASSESSMENT OF THE STATE OF MARINE BENTHOS

A direct assessment of the state of marine benthos requires bespoke surveillance and monitoring programmes against a specific objective to report against a defined target. The UK conservation agencies have started to develop such monitoring programmes to report on the objectives of the EC Habitats Directive. Similar programmes are being developed to report on the objectives of the EU Water Framework Directive. The UK's commitment to the OSPAR Joint Assessment and Monitoring Programme (JAMP) is fulfilled by the National Marine Monitoring Programme (NMMP). Up to 2003, the JAMP had focussed on the effects of pollution, so there were no formal targets for wider assessments of the status of benthic communities. Consequently the NMMP focuses on depositional soft sediments, including those within estuaries known to have had high levels of pollution; the NMMP does not consider other habitats or have a broad spatial coverage in UK seas.

NATIONAL MARINE MONITORING PROGRAMME: REPORT ON BENTHIC STATUS IN 2003/4

Introduction
In the previous National Monitoring Report, analysis showed that the major separation of sites was into either estuarine or coastal sites, due to their salinity regimes. To avoid this obvious separation and to assess the environmental factors which influence the benthic communities around the UK, estuarine and coastal sites are considered separately in this chapter.

Due to the limited data available for temporal analysis (1999–2001), a spatial analysis of the NMMP data collected in 2000 has been conducted for 28 estuarine and 31 coastal sites, and temporal trends are considered at only two sites from 1997 to 2001. Community structure depends heavily on salinity and on sediment structure and may also be affected by contamination. Relationships have been investigated between the benthic communities and environmental parameters of water depth, sediment type and the sedimentary concentration of contaminants.

Macrofaunal community data were standardised by the exclusion of colonial or epifaunal species such as hydroids or barnacles; nematode worms; juvenile fauna unassigned to a species; and species represented by only a single specimen in a sample.

Table 3.3 presents a summary of univariate statistics (Taxa (T), Abundance (A), evenness (J') and Shannon–Wiener index (H' – a measure of diversity)) for the NMMP 2000 dataset. Following the findings of the previous report (MPMMG, 1998) additional techniques for summarising the status of the benthic fauna, such as the UK 'Infaunal Trophic Index'(ITI) (Codling and Ashley, 1992) and Biotic Index (AMBI) (Borja et al., 2000) are also presented.

The data clearly show the differences between estuarine and coastal sites. The estuarine sites have larger populations but lower diversity than coastal sites. Coastal samples were processed using a 1000 μm sieve, while estuarine samples were extracted using a finer sieve (500 μm), which could account for the higher abundance in the latter samples. Estuarine sites have lower ITI results than coastal sites. This suggests a community bias towards surface deposit feeders at estuarine sites and a larger proportion of surface detrital or water column feeders at coastal sites. However, the ITI was developed to distinguish the impact of organic deposits from municipal sewage discharges on infauna in fully marine environments. In estuaries with naturally high riverine organic input, interpretation of ITI scores in relation to anthropogenic effect is compromised.

The AMBI biotic index scores can range from 0 to 7. Zero is indicative of a normal healthy benthic community which is unpolluted or not stressed and seven represents an extremely stressed or polluted site that is azoic. Both salinity regimes have AMBI scores in a range from less than 1 to over 5, which indicates that some sites have a slightly polluted or unbalanced community. Estuarine sites generally have higher scores than the coastal sites, suggesting that they are more impacted.

SPATIAL ANALYSIS OF NMMP COASTAL SITES FOR 2000

Multivariate analysis

Multivariate methods of data analysis provide a more sensitive measure of community change than univariate methods (Warwick and Clarke, 1991). Two multivariate techniques have been applied to the data: 'group average' cluster

Table 3.3. A summary of the results of the univariate statistical analysis and the calculation of benthic indices for the NMMP 2000 data set. Statistics are presented for Taxa (T), Abundance (A), Pielou's evenness (J'), Shannon Wiener diversity (H'), Infaunal Trophic Index (ITI) and Biotic Index (AMBI). Data are mean values for 0.1 m^2

		T	A	J'	H' (log e)	ITI	AMBI
Estuarine sites	Mean	23	22738	0.52	1.36	39.43	3.18
	Median	17	5671	0.53	1.44	40.81	3.29
	Max	93	185100	1.90	2.22	100.00	5.86
	Min	2	68	0.05	0.03	0.46	0.03
	Sdev	20	39806	0.31	0.54	29.03	1.78
Coastal sites	Mean	24	307	0.74	2.06	60.07	1.75
	Max	94	2876	0.95	3.11	88.69	5.68
	Min	3	11	0.45	0.93	7.50	0.25
	Sdev	19	558	0.13	0.47	16.76	1.13

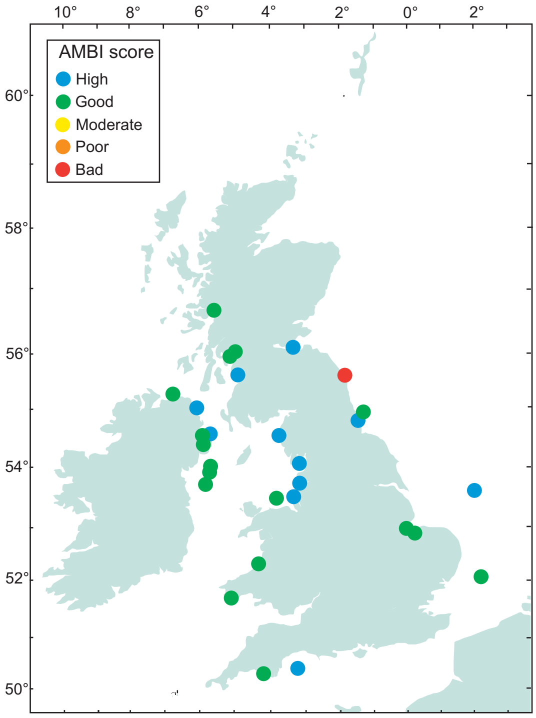

Figure 3.6. AMBI scores coloured by 'class' for the NMMP 2000 coastal sites

analysis (a classification technique) and 'multi-dimensional scaling' (MDS, an ordination technique). In both cases the dataset has been transformed (double square-rooted) and the Bray–Curtis Similarity Index applied.

Results from the cluster analysis indicate four main groups, which separate at a similarity level of 17%. These groupings are indicated on the MDS ordination plot, which is shown in Figure 3.7. Group A relates to those sites with low species abundance and taxa number which occur in coarse sediment with a low proportion of fine material. Group B contains high salinity sites, which are dominated by opportunistic species. Group C all have a silt and clay content in excess of 97%. Group D contains the remaining sites, which have high diversities and heterogeneous substratum offering a wide range of habitats for colonisation.

Which environmental factors best explain the macrofaunal community patterns? Spearman Rank correlation analysis relates environmental factors to macrofaunal community patterns (Table 3.4.)

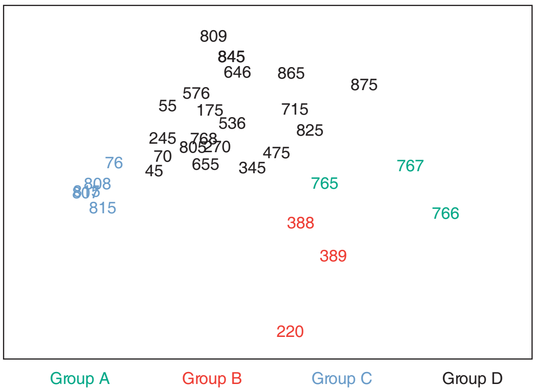

Figure 3.7. Results from multi-dimensional scaling (MDS) analysis of the NMMP 2000 coastal macrobenthic dataset

Table 3.4. Summary data indicating those environmental variables with the best correlation to the macrofaunal community patterns in the coastal sites

Environmental variable	Spearman rank correlation coefficient
Al	0.200
Cd	0.221
PAH – Bghip	0.098
PCB – cb52	0.027
water depth*	0.332
% silt/clay	0.562

*limited dataset available (Sites 45, 55, 70, 76, 175, 245, 270, 388, 536, 646, 807, 808, 809, 815, 825, 845 and 806 only)

These analyses showed a statistically significant correlation between community patterns and water depth or sediment characteristics, but no significant correlation with contaminant levels. The weak correlation between biotic patterns and contaminants in the sediment reflects the relatively uncontaminated character of the coastal sites. The influence of sediment type on the macrofaunal community is clearly shown by superimposition of the percentage silt/clay content on the MDS plot in Figure 3.8. Sites that have a high silt and clay content separate clearly from those sites with coarser sediment, indicating that sediment type strongly influences the macrobenthic community (Figure 3.8)

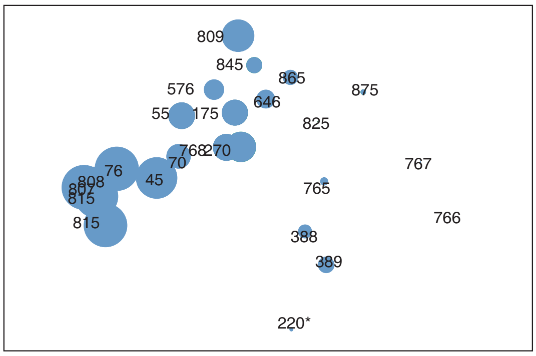

Figure 3.8. MDS plot of the NMMP 2000 coastal macrobenthic dataset and relative percentage silt/clay content of sediment. (Circle size indicates silt/clay content)

Temporal analysis (1997–2001)

Coastal sites in the inner and outer Belfast Lough were analysed for temporal trends because five years data (1997–2001) were available.

In the inner lough there were declining trends in the number of species, abundance, Shannon–Wiener diversity, and AMBI scores. However, the evenness and ITI values showed little change. No trend was apparent in the outer lough. The high faunal abundances in 1997/8 were attributable to dominance by the annelid worms *Cirratulus cirratus*, *Cirriformia tentaculata* and *Mediomastus fragilis*, as well as the amphipod crustaceans *Ampelisca diadema* and *Photis longicaudata*. The presence of these annelids suggested quite high nutrient input, although the ITI value did not reflect this. Populations of these species had diminished considerably by 2001.

Cluster analysis of inner lough data identified five distinct groups, coinciding with the five sampling years (Figure 3.9). Within any one sampling year the 5 replicates were similar but over the five-year period there was a consistent trend as depicted by the arrow.

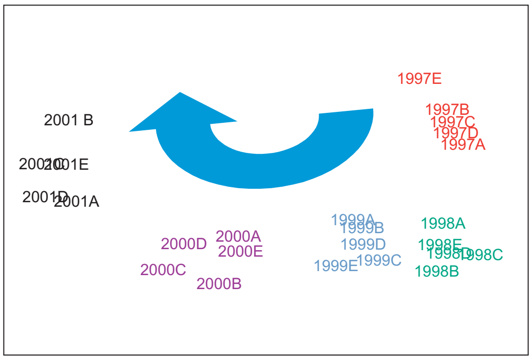

Figure 3.9. Results of multi-dimensional scaling (MDS) analysis of the temporal data for 1997–2001 at the inner Belfast Lough

Table 3.5. Univariate statistics for the number of species (S), abundance (A), Pielou evenness (J'), Shannon-Wiener diversity (H'), trophic index (ITI) and biotic index (AMBI) for Site 845, Belfast Lough from 1997-2001. Data represent mean values per 0.1m²

Year	S	A	J'	H'	ITI	AMBI
Inner Lough						
1997	59.00	3302.00	0.67	2.71	63.67	2.56
1998	66.80	3921.80	0.65	2.72	64.82	1.92
1999	61.40	1804.80	0.62	2.53	58.93	1.75
2000	48.40	994.80	0.68	2.64	65.51	1.40
2001	30.00	420.00	0.68	2.30	56.09	1.21
Outer Lough						
1997	20.20	95.80	0.78	2.29	56.06	0.68
1998	20.00	96.40	0.84	2.46	65.36	0.82
1999	30.60	183.20	0.76	2.58	71.56	0.71
2000	19.60	93.60	0.77	2.26	68.03	0.46
2001	12.40	34.00	0.87	2.18	70.64	0.61

Spearman rank correlation analysis revealed significant correlations between changes in the macrofauna and the sedimentary concentrations of organic nitrogen and organic carbon from 1999 to 2001.

Major human changes in 1997 to 2002 include the cessation of sewage sludge disposal in 1998, with consequent changes at Belfast sewage treatment works, reduction of major discharges from a fertiliser plant, increased dredging activities, and expansion of seabed mussel culture. Although trends were not evident in the outer lough, the benthic trends seen in the inner lough might therefore be related to a general decrease in its nutrient loading. The Belfast Lough case study puts these changes into a wider context. It is acknowledged that this time series is too short to derive authoritative conclusions, but it has been included as an example of the potential future utility of the NMMP.

SPATIAL ANALYSIS OF NMMP ESTUARINE SITE FOR YEAR 2000

Although both estuarine and coastal sites exhibited a wide range of AMBI values, estuarine sites were generally higher, suggesting more stress arising either naturally from salinity change or from human inputs of contaminants, or both.

Estuarine sites with greater diversity, evenness and ITI scores were in areas with small salinity gradients, low mobility of sediment and low organic enrichment. In contrast, high biotic index scores at sites with high abundance of certain opportunistic taxa indicate modified to heavily modified benthic communities (Figure 3.10).

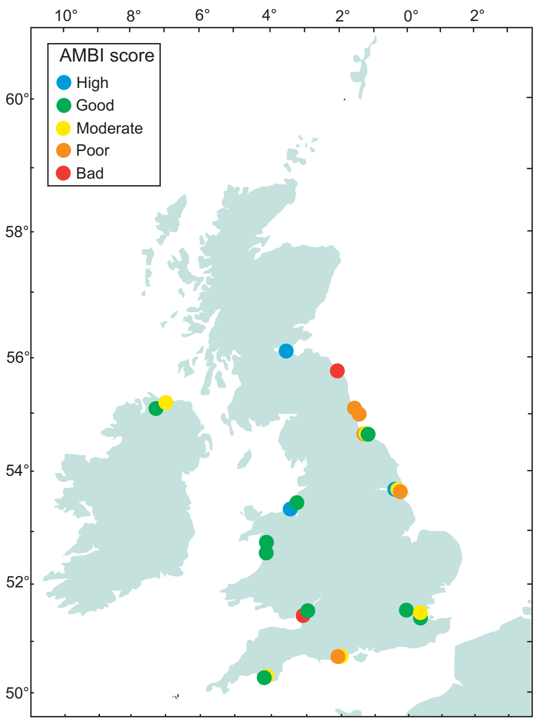

Figure 3.10. AMBI scores coloured by 'class' for the NMMP 2000 estuarine sites

Multivariate analysis

Results from 'group average' cluster analysis indicate six cluster groups, which separate at a similarity level of 17%. These cluster groups are presented on the MDS ordination plot in Figure 3.11.

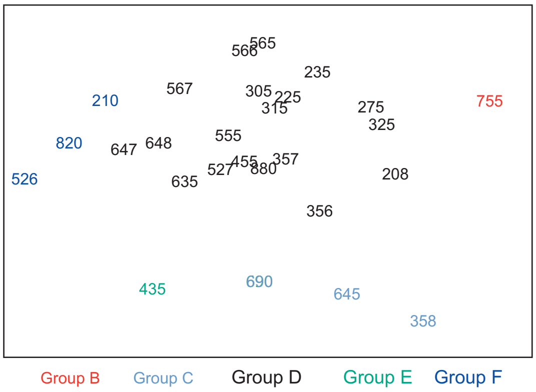

Figure 3.11. Results from multi-dimensional scaling (MDS) analysis of the NMMP2000 estuarine macrobenthic dataset; a fourth root transformation was used. Note: Site 625 is omitted, as it strongly separated from the remaining sites

Group A contains site 625 (Severn, Purton) which has very low diversity and contains only two taxa, one of which is extremely dominant. Group B represents site 755 (Mersey), which appears to have a well-balanced but depauperate community. Group C contains sites with low diversity dominated by one or two species. Group D represents sites with moderate diversity and a heterogeneous sediment environment. Group E represents site 435 (Thames, Woolwich), which has low diversity and is dominated by two oligochaete species. Group F contains sites with low diversity but high densities (> 8000 individuals per 0.1 m^2).

Table 3.6 shows Spearman rank correlation analysis. The correlation data suggest that physical factors rather than contaminants exert the greatest influence on the macrofaunal communities present in the various estuaries around the United Kingdom.

Table 3.6. Summary data indicating those environmental variables with the strongest correlation to the macrofaunal community patterns in the NMMP 2000 estuarine sites

Environmental variable	Spearman rank correlation coefficient
% silt/clay	0.456
Median particle size (Phi)	0.443
% organic carbon	0.193
Cr	0.211
Ni	0.202
Total PAH	0.253
Total PCB	0.188

Summary

The NMMP has not yet been running long enough for the data to be used to assess long-term trends. However, the programme does have considerable future potential for this to develop in the future. This is not least because of the adoption of standard sampling and QA protocols, which should be a major advance in ensuring consistency of data. The limitation discussed above with regard to site selection is scheduled to be addressed in the future.

CASE STUDIES ON LONG-TERM CHANGE

Whilst there are a limited number of programmes to assess benthic status at a national level, there are many local studies that have considered temporal trends in benthic community status, often over extended periods (>10 years). The JNCC commissioned a review of these studies with a view to determining whether it would be possible to derive a national view based on the summation of local schemes (Hiscock and Kimmance, 2003). The JNCC has established a website (http://www.marlin.ac.uk/tmp/jncc/home.htm) in conjunction with the Marine Biological Association, Plymouth to disseminate the results of this review in a user-queryable interactive manner, and to offer the facility for others to register any additional studies that were not captured by the initial review. However, when using such long-term datasets to evaluate changes, it was noted in 1993 that 'there is a paucity of long term data against which to rigorously test data for permissible change. This was due to a combination of insufficient replication and limited continuity in sampling over time' (MAFF, 1993).

SEA DISPOSAL GROUND IN THE NORTH SEA

Annual temporal and less frequent spatial changes in the benthic fauna, and in a range of physico-chemical measures of sediment quality, were examined at a sewage sludge disposal site off the Tyne estuary, UK, both before and after cessation of the activity (Figure 3.12; Rees *et al*., 1992, 2003).

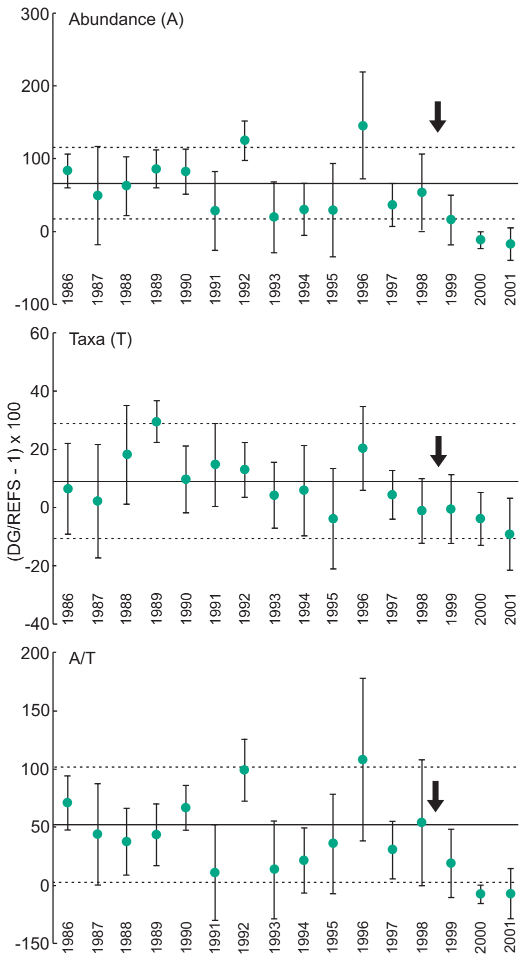

Figure 3.12. Means with 95% bootstrapped confidence limits for pairwise comparisons of univariate measures at the Tyne sewage sludge disposal site (DG) and southern reference station (REFS)

The 'baseline' (solid black line) denotes the average of the ratios for the first three years of sampling, and broken lines define, respectively, the upper and lower boundaries for acceptable departure from the status quo. Vertical arrows indicate the time of cessation of sewage sludge disposal in 1998 (Rees *et al*., 2003). In all cases, the 'baseline' values exceeded zero, indicating marginal enrichment of the fauna at the disposal site at the outset of the investigation (disposal commenced in 1978). Following cessation, the ratios declined toward zero, indicating that, for these measures, the disposal site and reference location were indistinguishable. This case study demonstrates the utility of the benthic fauna as a measure of subtle changes in response to human inputs/activities.

AN INDIRECT ASSESSMENT OF THE STATUS OF BENTHOS IN UK WATERS

It was explained earlier that the UK does not have a structured, coordinated surveillance programme to assess the status of benthic habitats and their associated communities in UK waters as a whole. Consequently, it is not possible to provide a direct assessment of the status of benthos at this time using contemporary data on temporal trends, set against clear environmental objectives and/or targets. It is possible to make an indirect assessment based on our knowledge of the relative impact of anthropogenic activities, together with information on their spatial and temporal distribution and relative intensity.

This indirect approach formed the basis of a series of recent initiatives that have offered an assessment of the status of benthos based on information from a variety of published and unpublished investigations. Studies related to specific pressures have mainly been local in nature and there is little convincing evidence of effects at a regional scale.

Nutrients

On the available evidence, there are no broad scale (regional sea) adverse impacts on the benthos arising from elevated levels of nutrients and organic matter. On a more local scale impacts have been described from a number of areas such as the Ythan Estuary (Raffaelli *et al*., 1989).

Hazardous substances

Similarly, there is no evidence (e.g. via the NMMP) of broad scale impacts on the benthos arising from the placement of hazardous substances. However, the benthos is stressed in local areas, for example due to hydrocarbon exploration and historical placement of dredged material. Studies of the Crouch estuary (Mathiessen et al., 1999) indicate that benthic communities affected by TBT contamination are now showing signs of recovery.

Non-native species

There is good evidence (from a variety of recent and historical studies) for the presence of non-native species in UK waters which may cause modification to natural biodiversity.

Climate change

The occurrence and persistence of non-native species may be linked to climate change. Several studies have identified clear relationships between benthic changes and climatic influences. However, direct evidence of benthic changes driven by anthropogenic climate change is not yet available, although the current MarClim research programme coordinated by the MBA programme will progress this. Hiscock (2004) has described a number of changes around the Lundy MNR which may be related to climate change.

Physical disturbance

There have been a number of targeted studies that have demonstrated impacts at a local level from a variety of factors and there is also some evidence of broader-scale impacts, particularly related to the effects of fishing at the seabed. Studies have concluded that the significance and duration (recovery time) of effects is related to the substratum, the nature of the species present and the nature of activity. Fishing has the largest potential for inducing impacts at a regional scale. Work from both the Irish and North Seas (Frid *et al*., 2000; Ball *et al*., 2000) have described specific impacts, although within these there are likely to be 'hotspots' of activity. Effects may be direct, through habitat damage and direct mortality, or indirect, due to food web impacts.

- OSPAR published a *Quality Status Report* in 2000 (OSPAR Commission, 2000) that comprised regional descriptions and an overview report.

- Countryside Council for Wales, Environment Agency Wales, Forestry Commission Wales and the Welsh Assembly Government published *The State of the Welsh Environment 2003*.

- English Nature published *State of Nature: Maritime – Getting onto an Even Keel* (Covey and Laffoley, 2002).

- Scottish Natural Heritage published *Natural Heritage Trends Scotland in 2001* (Mackey *et al*., 2001), followed by *Natural Heritage Trends: The Seas Around Scotland in 2004* (Saunders, 2004).

- ICES published the *Environmental Status of the European Seas* in 2003.

- The Irish Sea Pilot Project under the Review of Marine Nature Conservation was published in 2004 (Vincent *et al*., 2004).

- Clark and Frid (2001) published a review of studies on temporal trends in different components of the North Sea ecosystem, including benthos.

- Lindeboom and de Groot (1998) edited a report on a multinational study on the effects of fisheries on the benthos of the North Sea and Irish Sea

The following sections will not repeat the text from these documents; rather, it will summarise the main conclusions from some of these reports that relate to the status of marine benthos, where possible on a regional basis. Readers are encouraged to consult these reports directly (*using the hyperlinks where provided*) to gain a complete understanding of their key messages and conclusions.

OSPAR QUALITY STATUS REPORT 2000

The following text sets out the background to the assessments published by the OSPAR Commission. It was taken from the overview report (OSPAR Commission 2000).

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

> *To implement these commitments the OSPAR Commission decided in 1994 to undertake the preparation of Quality Status Reports (QSRs) for five regions of the North-East Atlantic: Region I, Arctic Waters; Region II, the Greater North Sea; Region III, the Celtic Seas; Region IV, the Bay of Biscay and Iberian Coast; Region V, the Wider Atlantic. These regions cover the entire maritime area of the OSPAR Convention. Those regions relevant to the UK are II, III and V. In addition, a single over-view report was published drawing the main conclusions from the regional reports.*

> *These reports describe the natural features of coastal and offshore environments of the OSPAR area and identify impacts arising from human activities. In general, they summarise the information available to mid-1998, focusing in particular on environmental changes and the extent to which these result from human activities, natural variability, or both. Another objective was to identify those gaps in scientific knowledge which currently impede the assessment of the environmental significance of certain activities and conditions and consequently to support management and policy formulation. The various natural processes and human-made pressures on the area are analysed and compared taking into account their severity and scale as well as their long-term significance for the environment, human health, resources and amenities.*

Whilst these reports consider a significantly wider geographic area than the UK seas, most of the main conclusions apply equally to the entire OSPAR area including the UK seas. The following sections cover the main factors relating to the status of benthic habitats and communities in UK seas. One of the long-standing problems in comparing various regional assessments has been the variation in which areas have defined. It should be recommendation that in future effort should be to define functional areas based on biology and hydrography.

Figures in parentheses are related to State of the Sea Areas.

REGION II: THE GREATER NORTH SEA (AREAS 1, 2, 3)

In making a judgement on the status of the North Sea, the authors ranked the human pressures according to their relative impact on the Region II ecosystem, including sustainable use. The following table is an extract showing those pressures in Class A: that is, those with the highest impact.

Class A	Human Pressure Category
Removal of target species by fisheries	Fisheries
Inputs of trace organic contaminants (other than oil and PAHs) from land	Trace organic contaminants
Seabed disturbances by fisheries	Fisheries
Inputs of nutrients from land	Nutrients
Effects of discards and mortality of non-target species by fisheries	Fisheries
Input of TBT and other antifouling substances by shipping	Trace organic contaminants

Benthic assemblages will be affected by all these pressures to some degree, although seabed disturbance and nutrient input will have the most direct effect on benthic species. Nutrient input and eutrophication are now subject to more stringent management through the commitments to the OSPAR process and EC directives (see Human Impacts section). Fishing activity remains largely unregulated, particularly in relation to its spatial distribution and intensity.

The effect of towed fishing gear on the benthos is well documented and comprehensively described by Lindeboom and de Groot (1998). Describing the detailed changes in the benthos as a consequence of fishing is complicated by the long history (more than 100 years) of fishing in the North Sea, and a lack of data from pre-fishing times. The effects of disturbance by fisheries appear to be related to the background level of physical disturbance of the region in the absence of trawling and the size of the benthos. Areas of relatively low natural disturbance typically show greater effects. Whilst the effects of fisheries on larger benthos are consistent, both increases and decreases have been reported in the abundance of small invertebrates in the aftermath of trawling (Lindeboom and de Groot, 1998). In some nearshore cases fishing has led to loss of target populations and changes to the physical structure of the habitat.

Fisheries activity would appear to have the largest spatial extent of the Class A impacts, affecting the virtually the entire North Sea seabed. The Region II report provided a table (Table 5.6) estimating the area of seabed affected by fishing activity. In the conclusions, it stated:

> Of the total beam trawl effort, 80% is conducted *by the Dutch fleet covering about 40% of the area between the Shetland Islands and Hardanger Fjord, and the Strait of Dover. Other investigations show that some areas are visited more than 400 times a year and some not at all. Sediments are turned over each time to a depth of at least 1–8 cm. Tracks may persist for a few hours in shallow waters with strong tides, or for years in the deeper areas. Disturbance of the seabed increases the resuspension of sediments and alters the structure of both soft and hard substrates. Disturbance by demersal gear, including in some areas gear used for catching shellfish, affects biogenic structures that provide a habitat for many organisms, e.g. mussel beds, cold water coral and Sabellaria reefs and seagrass beds. Changes in habitat structure are followed by changes in species assemblages.*

It also recommended:

> Closed areas should also be considered for *the protection of specific benthic habitats and species if identified to be of conservation value, and methods for the effective closure of benthic habitats should be further developed.*

From the information presented in the Region II QSR (North Sea), it is clear that the status of the benthos may be sub-optimal in intensively fished areas, particularly those areas of low natural disturbance and biogenic reefs.

SABELLARIA REEFS

The QSR 2000 drew attention to the fact that 'Most *Sabellaria* reefs in the German Wadden Sea have disappeared. This may be due to fishing activities and the subsequent sediment disturbances caused by trawling and dredging'. *Sabellaria* spp are polychaete worms that construct a protective tube out of sand. These organisms coexist in dense aggregations leading to the construction of large 'reefs' on the seabed.

These reefs tend to stabilise habitats and attract many other species, leading to a large increase in biodiversity. *Sabellaria spinulosa* reefs occur in the UK sector of the southern North Sea with particularly well-developed reefs recorded in the outer Wash and off East Anglia. A large reef has recently been discovered east of the Humberside coast during a survey for a proposed oil pipeline. Video footage of this reef showed some evidence of physical damage that was attributed to fishing activity. These reefs fall within the EC Habitats Directive Annex I habitat 'Reefs', so Member States can designate such areas as SACs. The UK is presently considering whether some of the known reef areas in the southern North Sea will qualify as SACs. These habitats are clearly under threat and their current relatively sparse distribution may be a consequence of the fishing activity in the North Sea.

REGION III: THE CELTIC SEAS (AREAS 5, 6)

Region III encompasses the entire western seaboard of the UK and thus includes a number of 'regional seas' – SW approaches, Bristol Channel and Severn Estuary, Irish Sea, Hebridean Sea. The QSR was based on three 'sub-regional' reports: Ireland's seas, Malin Shelf (Scottish waters) and the Bristol Channel and Irish Sea. There is a huge disparity in the amount of information available for the benthos of these three areas. The Irish Sea and the Bristol Channel have a long history of study including a number of broad scale synoptic surveys. There are many fewer data available for the Scottish coast to the north and west of the Mull of Kintyre; there are more data available for the Clyde Sea area. For obvious demographic reasons, the intensity of anthropogenic pressures and activities on the benthos varies along similar lines to the availability of data. Consequently, the Irish Sea in particular has a long history of study, exploitation and, more recently, marine management initiatives to tackle the impact of anthropogenic pressures on the ecosystem (Irish Sea Pilot Project under the Defra Review of Marine Nature Conservation http://www.defra.gov.uk/wildlife-countryside/ewd/rmnc/)

The OSPAR QSR identified fishing, the presence of endocrine disruptors, concentrations of Tributyl Tin (TBT), coastal development and climate change as 'issues of high importance because of their effects on the whole of Region III and beyond'. For benthos, the report stated:

Because many chemical contaminants tend to be deposited onto the seabed, either through adsorption onto particulate matter or simply by precipitation, benthic species are exposed to higher concentrations (subject to bioavailability) than species in the water column. They also provide the clearest indication of the physical effects of material disposed of at sea, dredging of seabed material and disturbance by fishing gears that are dragged over the seabed.

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

The impact of fishing disturbances on benthic communities and the seabed is very much dependent on fishing intensity, design of the gear and sediment type. It is well known that trawls and dredges towed along the seabed can displace, kill or injure animals that live on the seabed or in the sediment. Large numbers of invertebrates are caught in bottom trawls and discarded. The survival of these discards varies considerably and dead or injured animals provide a food source for benthic scavengers. Repeated disturbance by fishing gear alters benthic communities, causing a reduction in the carried out mainly in the Irish Sea.

In 1994, up to 25%, 22% and 8% of the total area of the Irish Sea seabed was disturbed by otter trawling, beam trawling and shellfish dredging respectively. More recent statistics suggest that fishing intensity may be even greater in the Irish Sea Nephrops grounds which can receive up to five sweeps per year from otter trawls deployed by the Irish fleet alone. This results in a general flattening of the sediment surface due to the collapse and burial of Nephrops burrows and filling in of the openings.

In deep soft muds, the deep tracks (up to 14 cm) left by the trawl doors can persist for prolonged periods, whereas in fine sediments exposed to tidal currents the marks tend to *disappear within 2–3 days. In trials using commercial beam trawls in the North Sea and Irish Sea discard mortality ranged from <10% for starfish (Asterias rubens) and brittlestars (Ophidtrix fragilis) to 90% for the bivalve Arctica atlantica. Most crustacean species and echinoderms with a hard outer shell suffered intermediate levels of mortality. The greater penetration depth of beam trawls compared to otter trawls can result in higher numbers of discarded, non-target invertebrates. However, differences in the total direct mortality due to otter and beam trawling are apparent only in silty areas where the otter trawl penetrates less deeply. Non-target invertebrates, principally crustaceans and molluscs, comprise only 5% of the total catch in Nephrops trawls in the Irish Sea.*

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

In relation to the effects of pollution on the benthos, the report concluded:

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

For the Bristol Channel/Irish Sea/Clyde Sea part of the region, it is clear that the intensity of anthropogenic pressures on parts of the benthic system will have reduced its quality status. Over the Hebridean Sea, the effects of pollution and coastal development will be much less, but there remains a significant level of fishing activity in these areas. In the absence of any surveillance and monitoring programme, we can only speculate that areas subject to intensive demersal trawling fishing activity will also have reduced quality status. The Region III QSR 2000 concludes that for coastal areas:

This [evidence] provides a strong argument for a more integrated approach to coastal zone management that includes the preparation of long-term plans for the use, development and conservation of coastal areas. Such plans are being developed in some areas.

It is apparent that such a process should be extended to the entire sea area – this forms the basis of the Irish Sea Pilot Project.

REGION V: THE WIDER ATLANTIC OCEAN (AREA 7)

Benthic habitats in oceanic areas differ from coastal systems in one very important aspect:

Apart from chemoautotrophic organisms, *below the euphotic zone all living systems depend ultimately on inputs of organic matter sinking or being transported down through*

Ranking	Issue	Degree of concern	Impact potential	Comment
1	Fisheries	High	1 or 2	Clear evidence of impacts on some but not all species and ecosystems
2	Habitat changes	High/Medium	2	Induced by fishing activity and industrial exploitation
3	Hydrocarbons	Medium	2	Tar balls on beaches; environmental impacts limited

the thermocline. All benthic communities in (UK part of) Region V inhabit depths that are too deep for them to be directly supported by photosynthesis.

Benthic community status will be affected by any anthropogenic pressure or activity that disrupts the flow of energy down from surface waters, in addition to any direct disturbance to the seabed. Assessing the status of these areas presents an even greater challenge due to the logistical difficulties in actually sampling the benthos in anything other than a few locations.

Above is an extract of Table 6.1 showing the order of concern regarding regional level impacts within Region V, together with the level of scientific evidence for these impacts. For impact potential, 1: clear evidence, 2: some indications, 3: potential impact.

Physical disturbance to the seabed is clearly highlighted as the most significant concern in Region V, especially in relation to fishing activity:

Open ocean fishes, especially those inhabiting deep water tend to be vulnerable to overexploitation, because they are at the ends of long food chains, are slow growing and have low fecundities. Evidence is beginning to emerge that the sorts of mechanical damage being inflicted upon North Sea benthic habitats and communities by trawling (Lindeboom and de Groot, 1998) is also being inflicted on some of the deeper ecosystems. The initial indications are that these impacts may not only be quite extensive already but may also be more persistent (Figure 5.18). Several core samples and seabed photographs have shown clear signs of disturbance, including plough marks, the burial of sponges, strong odours of hydrogen sulphide and snagged nets (Figure 5.19).

There are no data specific to the Atlantic that indicate how long the scars from trawling persist in deeper water but in the Pacific, an experiment was conducted to investigate the impact of possible seabed mining. This experiment showed that plough marks were still clearly visible after seven years (Thiel and Forschungsverbund TUSHE, 1995) and that the macrofaunal populations still showed clear signs of perturbation (Borowski and Thiel, 1998). The technical challenges posed by the exploitation of deepwater stocks means that they tend to be fished once other more accessible stocks no longer provide adequate returns, either because of overfishing or because quotas have been filled. Thus fishing for the deeper-living species tends to be more intermittent, less predictable and so less manageable than shallow-living stocks.

Furthermore, the report highlighted the issues associated with habitat changes:

There is concern about the clear signs of damage being inflicted by trawling on soft-bottom habitats and biological aggregations centred at depths of around 1000 m. Without baseline data from systematic surveys prior to the exploitation it is impossible to evaluate the extent of any damage caused. Some of the fishing techniques used, particularly trawling, are known to cause severe and probably persistent mechanical damage locally to deep-sea habitats. Signs of mechanical disturbance are frequently noticed during scientific investigations at slope depths of 500–1000 m (although such observations were not the objective of the investigation). Particularly vulnerable are those habitats which are created by biological structures, such as the dense aggregations of sponges (or ostur) and the carbonate mounds created by deep-sea corals. It seems unlikely that all such damage is *accidental; some carbonate mounds are 200 m high and so easily large enough to be detected by sonar. Anecdotal reports that chains have been towed across such features 'to improve' the fishing ground need to be taken seriously, if only to discount them. Habitat changes also result from dumping and the sinking of vessels. However, sunken vessels are the targets of treasure hunters rather than foci for studies to understand the chemical and biological impacts of sunken ships on deep-sea environments and there have been very few assessments of the old dump sites. Those that have been carried out have focused on detecting chemical contamination rather than assessing impacts on the biological communities.*

It is clear that the benthic communities in Region V are subject to adverse anthropogenic pressures and activities but the spatial extent of likely damage is unknown. Effective management of these activities poses a particular challenge since the UK is not the 'competent authority' in a regulatory sense for activities 'on the sea' (fishing). Nevertheless, urgent action is required to regulate these activities since many of the deep sea habitats are particularly susceptible to physical damage.

Seamounts and cold-water corals

Seamounts and cold-water coral reefs are two offshore habitats that are particularly vulnerable to physical disturbance, and have attracted considerable attention in recent years.

Seamounts are important habitats in the open ocean (Rogers, 1994). The summits are often well scoured by currents but the flanks are often inhabited by dense concentrations of suspension feeding benthic species. For benthic species in particular, seamounts function as islands, so there is a high degree of endemism, because the populations of shallow-living species inhabiting the summits are genetically isolated.

In recognition of their vulnerability and the relative lack of information on the status of their biota, seamounts are attracting significant research interest and a number of large multi-disciplinary projects are underway to improve our knowledge (http://www.rrz.uni-hamburg.de/OASIS/Pages/page1.html).

Cold-water coral reefs, often built by Lophelia pertusa, are present in the North-West Atlantic Ocean. These structures result in a three-fold increase in biological diversity compared to surrounding areas of seabed. They form 'biodiversity hot-spots' in oceanic benthic environments. There is evidence that these cold-water coral reefs have already been damaged by fishing activity. The following text is an extract from ICES (2003):

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

Seamounts and cold-water coral reefs both fall within the definition of the Annex I habitat 'reefs' of the EC Habitats directive and qualifying areas can be designated as SACs. The UK is presently investigating these habitats in its offshore area with a view to designating appropriate areas. The Darwin Mounds off NW Scotland is the most advanced in terms of the initial assessment process. One positive development is the introduction of a 'technical measure' by the EC to ban demersal fishing in an area around the Darwin Mounds to try to reduce any further damage to the seabed habitats and associated biota. Nevertheless, there remain many known locations of cold-water coral reefs for which there are no restrictions on demersal fishing and therefore the likelihood of their continued present must be poor.

Within the UK the devolved administrations have each taken their own approach to producing countrywide assessments.

THE STATE OF THE WELSH ENVIRONMENT 2003

A state of the environment report for Wales was published by the Welsh Government agencies in 1999. These agencies updated the information in 2003 to set out changes since 1999. The reports cover all habitats – land and water – so there is limited information on marine benthic systems. Perhaps the strongest message is 'Overall the picture is incomplete and we need better information on the state of the marine environment if we are to tackle its problems', re-emphasising the message presented earlier on the lack of available data to undertake assessments. Welsh Agencies have made significant advances in reviewing available information and implementing site protection for marine habitats. Over three-quarters of the Welsh coastline is designated as being of landscape, wildlife or historic importance – 60% is proposed as candidate Special Areas of Conservation (SAC). The Countryside Council for Wales has invested significant resources into improving our understanding of marine biodiversity:

- All intertidal areas with SAC have been surveyed.
- A further 40% of the Welsh coast has been surveyed to map its habitats, increasing the total coast length surveyed to 76%.
- As part of the marine SAC designation process subtidal sandbanks, sea caves and tide-swept areas in Welsh waters have all been surveyed. This has revealed several rare or scarce species not previously recorded in Wales, such as the mantis shrimp *Rissoides desmaresti* and anemone *Edwardsia timida*.
- A second edition of the BAP Atlas has been produced, providing information on 58 species, 6 species groups and 12 habitats.
- Underwater monitoring techniques have been developed to record potential changes in seabed habitats and species.
- Marine Environment High Risk Areas around the coast have been identified.
- An inventory of coastal and marine locations where biodiversity is vulnerable to pollution has been published.

The 1999 report commented on early signs of habitat and species recovering following the major oil disaster caused by the *Sea Empress* running aground in February 1996 outside Milford Haven. In 2003, habitats and populations of species affected along the 200 km of coast oiled by the spill were considered to have recovered fully.

This report mentions some of the problems associated with the introduction of non-native species:

Japanese wireweed, Sargassum muticum, continues to spread around our coast and other non-native species continue to be introduced by accident. The situation could be exacerbated by climate change, which has seen a rise of the average sea temperatures in coastal and offshore waters by about 1°C since 1970.This is likely to affect species that are at the edge of their range and allow non-native species from warmer seas to establish in Welsh waters. Overall the picture is incomplete, and we need better information on the state of the marine environment if we are to tackle the problems that it faces.

Gathering such information is difficult and expensive. As traffic in Welsh ports continues to rise, so does the risk that ships will introduce non-native species.

Introductions of non-native species to the UK marine environment are an ongoing problem and, in a management context, will prove to be challenging in the implementation of the EC Habitats and Water Framework Directives.

STATE OF NATURE: MARITIME – GETTING ONTO AN EVEN KEEL

English Nature reviewed the status of the maritime environment around the coast of England in 2002. They considered the anthropogenic pressures on the major marine habitats highlighting the key issues of concern, and reviewed the wider impact of coastal development, marine pollution and fisheries. The key issues were:

Habitat	Key issues
Saline lagoons	Loss of existing lagoons through coastal squeeze against sea defences Lack of lagoon creation through interruption of natural coastal processes Poor water and sediment quality as a result of diffuse pollution and/or disrupted water exchange
Estuaries	Poor water and sediment quality from diffuse and some point source inputs Loss of habitats due to coastal squeeze against sea defences Loss of habitats due to inappropriate development and land claim Maintenance dredging, removing sediment and disrupting estuarine equilibrium
Sandy and muddy seashores	Loss of habitat through coastal squeeze and interference with natural coastal processes Sediment extraction in some locations Poor water and sediment quality
Rocky shores	Cumulative habitat loss from development or coastal defences Poor water quality in a number of locations Climate change
Underwater sediments	Fishery disturbance to populations and seabed habitats Poor water quality, leading to sediment contaminant loading Aggregate extraction
Rocky seabed	Fishery pressure on some rocky reefs and delicate plant and animal communities Climate change

There are clearly a number or recurring themes in these key issues. Coastal development is reducing the extent of marine habitats at a greater rate than habitat creation programmes. Poor water quality through land-based pollution is significantly degrading many coastal areas, particularly enclosed bays and estuaries – both habitats are listed on Annex I of the EC Habitats Directive. Fishing activities are degrading benthic habitats and their associated communities, particularly in the North Sea.

English Nature makes the case for changing our approach to managing the marine environment. Traditionally we have adopted a sectoral approach to managing activities where there has been little integration between the sectors. A more integrated approach is required and English Nature describes how an *ecosystem approach management* could deliver improvements to the state of the marine environment. It is important to define the environmental objective for ecosystem management and an associated target. English Nature suggests 'A key target of any new approach must be to reverse the declines in biodiversity and improve maritime environmental quality'. This target is the same as the Göteborg Target set by the EU[1 above]. Establishing an objective with a clear target is however only the first stage – to assess the state of benthos we need to establish appropriate surveillance and monitoring programmes to determine compliance with the target.

NATURAL HERITAGE TRENDS SCOTLAND

Scottish Natural Heritage reviewed the status of all the natural heritage features in Scotland, both on land and in water. The section on marine systems highlighted the relative lack of information for much of Scotland's marine waters, despite significant marine survey activity in recent years. Coastal issues were highlighted in the report's synthesis on marine waters:

At the interface between land and sea, and between fresh and salt water, a considerable amount of European activity is concentrated around the coastal zone. In 1995, the greatest pressures on the coast were urbanisation and transport, agriculture, tourism and recreation, fisheries and aquaculture, industry and energy production. Associated problems included local alterations to the natural balance of erosion and sedimentation, habitat loss and degradation, chemical and organic pollution, contamination by human pathogens, nutrient enrichment leading to algal and phytoplanktonic blooms with deoxygenation and toxic poisoning, bioaccumulation of organochlorine pesticides and PCBs, oil spills from shipping and land-based sources, and environmental and amenity degradation through littering. By 1998 the North Sea was considered to be threatened by overfishing, high nutrient and pollutant concentrations (EEA, 1998).

Much of the population and infrastructure of Scotland are located on or close to the coast. By the late 1990s it has been estimated that around 10% of Scotland's coastline was affected by intensive urban or industrial use, although the visual impact and perception of development can be greater. Land-claim has historically resulted in losses of intertidal mudflats: by as much as 50% within the inner Forth estuary (upstream of the Forth Road Bridge) over the past two centuries. High nitrate levels have a greater impact on marine and coastal waters than fresh water. Excessive growth of green algae in the River Ythan estuary, to the north-east of Scotland, has formed extensive, dense mats which have caused changes to invertebrate communities living in the mud (SEPA, 1999). In 2000 the catchment was designated a Nitrate Vulnerable Zone, requiring reductions in water pollution from agricultural sources. However, since the 1970s some of the most polluted parts of the Forth and Clyde estuaries and their tributaries have been considerably cleaned up, resulting in recolonisation by invertebrates and fish. Whilst improvements to water quality continue, bathing water quality has not yet fully achieved mandatory compliance for all identified bathing waters, with 85% compliance in 2000 (SEPA, 2000). Within the clean, sheltered waters of the west coast and Northern Isles, fish farming expanded in the 1980s. Whilst marine survey coverage has increased greatly in recent decades, the extent, abundance, status and ecology of most marine habitats and species remain poorly known. An exception is the commercially exploited fish species. By 2001, most commercial fish species in the seas around Scotland, including some deepwater species, were in decline and outside of safe biological limits.

Assessing the status of the Scottish marine waters, particularly those off the north and west coast, is probably one of the biggest challenges due to their remote and relatively inaccessible nature and the difficulties that this creates in monitoring the intensity of human activities such as fishing.

Natural Heritage Trends: The Seas around Scotland (Saunders *et al.*, 2004)
In 2004 Scottish Natural Heritage reviewed the status of the seas around Scotland, highlighting a relative lack of information for much of Scotland's marine waters.

This report brings together details based on the best information available on natural heritage trends in the Scottish marine environment.

Issues relating to the use of the sea were highlighted. Fish farming has raised various issues concerning the release of therapeutic medicines and the extent of organic deposition. The growth of the industry has prompted concern about the effects of nutrients over wider areas and, although there is little relevant hard evidence, this will receive more attention in the future.

Currently, almost all sea lochs with conditions suitable for mariculture have at least one installation, prompting concerns about localised impacts on the sea bed, aesthetic degradation of the landscape, nutrient enrichment of coastal waters and interactions with wild populations. Salmon farming in particular has attracted criticism, with concerns over disease outbreaks and interactions with wild salmon populations (Baxter and Hutchinson, 2002).

A section on quality of the marine environment highlighted issues in relation to non-native species and environmental change:

Of 24 non-native species which have been identified in Scottish waters, twelve are algae (three diatoms), one an anemone, one a polychaete worm, five are crustaceans (including two barnacles), four are molluscs and one is a sea squirt. Many are reported to have spread rapidly in Scottish waters, some becoming established over large areas. The effects of introduced species on their host environment can include competition with native species for food and space, habitat alteration, changes in water quality, alteration of the gene pool through hybridisation, predation and the transmission of disease or parasites.

Enclosed areas of sea bed, such as in sea lochs, may experience greater seasonal impacts from deoxygenation due to increased thermal stratification, or temperature layering. This inhibits the distribution of oxygen throughout the water column and thus depletes its availability at the sea bed.

An examination of the possible effects of currently predicted rises in sea and air temperature on the distribution of marine species and communities was undertaken by Hiscock et al. (2001). They concluded that species losses over the next 100 years would be restricted to a small number of northern species currently at their southern limit. Warming may increase the diversity of Scottish seabed communities owing to an influx of a greater number of southern species.

The conclusion to the report discussed that despite Scotland's seas supporting a wide range of marine habitats and species, these have been subject to a multitude of pressures and without improved knowledge, care and long-term commitment to their protection, they could be irreparably damaged. In general, the overall level of coastal development is low and in many areas has declined steadily over a period of perhaps 30 years.

ICES ENVIRONMENTAL STATUS OF EUROPEAN SEAS

ICES describes the marine benthic habitats and their associated communities in the European seas, highlighting those habitats that are considered uncommon and/or threatened. The section concludes with a short section considering recent changes in the North Sea ecosystem, noting the apparent shift in the benthic community from long-lived species to more opportunistic species. It is not clear what factors caused such changes, but at the scale of the whole North Sea, climatic changes, fishing and eutrophication are thought to be primarily responsible for many of the long-term changes. The report then provides evidence for the effects of human impacts on marine biodiversity with sections on climate change, fisheries, nutrients and eutrophication, harmful algal blooms, contaminants and their effects, the oil and gas industry, shipping and transport and coastal zone issues, including marine aggregate extraction. The issues most relevant to benthic communities were:

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

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

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

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

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

Oil and gas industry: Impacts of oil and gas extraction
Drilling muds – These cuttings contain contaminants and, especially where oil-based fluids have been used, are potentially toxic to marine life. While the fields have been in operation, this has caused only localised disturbances close to the platforms, as shown by changes in benthos communities.

Shipping and transport: Impacts of ballast water introductions
Taking the UK as an example, it is estimated that at least 15 species of seaweeds, five species of diatoms, one flowering plant and 30 invertebrate animals are non-native marine species that have become established in UK waters. Of these, 18% of introductions are definitely attributable to ballast water or via fouling on ships' hulls. Many other species will have been transported but were unable to become established (populations).

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

ICES felt that it was inappropriate to rank human activities according to their relative impact on marine ecosystems and so presented a series of key messages. The following are considered to be most appropriate to marine benthos:

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

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

SUMMARY

The key messages that emerge from these indirect assessments are:

- Benthic communities may be severely affected by fishing activity, particularly those communities that are not subject to natural environmental disturbance. However, the spatial distribution of fishing effort and methods is patchy, as is the distribution of those benthic communities affected by this activity.

- There is an urgent need to establish a process to gather data for the wider marine environment – both existing data and new data – and to develop nationally agreed indicators or assessment measures to properly assess the status of benthic communities.

- Human activities should be considered in an integrated manner to assess the overall anthropogenic impact on marine benthic ecosystems, and to contribute to a more holistic, ecosystem approach to management.

PROGRESS AGAINST OBJECTIVES

At present, the concept of establishing environmental objectives in relation to benthic communities is an emerging process and there are few formalised objectives established. The following table summarises the progress against the known objectives:

Source	Objective	Progress
Defra Marine Stewardship Report	Clean, healthy, safe, *productive* and *biologically* diverse oceans and seas	Insufficient information or appropriate tools to make an assessment at the level of UK Seas.
EC Habitats Directive	Benthic feature should achieve *Favourable condition* at each SAC; Benthic feature should attain *Favourable conservation* status in UK	Monitoring the status of Special Areas of Conservation (SACs) started in 2000 and is an on-going activity. Monitoring must be complete by the end of 2006 and the first report on status is due in early 2007
EU Water Framework Directive	Good ecological status for all water bodies by 2015; the status of quality elements should not decline: a water body at *high* status that declines to *good* status will not meet the objective	The WFD was transposed into national legislation in December 2003. The first broad assessment of status is due in 2006.

Source	Objective	Progress
OSPAR EcoQO	Benthic communities: the density of sensitive and opportunistic species Threatened and declining species: Presence and extent Neither of these objectives are formalised	There is an ICES working group that will consider the sensitive and opportunistic species in late March 2004. There are no surveillance or monitoring programmes in place to collect data to assess these EcoQOs
OSPAR Joint Assessment and Monitoring Programme (JAMP)	Objectives for habitats and species: BA-1 An assessment in 2005 of the pilot project on ecological quality objectives for the North Sea BA-2 An assessment in 2006 of the status of the species and types of habitats that have been placed on the OSPAR List of threatened and/or declining species and habitats; BA-3 An assessment in 2006 of the changes in the distribution and abundance of marine species in relation to changes in hydrodynamics and sea temperature; BA-4 A further assessment in 2009 of the status of the species and habitats that have been placed on the OSPAR List of threatened and/or declining species and habitats	The JAMP was agreed in 2003 but it is not clear how the assessments will proceed. UK does not have any surveillance or monitoring programmes in the wider environment (beyond NMMP) to provide data to make these assessments.
Göteborg Target set by the EU	Biodiversity decline should be halted with the aim of reaching this objective by 2010	It is not clear how this objective will be assessed, particularly in relation to the lack of surveillance and monitoring programmes in the wider marine environment.

Overall, the UK is taking appropriate measures to undertake the assessments against the objectives of the European Directives. However, it is not clear at present how the UK will contribute to the broader targets agreed through International Conventions and Agreements, particularly in areas away from the coast in the wider offshore parts of UK seas.

Despite some of the local specific issues raised above, which will continue to require attention, the general conclusions about the state of the UK benthos are:

- U.K. Marine Communities are conspicuous for their variety and frequently high biodiversity
- They may be ranked as among the most important in any contemporary Europe-wide assessment
- The marine biota respond in various ways to climatic events, trends and direct human influences and benthic communities are ideal indicators, as well as having intrinsic value in an ecosystem context
- Assessments continue to be inhibited by the absence of synoptic survey data covering the entire UK shelf sea area and the limited maintenance and coordination of time series data.

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4. State of cetaceans

KEY MESSAGES

The key messages to emerge from the following section considering the different aspects of the status of cetaceans in UK seas are:

- **Of the 28 species of cetacean that occur, only about 10 are commonly recorded in UK waters.**
- **Strategic, systematic monitoring *sensu strictu* of cetacean populations needs to be carried out at a UK-wide scale. It is therefore not possible to report on trends in the status of cetacean populations.**
- **Baseline data for future surveillance of cetacean populations should be collected through enhanced coordination of cetacean sightings programmes, special projects (such as SCANS II), and via development of the Joint Cetacean Database project.**
- **The UK needs to continue to maintain current surveillance of cetacean populations to determine trends.**
- **No indicators of state have yet been determined for UK cetacean populations and as yet there are no reliable methods of using sightings data to establish population trends.**
- **The UK needs to develop statistically robust methods to monitor cetacean density at appropriate geographical scales.**
- **There are three Special Areas of Conservation (SACs) containing bottlenose dolphins in the UK. Two areas in UK waters, the Moray Firth and Cardigan Bay, have been identified that have semi-resident groups; both these localities have been selected as SACs. The Lleyn Peninsula and the Sarnau SAC in Wales list bottlenose dolphins as a qualifying feature but not the primary reason for site selection.**
- **Although no sites have yet been proposed for harbour porpoises, the UK is actively considering doing so.**
- **Assessments to give an indication of status under the requirements of the EC Habitats Directive have not yet been carried out. There is a target to assess and report on these by 2006. There is therefore currently no information available on the status of bottlenose dolphins (*Tursiops truncatus*) at Special Areas of Conservation (SACs).**
- **Ecological Quality Objective (EcoQO): The UK and other signatory states are committed to reduce porpoise bycatch to less than 1.7% of the best available estimate of abundance for major fishing areas in the short term.**

INTRODUCTION

The nature of the marine environment and of cetaceans themselves renders the study of these animals in their natural habitats extremely difficult. The extent of UK continental shelf waters, allied to the fact that cetaceans usually break the surface of the sea only briefly, means that comparatively few data exist on their distributions and abundance. Until recently, no UK-wide, coordinated approach to the recording of cetaceans sightings had been established. The publication of an atlas of cetacean distribution in north-west European waters (Reid *et al*., 2003) saw the amalgamation of three separate cetacean databases into one Joint Cetacean Database (JCD); this database represents the most up-to-date statement on the distribution and relative abundance of all 28 species recorded in UK waters in the latter part of the 20th Century.

The JCD comprises two long-term datasets and one 'snapshot' dataset. The former include the Sea Watch Foundation database, comprising effort-related sightings data collected since 1973, and the European Seabirds at Sea database, established and maintained by the Joint Nature Conservation Committee and comprising effort-related data collected since 1979. These are complemented by data from the only large-scale survey in (part of) UK waters that has aimed to assess the absolute sizes of small cetacean populations, the Small Cetacean Abundance in the North Sea (SCANS) survey conducted in June/July 1994 (Hammond *et al*., 1995; Hammond *et al*., 2002).

Several other datasets exist that might be combined with the JCD, but these are all relatively small-scale, cover restricted parts of UK waters (e.g. various Iceland/Norway/Faroe surveys that have covered wide areas of the North-East Atlantic, but not much in UK 200 nautical mile waters), or span fewer, more recent years. They also include records made from vessels conducting seismic surveys (e.g. Stone, 2003). In addition, studies using deep-sea hydrophones have shown the existence of the large whales in waters west of UK throughout the year, with some seasonal patterns.

CURRENT STATUS

Of the 28 species (see Table 4.1) that may occur over and just off the UK continental shelf, only about 10 are commonly recorded, while the others occur infrequently but not necessarily irregularly (Reid *et al*., 2003). The total species complement is comparable to other areas at the same latitude and represents a diverse assemblage of this group.

Population estimates exist for a few species at something more than a local scale. Line transect surveys in the early 1990s produced estimates for: *Lagenorhynchus* dolphins in the North Sea and Celtic Sea; for minke whales (*Balaenoptera acutorostrata*), the white-beaked dolphin (*Lagenorhynchus albirostris*), and the harbour porpoise (*Phocoena phocoena*) in the North Sea; and for the short-beaked common dolphin (*Delphinus delphis*) in parts of the Celtic Sea and an adjacent offshore area (Hammond *et al*., 2002; Goujon *et al*., 1993). In addition, population estimates exist for the Moray Firth (Wilson *et al*., 1997), Cardigan Bay (Lewis, 1992; Arnold *et al*., 1997; Evans, *et al*., 2002) and Channel populations (Liret *et al*., 1998) of the common bottlenose dolphin (*Tursiops truncatus*), and for Risso's dolphin (*Grampus griseus*) in the north-western Minch based on capture recapture or individual photo-id methods.

For the Moray Firth, the data suggest a stable bottlenose dolphin population (Thompson *et al*., 2004). For no other species or population is there any reliable information on trends in population size.

Current research includes dedicated cetacean surveys, such as photo-ID studies that are carried out at various locations around the UK annually, notably in the Northern Isles, Inner Hebrides and off south-west Wales. Opportunistic data are also collected throughout UK continental shelf waters. Strategic, systematic monitoring *sensu strictu* of cetacean populations is not carried out at a UK-wide scale. Enhanced coordination of cetacean sightings programmes, via development of the JCD project, should be established in order to define appropriate baseline information for future surveillance of cetacean populations.

Table 4.1. Status of cetacean species occurring in UK waters

Species	Common and regularly recorded over/ near UKCS?	Population estimate for UK/ adjacent waters?	Date of estimate
Northern right whale *Eubalaena glacialis*			
Humpback whale *Megaptera novaeangliae*			
Minke whale *Balaenoptera acutorostrata*	✓	c. 8,500 (95% CI: 5,000-13,500) in the North Sea, Celtic Sea and Skagerrak (Hammond *et al*., 1995)	1994
Sei whale *Balaenoptera borealis*			
Fin whale *Balaenoptera physalus*			
Blue whale *Balaenoptera musculus*			
Sperm whale *Physeter macrocephalus*	✓		
Pygmy sperm whale *Kogia breviceps*			
Cuvier's beaked whale *Ziphius cavirostris*			
Northern bottlenose whale *Hyperoodon ampullatus*			
True's beaked whale *Mesoplodon mirus*			
Gervais' beaked whale *Mesoplodon europaeus*			
Sowerby's beaked whale *Mesoplodon bidens*			
Blainville's beaked whale *Mesoplodon densirostris*			
Beluga or White Whale *Delphinapterus leucas*			
Narwhal *Monodon monoceros*			
Common bottlenose dolphin *Tursiops truncatus*	✓	c. 130 in the Moray Firth (Wilson *et al*., 1997); c. 130-350 in Cardigan Bay (Lewis 1992, Arnold *et al*., 1997); c. 85 in the Channel, including north-west France (Liret *et al*., 1998)	Various
Striped dolphin *Stenella coeruleoalba*			

Table 4.1. (continued) Status of cetacean species occurring in UK waters

Species	Common and regularly recorded over/ near UKCS?	Population estimate for UK/ adjacent waters?	Date of estimate
Fraser's dolphin *Lagenodelphis hosei*			
Short-beaked common dolphin *Delphinus delphis*	✓	c. 75,500 (95% CI: 23,000-249,000) in Celtic Sea (Hammond *et al*., 1995) and c. 62,000 (95% CI: 35,500-108,000) in adjacent Atlantic waters (Goujon *et al*. 1993)	1994 1993
White-beaked dolphin *Lagenorhynchus albirostris*	✓	7,856 (95% CI: 4,032-13,301) in the North Sea and Channel (Hammond *et al*., 1995)	1994
Atlantic White-sided dolphin *Lagenorhynchus acutus*	✓	No data available	N/A
Combined *Lagenorhynchus* species	✓	c. 11,760 (95% CI: 5,867-18,528) in the North Sea, Celtic Sea and Baltic Sea (Hammond *et al*., 1995)	1994
Risso's dolphin *Grampus griseus*	✓	At least 142 in the northwestern Minch (Atkinson *et al*., 1999)	1999
Melon-headed whale *Peponocephala electra*			
False killer whale *Pseudorca crassidens*			
Killer whale *Orcinus orca*	✓		
Long-finned pilot whale *Globicephala melas*	✓		
Harbour porpoise *Phocoena phocoena*	✓	c. 280,000 in the North Sea (Hammond *et al*., 1994)	1994

Strandings of cetaceans around the coasts of Britain are recorded and summarised by the Institute of Zoology (England and Wales) and the Scottish Agricultural Centre's Veterinary Investigation Centre (Scotland); see http://www.defra.gov.uk and http://www.nhm.ac.uk. This scheme yields much valuable information on the basic biology and pathology of UK cetacean species. However, strandings data are imprecise and imperfect indicators of the population status or trends of cetaceans; nor are they necessarily indicative of wider ecosystem health.

INDICATORS OF STATE

No indicators of state have yet been determined for UK cetacean populations and as yet there are no reliable methods of using sightings data to establish population trends. For Special Areas of Conservation (SACs) for bottlenose dolphins, conservation objectives will be established as part of the Joint Nature Conservation Committee's Common Standards for Monitoring programme. Draft guidelines suggest that the number of animals using the SAC should be stable or increasing, and this will require monitoring of these populations. How this might be done for the Moray Firth has been addressed by Thompson *et al*. (2004) and for Cardigan Bay by Evans and Baines (2004).

For bottlenose dolphins and for other species of cetaceans, a primary problem is that trends in sighting rates or in estimates of abundance or density for specific areas may be obscured by shifts in distribution. There is as yet insufficient information on population distribution and differentiation to be clear about the significance of changes in abundance at a local or even a regional scale where cetaceans may disperse across very large marine areas.

PROGRESS TOWARDS ENVIRONMENTAL OBJECTIVES

Existing environmental objectives for cetaceans are established at a European level. Most of these relate to bycatch – the accidental capture of cetaceans during fishing operations. This is almost certainly the most important direct anthropogenic impact on cetaceans in the region.

The UK is a party to the Agreement on the Conservation of Small Cetaceans of the Baltic, North-East Atlantic and North Sea (ASCOBANS). An international workshop convened jointly by the International Whaling Commission and ASCOBANS modelled the effects of bycatch on populations of harbour porpoises and found that an unacceptable interaction would occur if bycatches represented more than 1.7% of the best estimate of abundance. No similar work has been carried out on other cetaceans, including common dolphins, although such work is currently planned under the EU funded NECESSITY project. The UK is required under the EC Habitats Directive (92/43/EC) and the EC Council Regulation 812/2004, laying down measures concerning incidental catches of cetaceans as with all other EU member states, to introduce a system to monitor the incidental capture and killing of all cetaceans.

Efforts have focussed on identifying those fisheries most likely to have effects on cetaceans at the population level, and on ways of reducing bycatch in those fisheries. Two key pieces of information are required to enable the first of these objectives. The first is an estimate of the numbers of animals being caught and the second is an estimate of the size of the population to which those animals belong. From a conservation (i.e. population level) standpoint, a bycatch of a certain size from a small population of cetaceans would be more serious than the same number caught from a large population.

The levels of monitoring that are required to be sure that estimates of bycatch rate are effectively determined were addressed by the Sea Mammal Research Unit (SMRU) and the Research Unit for Wildlife Population Assessment (RUWPA; Northridge and Thomas, 2003) at St Andrews University. Estimates of cetacean abundance by large-scale survey were last made in 1994 (Hammond *et al*., 2002) Bycatches of harbour porpoises in gillnet fisheries in the North Sea and on the Celtic shelf to the south-west of Britain exceed 1.7% of the best abundance estimates. Worldwide research shows that the most promising technique to reduce bycatch in gillnet fisheries (other than the cessation of fishing) is the use of acoustic deterrents ('pingers') attached to nets. These appear to be effective in producing high-frequency sound that deters harbour porpoises from approaching nets. Field trials of pingers have been successful, but concerns about the reliability of some models still remain, and further trials of reliability coordinated by SeaFish are under way.

ECOLOGICAL QUALITY OBJECTIVES (ECOQOS)

Under the Oslo–Paris Convention (OSPAR), several Ecological Quality Objectives (EcoQOs) for the North Sea have been formulated. The UK and other signatory states to ASCOBANS, are committed to reduce porpoise bycatch to less than 1.7% of the best available population estimate for major fishing areas in the short term. This target is also recognised by the OSPAR Commission and has been established as an EcoQO. The UK has a national plan to minimise porpoise bycatch, and an EU Regulation also supports the same objective.

HABITATS DIRECTIVE

The common bottlenose dolphin (*Tursiops truncatus*) and the harbour porpoise (*Phocoena phocoena*) are listed on Annex II of the Habitats Directive, so member states are required to select Special Areas of Conservation (SACs) for their protection. Such sites will be proposed only where there is a clearly identifiable area representing the physical and biological factors essential to their life and reproduction (Article 4.1). Monitoring options are currently being developed for bottlenose dolphin candidate SACs (Evans and Baines, 2003). The available distribution data for bottlenose dolphin do not readily indicate that there are other areas offshore (beyond 12 nautical miles) where the species aggregates, and which might be essential for its survival and reproduction.

The European Commission recommended that areas important for the harbour porpoise should be identified on the basis of: (1) the continuous or regular presence of the species (although subjected to seasonal variation); (2) good population density (in relation to neighbouring areas); and (3) a high ratio of young to adults during certain periods of the year. JCD data have been analysed in order to evaluate whether areas can be identified for this species using these criteria. However, to date no site has been proposed for firm SAC classification.

Harbour porpoise are listed as ‘D grade’ in a number of SACs around the UK. This means that they are present in these areas but are categorised as a ‘non-significant population’ under the selection criteria in accordance with Section B of Annex III of the Directive; consequently, conservation objectives have not been set for these populations. This reflects the relative importance of these populations at the sites, but the lack of data does not support their listing at a higher grade.

There is currently little information available on the status of bottlenose dolphin (*Tursiops truncatus*) populations in SACs in the UK. Progress to date has involved the development of a number of tools to assist in assessing the current status of Marine SAC interest features. Assessments will be undertaken over the next two years to fulfil the requirements of the *EC Habitats Directive*. These SACs must be assessed and the results reported on by 2006.

Under Annex IV of the Habitats Directive all cetaceans are deemed to be species of community interest in need of strict protection and as such must be maintained at a favourable conservation status. Conservation status will be taken as ‘favourable’ when:

- population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and
- the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and
- there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

These objectives are not easy to address in relation to cetaceans and little progress has yet been made as to how they may be addressed. Wider measures to conserve favourable conservation status have been addressed through a Council Regulation laying down measures concerning incidental catches of cetaceans in fisheries and also an amending regulation (EC) No. 88/98. This regulation completes the response to scientific advice by providing additional measures to address the incidental catches of cetaceans in fisheries.

These measures include:

- restrictions on the use of drift-nets in the Baltic Sea and phasing out before 1 January 2008
- the mandatory use of acoustic deterrent devices in certain fisheries, and
- coordinated monitoring of cetacean bycatch through compulsory on board observers for given fisheries.

There remains much work to be done to develop reliable indicators of population status for cetaceans and future monitoring programmes will provide important contextual information against which an overall assessment of the state of cetacean populations can be made.

Further recommendations for research include the need for fishing gear research and development, for regular surveying of cetacean populations to determine trends, including a large-scale survey (SCANS II); and a certification scheme to label fish caught for the consumer market as 'cetacean-friendly'.

Under the proposed SCANS II project, statistically robust methods will be developed to monitor cetacean density at appropriate geographical scales. The Joint Nature Conservation Committee will continue to maintain the current surveillance programmes on cetaceans.

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5. State of seals

KEY MESSAGES

The key messages to emerge from the following section considering the different aspects of the status of seals in UK seas are:

- **The UK holds 39% of the world's population of grey seal; 90% of British grey seals breed in Scotland.**
- **Grey seal population has grown steadily since the 1960s to an estimated maximum population of 123,000 in 2002.**
- **Grey seal pup production increased steadily from 1984–1996, and has remained broadly static since 2000.**
- **The UK holds approximately 40% of the world population of the European sub-species of common seal. Total population estimate is 50–60,000, 5% of the world's population.**
- **Currently there is one Ecological Quality Objective (EcoQO) for seals: seal population trends in the North Sea. Further analysis of existing data collection could establish and report against this Ecological Quality Objective (EcoQO).**
- **The UK has selected 11 Special Areas of Conservation (SACs) for common seals and 11 Special Areas of Conservation (SACs) for grey seals under the EC Habitats Directive.**
- **No current assessment of SAC status is available although mechanisms are being implemented to report the status of seal features at the end of 2006.**

INTRODUCTION

Under the Conservation of Seals Act 1970, the Natural Environment Research Council (NERC) has a duty to provide scientific advice to government on matters related to the management of seal populations in the UK. NERC has appointed a Special Committee on Seals (SCOS) to formulate this advice so that it may discharge this statutory duty.

Formal advice is given annually based on the latest scientific information provided to SCOS, mainly by the Sea Mammal Research Unit (SMRU). This advice includes an assessment of seal populations, diet, behaviour, epidemiology and habitat use. The annual assessment of seal populations includes information from surveys conducted by SMRU that are concentrated mainly in Scotland, as well as counts from the Countryside Council for Wales and Dyfed Wildlife Trust in Wales, the National Trust at the Farne Islands and Lincolnshire Wildlife Trust at Donna Nook.

The Grey seal (*Halichoerus grypus*) and Common seal (*Phoca vitulina*) are listed on Annex II of the EC Habitats Directive, thereby requiring member states to designate sites for their protection. The UK has designated 22 Special Areas of Conservation (SACs) for seals (Figures 5.4 and 5.5). The status of seal populations on these sites must be assessed every six years, and will next be reported in 2007.

GREY SEAL (*HALICHOERUS GRYPUS*)

The grey seal *Halichoerus grypus* is the larger of the two resident species in the UK. Adult males may weigh 350 kg and grow to over 2.3 m in length. Females are smaller at a maximum of 250 kg in weight and 2 m in length.

Grey seals feed at sea but return regularly to haul out on land to rest. Individual seals will often move repeatedly between a haul-out and a foraging location spending several days at each during each cycle. Haul-outs are occupied for longer during moult. Haul-out sites can be on rocks, tidal sandbanks or shingle.

Typical breeding habitat is on isolated islands where there is easy access from the sea to grass sward or dunes above the high tide level. Grey seals also breed in smaller numbers on exposed rocky coasts and in caves but occur in most coastal habitats at other stages of their life cycle. They form polygynous breeding groups, but the size of the groups and the sex ratio varies with the nature of the habitat and location. The breeding season occurs earliest in south-west Britain where pups are born from August to October. The timing of births becomes progressively later in a clockwise pattern around Britain, with the peak of births during mid–late September in Wales, mid-October in west and north Scotland and early December at the Isle of May (Firth of Forth) and the Farne Islands. At Donna Nook, in Lincolnshire, pups are born primarily in November and December. The largest concentrations of breeding grey seals are in the Hebrides and the Orkney islands.

Female grey seals give birth to a single white-coated pup, which is weaned after 17 to 21 days. Pups moult their white 'lanugo' pelage towards the end of lactation. Mating also occurs towards the end of lactation and after weaning females leave the breeding colony. Pups then remain on the breeding colony for up to two weeks before departing to feed at sea. There is no parental care for the pups after weaning.

COMMON SEAL (*PHOCA VITULINA*)

The common seal *Phoca vitulina* (also known as the harbour seal) is the smaller of the two resident species in the UK, reaching a length of up to 1.85 m and weighing up to 130 kg (both measurements for adult males; females are slightly smaller). Common seals are found all round the UK coast but the greatest numbers are in the Hebrides and the Orkney islands. They tend to occupy more sheltered waters than grey seals but can also move up to 100 km offshore to feed. Common seals require suitable haul-out sites where they can rest, moult and give birth and raise their pups. In most areas they tend to haul out at low tide on intertidal sandbanks, skerries or beaches. Adult females give birth to a single pup between late May and early July. Pups are born without a white coat and can swim almost immediately. They are weaned after about 4–5 weeks. Mating occurs soon after weaning and occurs in the water where males hold aquatic territories. Common seals differ from grey seals in that they do not aggregate into discrete colonies to breed. The dispersed nature of the breeding groups and the fact that pups are able to swim within hours of birth means that pup production is difficult to estimate. Females with pups can be very widely dispersed and some pups may be at sea with their mothers at the time of surveying.

CURRENT STATUS

There are a number of sites around the UK designated for the conservation of grey and common (or harbour) seals.

GREY SEAL (*HALICHOERUS GRYPUS*)

Figure 5.1 shows the main breeding sites of grey seals around the UK. Some sites have been designated as Special Areas of Conservation (SACs) to ensure coverage of the geographical range of breeding in the UK. The sites recommended for selection contain a significant proportion of the UK breeding population of grey seals but they also contain examples of small populations at the extremes of the breeding range, e.g. in Wales and at Donna Nook.

About 39% of the world population of grey seals is found in Britain, with over 90% of British grey seals breeding in Scotland – the great majority in the Hebrides and in the Orkney islands (SCOS, 2003).

There are also breeding colonies in Shetland, on the north and east coasts of mainland Britain and in south-west Britain. The total number of grey seals in Britain has grown steadily since the 1960s when records began (Figure 5.1). In 2002, there were between 97,900 and 123,000 grey seals. There is increasing evidence that the population is beginning to stabilize (SCOS, 2003).

Figure 5.1. A map showing the main breeding sites of grey seals around the UK. There are further, smaller, dispersed breeding sites around the coasts of Cornwall and Wales

Trends in grey seal pup production

The number of pups born in a seal population can be used as an indicator of the size of the population. About 85% of the pups born throughout Britain are surveyed annually. The total number of seals associated with the regularly surveyed sites is estimated by applying a population model to the estimates of pup production.

Estimates of the total number of seals at other breeding colonies that are surveyed less frequently are then added in to give an estimate

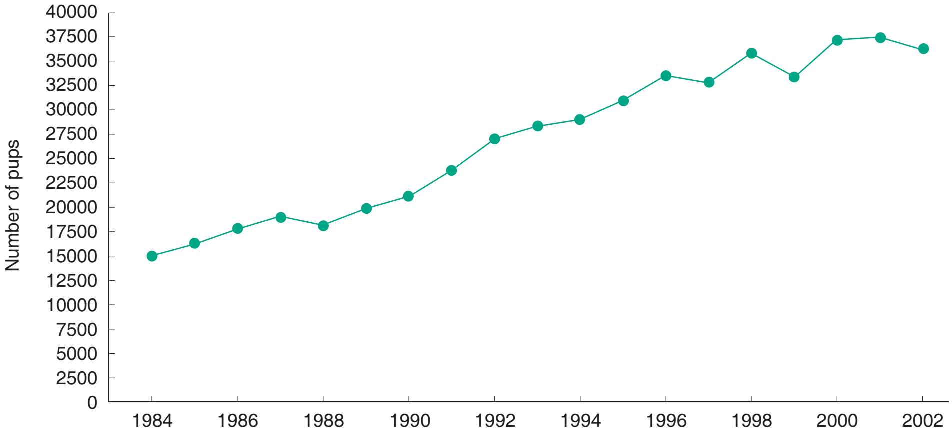

Figure 5.2. Total estimated grey seal pup production for all major breeding colonies in Scotland and England (excluding Loch Eriboll, Helmsdale and Shetland) from 1984 to 2002. Estimates are within ±14% of the point estimates (SCOS, 2003)

of the total British grey seal population. For the Scottish colonies and the Farne Islands time series of annual pup production estimates are 20–40 years in duration. Further details are given in SCOS (2003).

Between 1984 and 1996, estimates of the total number of pups born at regularly surveyed colonies increased year on year (SCOS, 2003). In 1997, estimated pup production fell for the first time but recovered again in 1998 in line with the previously observed upward trend. However, there was a second temporary decline in 1999 followed by a recovery in 2000. Pup production remained nearly static between 2000 and 2001 and showed a small decline in 2002 (Figure 5.2). This variation demonstrates that the trend in pup production is not linear and that density dependence is having an effect on pup numbers.

COMMON SEAL (*PHOCA VITULINA*)

Common seals are found around the coasts of the North Atlantic and North Pacific from the sub-tropics to the Arctic. Common seals in Europe belong to a distinct sub-species which, in addition to the UK, is found mainly in Icelandic, Norwegian, Danish, German and Dutch waters. Britain holds approximately 40% of the world population of the European sub-species (SCOS, 2003).

Within the UK, common seals are found from Northern Ireland and the southern Firth of Clyde clockwise round the coast to the Thames estuary. The vast majority of common seal haul-outs are found on the coasts of Scotland, especially around the west coast of Scotland and throughout the Hebrides and Northern Isles (Figure 5.3). On the east mainland coast their distribution is more restricted, with particular concentrations in the Wash, Firth of Tay and Moray Firth. A smaller number is found in Strangford Lough, Northern Ireland.

Population estimates of common seals

Surveys of common seals are carried out during the moult in August. Recent surveys and overall estimates are summarised in SCOS (2003). It is impractical to survey the whole of the coastline every year, but current plans will survey the whole coastline across five consecutive years. Seals spend the largest proportion of their time on land during moult and they are therefore visible during this period to be counted in the surveys.

Between 1996 and 2001, about 33,800 common seals were counted in the whole of Britain, of which 29,800 (88%) were in Scotland and 4,000 (12%) were in England (SCOS, 2003). A total of 1,200 seals were counted in Northern Ireland. The total British population cannot be estimated accurately, but is currently thought to be in the region of 50–60,000 (SCOS, 2003). This is

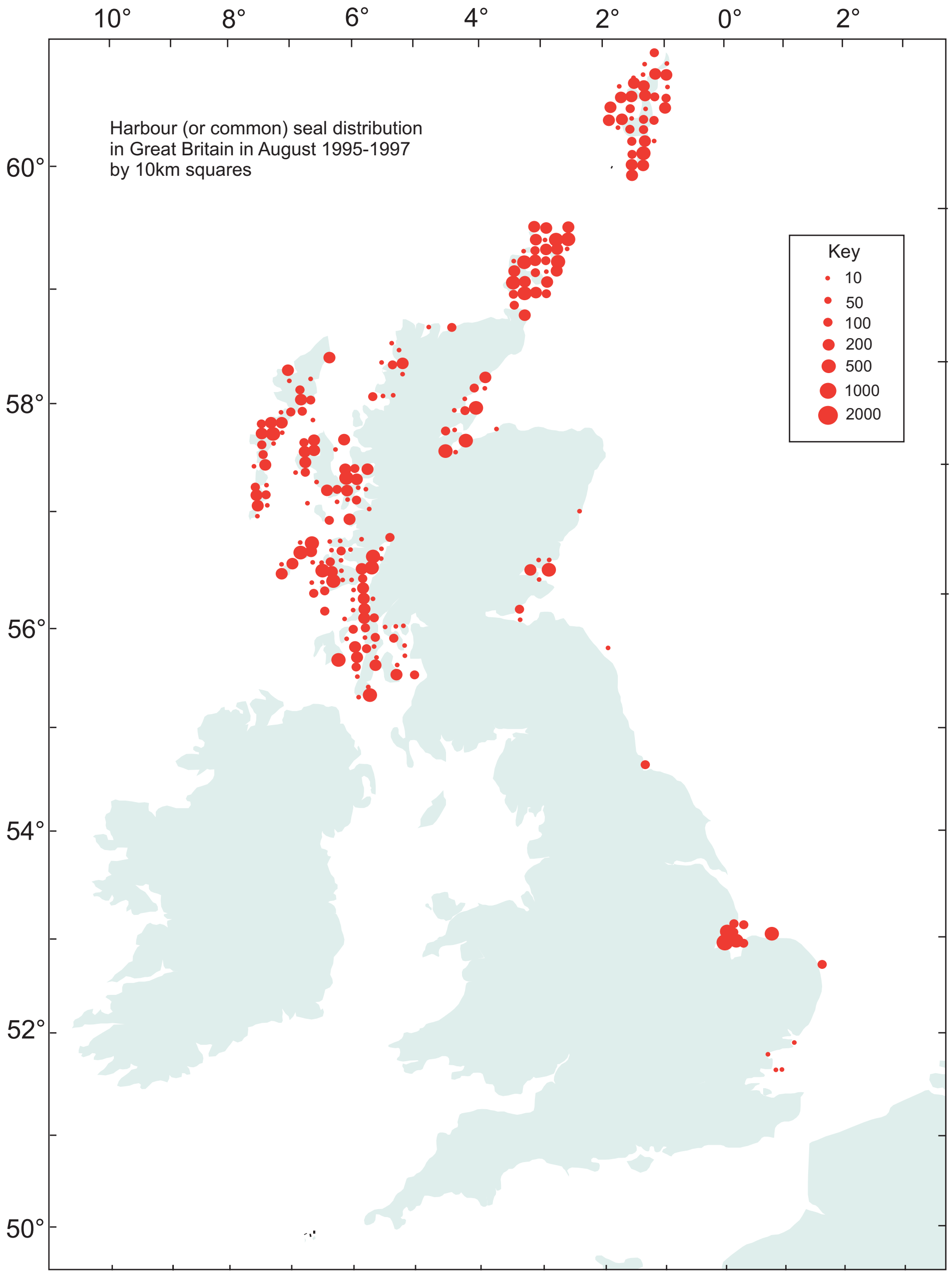

Figure 5.3. The main haul out sites of common seals around the UK

estimated as approximately 5% of the world population of common seals, and approximately 50% of the post-PDV European population.

Epidemics of phocine distemper virus (PDV) affected British seals in 1988 and 2002. This virus infects both grey and common seals but causes deaths mainly in common seals. The population of common seals had recovered from the effects of the epidemic in 1988 by the time of the next epidemic. In 2002 the total number of carcasses found in Britain amounted to about 10% of the minimum estimated population of common seals (SCOS, 2003). The population along the east coast of England (mainly in the Wash) was most affected with up to 35% of the population dying. In contrast, this epidemic had little impact on common seals in Scotland where the population appears to have been roughly stable for at least the past decade. The PDV outbreak of 2002 has now run its course.

INDICATORS OF STATE

The most appropriate indicators of state in seal populations involve (1) the absolute size of seal populations; (2) the metapopulation structure; and (3) the dynamics of births, death, immigration and emigration. Together, these provide necessary tools to understand the vulnerability of the populations and the ways in which they are likely to react to additional stressors such as increased hunting, bycatch in fishing gear and other marine obstacles and changes in food and habitat availability. Relative to most wild mammals in the UK and to most other marine organisms, both the absolute size of seal populations and the metapopulation structure are reasonably well understood. Information about birth rates, death rates and migration processes is less complete, but remains adequate to allow assessment of the vulnerability of these populations.

Current data showing trends in abundance integrate across these specific measures to provide a broad indicator of the state of the population. Therefore, the current investments in site-specific survey of both grey and common seals in the UK are a cost-effective means of monitoring changes in state through time, although they provide little indication about the underlying reasons for changes in state.

ENVIRONMENTAL OBJECTIVES

ECOLOGICAL QUALITY OBJECTIVES (ECOQOS)

The Oslo–Paris Convention (OSPAR) is testing a system of Ecological Quality Objectives (EcoQOs) in the North Sea. There is currently one OSPAR Commission EcoQO being tested for seals, 'seal population trends in the North Sea'. The 'Utilization of seal breeding sites in the North Sea' has also been proposed for future development. The data for these EcoQOs are embedded in the SCOS advice (SCOS, 2003). This application of the information could be expanded in the next round, due out towards the end of 2004, providing that a request to do so is forthcoming from the Department for Environment, Food and Rural Affairs (Defra).

Data about the number of grey seal pups produced at each breeding site in the North Sea have been collected annually since 1960. This type of data collection is likely to continue for the foreseeable future and it will provide the information required to establish both EcoQOs for grey seals. It would be useful to have more information about the underlying processes leading to variations in EcoQOs which have mainly been designed to fit the information available.

Information about the abundance and use of breeding sites by common seals is less comprehensive (SCOS, 2003) and it is also more difficult to define breeding sites in this species than in grey seals. However, regular counts exist for all the major breeding sites in the North Sea and, in the case of the main sites (the Wash and Moray Firth), there have been annual surveys for at least the past 15 years (SCOS, 2003).

HABITATS DIRECTIVE

The UK has proposed candidate Special Areas of Conservation (SACs) for seals (See Appendix 1): there are 11 sites for grey seals (Figure 5.4) and 11 sites for common seals (Figure 5.5). Representative breeding colonies have been listed as proposed SACs for grey seals. For common seals, areas where these animals are found regularly to haul out have been proposed. This includes regions on Islay, Eriskay, Skye, Orkney, Shetland, the Dornoch Firth (inner Moray Firth), the Tay Estuary and the Wash. No feeding areas have been proposed. Site selection has favoured sites that are important both as general haul-out sites and for moulting and pupping. Most sites are concentrated in Scotland and this reflects the relatively large number of grey and common seals in that region, but the Wash, which contains the largest breeding group in the south of the common seal's range in the UK, is also included. Sites have been selected using the most up-to-date population data, but these sites are small relative to the range of the seals using them and small shifts in seal distribution could lead to apparent declines in the numbers using the sites designated as SACs. It is anticipated that this survey effort will continue and that

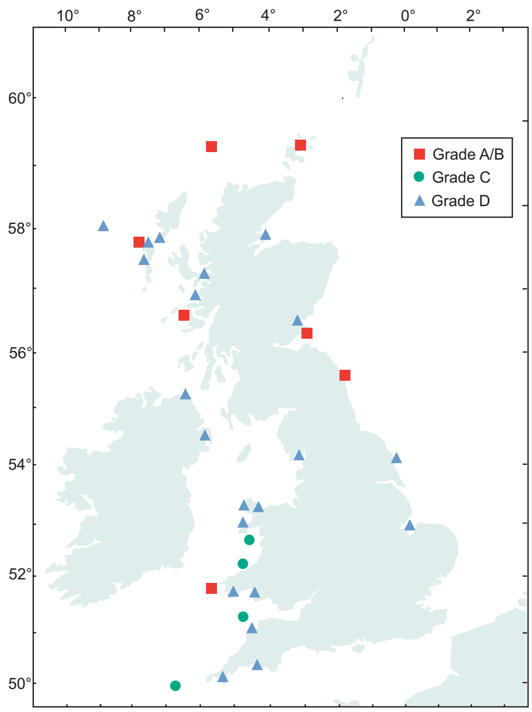

Figure 5.4. The distribution of Special Areas of Conservation (SACs) with grey seal features[1] (maps provided by the Joint Nature Conservation Committee)

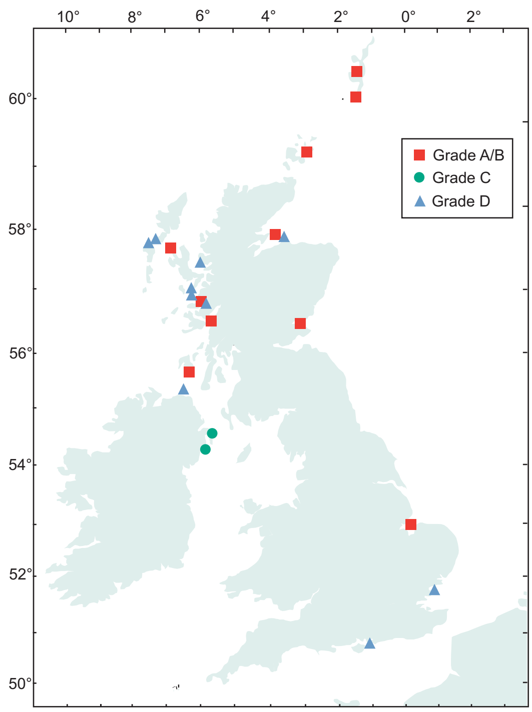

Figure 5.5. The distribution of Special Areas of Conservation (SACs) with common seal features1 (maps provided by the Joint Nature Conservation Committee)

there will be continuing efforts to underpin these population data with new information about metapopulation structure and factors affecting the rate of population change. Progress to date has involved the development of a number of tools to assist in assessing the current status of SACs.

There is currently no information available on the status of SACs designated for seals. The conservation agencies are currently undertaking monitoring programmes to assess the status of SAC features to meet the next reporting deadline at the end of 2006.

REFERENCE

SCOS (2003). *Report of the UK Special Committee on Seals*. Natural Environment Research Council, Swindon, UK. Available from http://smub.stand.ac.uk/CurrentResearch.htm/scos.htm

[1] Grade A/B are those sites which have been selected for that feature, Grade C sites are where the Annex I habitat is a qualifying feature, but not a primary reason for site selection, Grade D sites contain features of below SSSI quality (so are not considered as part of the reasons for designation of a site), but the feature does occur on a site qualified for other features.

APPENDIX 1

The following tables provide current (December 2004) information for the 11 candidate SACs for Phoca vitulina (common seals) and Halichoerus grypus (grey seals) and are taken from the JNCC's SAC selection pages: http://www.jncc.gov.uk/page-1457.

Further detailed information about SACs in the UK, including site descriptions, together with downloadable data including a SAC summary spreadsheet, GIS boundary data and copies of site documentation, is also available.

S1365 *Phoca vitulina* Common seal has 11 SACs. Sites are sorted alphabetically within country

EU Code	Name	Country	Local Authority	Grid Ref
UK0017075	The Wash and North Norfolk Coast	E	Lincolnshire; Norfolk	TF558403
UK0016612	Murlough	NI	Down	J408360
UK0016618	Strangford Lough	NI	Down	J529707
UK0030230	Ascrib, Isay and Dunvegan	S	Highland	NG222565
UK0019806	Dornoch Firth and Morrich More	S	Highland	NH788863
UK0030182	Eileanan agus Sgeiran Lios mór	S	Argyll and Bute	NM888471
UK0030311	Firth of Tay & Eden Estuary	S	Angus; City of Dundee; Fife; Perth & Kinross	NO420294
UK0012711	Mousa	S	Shetland Islands	HU462241
UK0030069	Sanday	S	Orkney Islands	HY715442
UK0030067	South-East Islay Skerries	S	Argyll and Bute	NR446474
UK0012687	Yell Sound Coast	S	Shetland Islands	HU467755

S1364 *Halichoerus grypus* Grey seal has 11 SACs. Sites are sorted alphabetically within country

EU Code	Name	Country	Local Authority	Grid Ref
UK0013694	Isles of Scilly Complex	E	Cornwall; Isles of Scilly	SV883111
UK0013114	Lundy	E	Devon	SS136465
UK0017072	Berwickshire and North Northumberland Coast	ES	Northumberland; Scottish Borders	NU206401
UK0017096	Faray and Holm of Faray	S	Orkney Islands	HY529378
UK0030172	Isle of May	S	Fife	NT644999
UK0012694	Monach Islands	S	Western Isles/ Na h-Eileanan an Iar	NF644622
UK0012696	North Rona	S	Western Isles/ Na h-Eileanan an Iar	HW811327
UK0030289	Treshnish Isles	S	Argyll and Bute	NM289429
UK0012712	Cardigan Bay/ Bae Ceredigion	W	Ceredigion; Penfro/Pembrokeshire	SN214641
UK0013116	Pembrokeshire Marine/ Sir Benfro Forol	W	Penfro/Pembrokeshire	SM503093
UK0013117	Pen Llyn a`r Sarnau/ Lleyn Peninsula and the Sarnau	W	Ceredigion; Gwynedd; Powys	SH401130

6. State of breeding seabirds

KEY MESSAGES

The key messages to emerge from the following section considering the different aspects of the status of seabirds in UK seas are:

- **Seabird 2000 – a complete census of breeding seabird in Britain and Ireland (1998–2002) – provides the most up-to-date population estimates of all 25 species of seabird breeding in the UK, including the first ever estimates for nocturnal species.**
- **An assessment of status through population trends over the last 15–30 years is possible for 21 species by comparing Seabird 2000 population size estimates with those from two previous censuses conducted in 1969–70 and 1985–88.**
- **The most recent census of UK breeding seabirds in 1998–2002 has shown that, compared with the first census in 1969–70 the UK coastal populations of 12 species have increased in size by more than 10%, two have decreased by more than 10% and six have changed by less than 10%. But more recently, compared with the last census in 1985–88, the populations of only seven species have increased in size by more than 10%, while eight have declined by more than 10% and five have changed by less than 10%.**
- **It is possible to assess the status of some species on an annual basis through measurements of breeding numbers and breeding success collected from a sample of colonies both regionally and nationally throughout the UK, conducted as part of the Seabird Monitoring Programme (SMP).**
- **The causes of change in numbers and breeding success are complex, varied between species, varied geographically and in some cases not fully understood. Some causative factors are related to the state of the UK's seas (e.g. climate, sea-surface temperature, plankton biomass, sandeel stocks), while others may be terrestrial based, highly localised or originated from overseas at non-breeding areas. Hence changes in population size and breeding success of some seabird species may be effective indicators of the state of the seas, while other species may not.**
- **Currently there are two seabird-related Ecological Quality Objective (EcoQO) under testing relating to (1) the proportion of oiled Common guillemots among those found on North Sea beaches; and (2) the use of Black-legged Kittiwake breeding success as an indicator of sandeel availability near their colonies. Others are under consideration by the OSPAR Commission.**
- **The UK has designated 95 Special Protection Areas (SPA) due to their qualifying breeding populations of one or more seabird species or breeding seabird assemblage. In addition, work is under way to identify seaward boundary extensions to existing seabird colony SPAs; important inshore non-breeding areas for seaducks, divers and grebes; and offshore areas used by marine birds. To date, only one wholly marine UK inshore SPA has been designated.**

INTRODUCTION

In 1979, the European Community adopted the Council Directive on the Conservation of Wild Birds (79/409/EEC), referred to as the 'Birds Directive'. The Birds Directive covers the protection, management and control of all naturally occurring birds and their eggs, nests and habitats within all EU Member States. Species that warrant special conservation measures concerning their habitat are listed in Annex I of the Directive, which includes eight of the 25 species of seabird currently breeding in the UK. Furthermore, Article 4 of the Directive has led to the creation of a network of Special Protection Areas (SPA) throughout the European Union that contain important habitat for breeding, wintering and migrating birds listed in Annex I and a further 16 regularly occurring migratory species of seabird not listed in Annex I. In the UK, a total of 243 such sites have been included in the SPA Network. The Birds Directive states that habitat within Special Protection Areas (SPAs) should be protected from deterioration to ensure the survival and reproduction of important endemic bird populations. A crucial part of SPA management is the regular monitoring of trends and variations in population levels.

The Joint Nature Conservation Committee's Seabird Monitoring Programme (SMP) facilitates the coordination of seabird monitoring on a UK-wide basis. The aim of the programme is to ensure that sufficient data on breeding numbers and breeding success of seabirds are collected both regionally and nationally to enable their conservation status to be assessed. The programme assists the Joint Nature Conservation Committee, Royal Society for the Protection of Birds (RSPB) and partner organisations, including the statutory country nature conservation agencies, to monitor aspects of the health of the wider marine environment and to provide sound advice relevant to the conservation needs of breeding seabirds. Since 1989, the results of the SMP have been published in an annual report: *Seabird Numbers and Breeding Success in Britain and Ireland*, by the Joint Nature Conservation Committee in collaboration with RSPB and the Shetland Oil Terminal Environmental Advisory Group (SOTEAG). The information contained in these reports is collated from many sources. These include research staff and wardens from a variety of organisations including RSPB, SOTEAG, the Joint Nature Conservation Committee, Scottish Natural Heritage, English Nature, Countryside Council for Wales, Irish National Parks and Wildlife Service, the Wildlife Trusts, bird observatories, National Trust and National Trust for Scotland, the Centre for Ecology and Hydrology and BirdWatch Ireland. Many dedicated fieldwork volunteers also contribute valuable data to the SMP. The most recent annual reports are available for download at http://www.jncc.gov.uk/page-2143.

While the SMP conducts annual monitoring of a sample of the breeding seabird population in the UK, complete censuses of all breeding seabirds in UK have been conducted to obtain total population estimates that provide a baseline, against which subsequent monitoring can be compared. The most recent UK population estimates (see Table 6.1) were obtained in 1998–2002 during Seabird 2000, a Joint Nature Conservation Committee-led census of breeding seabirds in the UK and the Republic of Ireland (Mitchell *et al*., 2004; http:// http://www.jncc.gov.uk/page-3120). Over 1000 surveyors took part in Seabird 2000 and censused almost 8 million seabirds in 3,200 colonies along 40,000 km of coastline and at 900 inland sites. The project is a partnership between the Joint Nature Conservation Committee, the country nature conservation agencies, RSPB, the Seabird Group, SOTEAG, BirdWatch Ireland and National Parks and Wildlife Service (Department of Environment, Heritage and Local Government – Republic of Ireland). There have been two previous seabird censuses – 'Operation Seafarer' conducted by the Seabird Group in 1969–70 (Cramp *et al*., 1974) and 'The Seabird Colony Register' coordinated jointly by the Seabird Group and the Nature Conservancy Council in 1985–88 (Lloyd *et al*., 1991).

CURRENT STATUS

This section highlights the main findings of Seabird 2000; a detailed report of the survey is given in Mitchell *et al.* (2004). Currently, 25 seabird species breed in the UK. The total number of seabirds breeding along the UK coastline has increased from 4.4 million in 1969–70 and 5.6 million in 1985–88 to 6.7 million in 1998–2002, with an additional 225,000 gulls, terns and Great Cormorants breeding at inland sites.

Table 6.1. Numbers of seabirds breeding in the UK 1969-2002. All counts are 'pairs' unless otherwise stated

Species	Coastal colonies only					
	Operation Seafarer (1969-70)	SCR Census (1985-88)	Seabird 2000 (1998-2002)	Percentage change since Seafarer	Percentage change since SCR	Seabird 2000 (1998-2002) inland and coastal
Northern Fulmar	291,880	519,602	505,073	73%	-3%	505,073
Manx Shearwater			299,722			299,722
European Storm-petrel			25,710			25,710
Leach's Storm-petrel			48,047			48,047
Northern Gannet	116,006	161,768	226,553	95%	40%	226,553
European Shag	31,093	38,294	28,880	-7%	-25%	28,880
Great Cormorant	6,168	6,825	7,487	21%	10%	9,133
Arctic Skua	1,039	3,388	2,136	106%	-37%	2,136
Great Skua	3,079	7,645	9,634	213%	26%	9,634
Mediterranean Gull	0	1	110			110
Black-headed Gull	73,607	77,197	77,326	5%	0%	138,014
Common Gull	12,295	15,362	20,889	70%	36%	48,720
Herring Gull	299,876	161,810	141,703	-53%	-12%	143,656
Lesser Black-backed Gull	48,575	63,198	89,261	84%	41%	113,808
Great Black-backed Gull	19,246	17,970	17,450	-9%	-3%	17,470
Black-legged Kittiwake	408,337	505,465	379,895	-7%	-25%	379,895
Sandwich Tern	11,068	14,766	12,490	13%	-15%	12,490
Roseate Tern	955	323	56	-94%	-83%	56
Common Tern	12,086	13,287	12,021	-1%	-10%	12,012
Arctic Tern	51,440	76,908	53,388	4%	-31%	53,388
Little Tern	1,608	2,577	1,947	21%	-24%	1,947
Common Guillemot[1]	601,094	1,083,881	1,421,376	136%	31%	1,421,376
Razorbill[1]	131,932	155,148	188,641	43%	22%	188,641
Black Guillemot[2]		38,048	39,316		3%	39,316
Atlantic Puffin	425,408	488,925	581,110	37%	19%	581,110

[1] individuals
[2] pre-breeding adults

Population changes recorded by the three censuses over the last 30 years have varied considerably between the 25 different species. Between 1969–70 and 1998–2002, the UK coastal populations of 12 species have increased in size by more than 10%, two have decreased by more than 10% and six have changed by less than 10% (Figure 6.1, Table 6.1). [An arbitrary descriptor of 10% has been used to distinguish between 'small changes' that may simply reflect differences in survey effort between successive censuses, and more substantial changes that are more likely

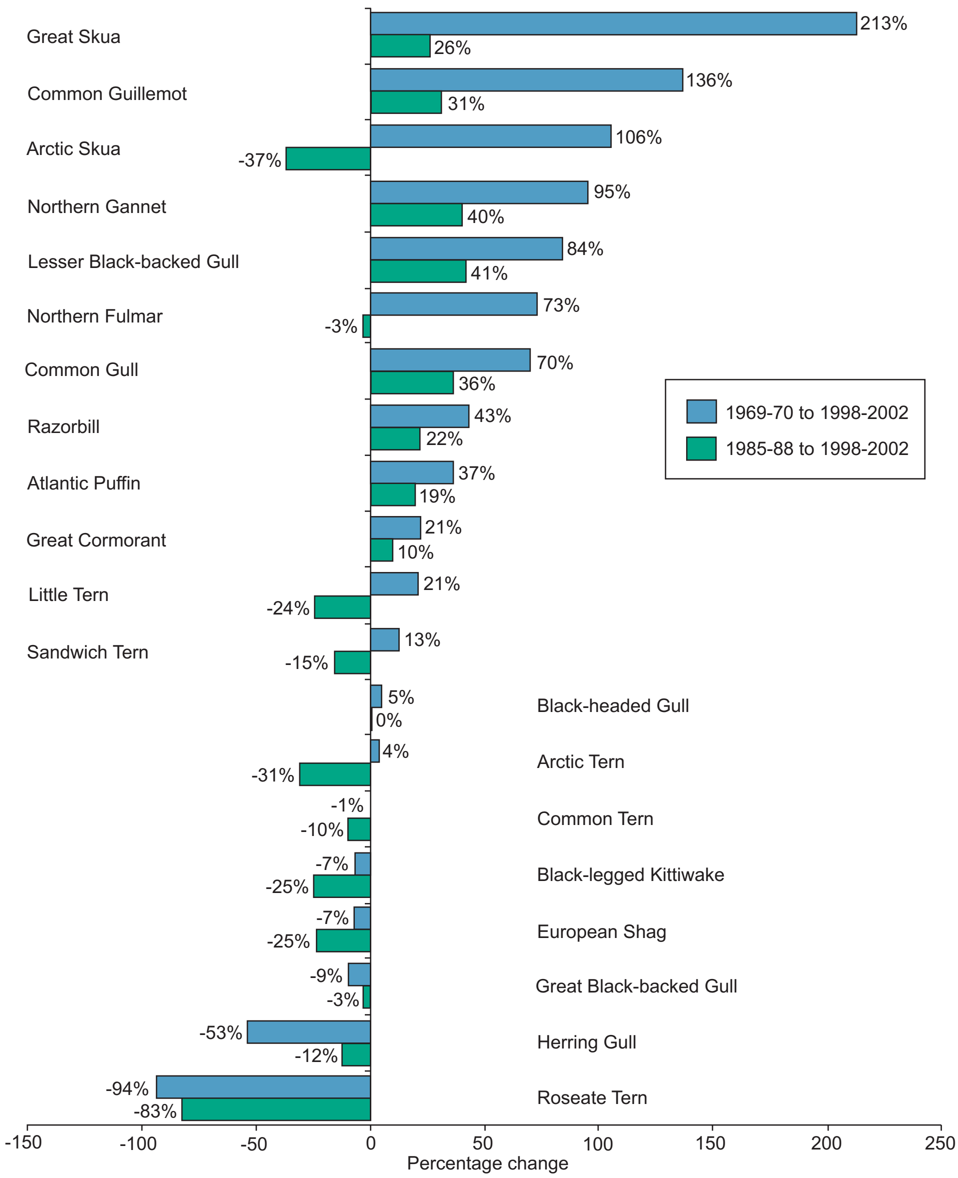

Figure 6.1. Percentage changes in the number of seabirds breeding in the UK between Seabird 2000 (1998–2002) and Operation Seafarer (1969–70) and the SCR Census (1985–88). Note: percentage changes refer to coastal-nesting seabirds only - inland colonies were not surveyed during the Operation Seafarer (1969-70) and the SCR Census (1985-88). Manx Shearwater, Leach's Storm-petrel and European Storm-petrel are omitted as they were not surveyed during the Operation Seafarer (1969-70) and the SCR Census (1985-88). Survey methods for Black Guillemots during Operation Seafarer (1969-70) were not comparable with Seabird 2000 (1998-2002)

to reflect real trends in the size of the breeding population]. Roseate Tern numbers in the UK have declined by 94% over the last 30 years due to a gradual emigration of birds from Britain, across the Irish Sea to several colonies along the east coast of the Republic of Ireland. During the same period, Herring Gull numbers declined by 53% despite a substantial rise in the number nesting in urban areas throughout the 1980s and 1990s. The greatest increases over the last 30 years have been in the numbers of Great Skuas (213%), Common Guillemots (136%), Arctic Skua (106%), Northern Gannet (95%), Lesser Black-backed Gull (84%), Northern Fulmar (73%) and Common Gull (70%). However, the increase in numbers of both species of skua may be overestimated since they were under-recorded in 1969–70 and numbers of Arctic Skuas have decreased by 37% since 1985–88. Likewise, numbers of Black-legged Kittiwakes, European Shags, Sandwich Terns, Arctic Terns and Little Terns have declined by more than 10% since 1985–88. The number of Common Gulls and Black-headed Gulls breeding on the coast appear to be increasing and stable respectively, but the overall range throughout the UK, including inland breeding sites (holding 57% and 42% respectively of the total UK populations in 1998–2002) have contracted by 25% and 50% respectively since 1988–91. The changes in numbers of some species have varied considerably in different parts of the UK. For example, numbers of Atlantic Puffins breeding at colonies in the North Sea have substantially increased in the last 15–30 years, whereas elsewhere numbers have remained stable.

It is impossible to assess changes in numbers of some species over the last 30 years. Mediterranean Gulls have colonised the UK since the last census in 1985–88 and there were 110 pairs in 1999–2002 breeding mainly in southern England. Due to the recent development of effective survey techniques, Seabird 2000 was the first census to obtain accurate population estimates of nocturnal species, i.e. European Storm-petrels, Leach's Storm-petrels and Manx Shearwaters (Table 6.1). All three species are confined to the north and west coasts of the UK, with colonies in the North Sea confined to Orkney and Shetland. The UK holds 68–94% of the world population of Manx Shearwaters and 3–11% of the World's European Storm-petrels, but less than 1% of the world's Leach's Storm-petrels, although the centre of the East Atlantic population is on St Kilda, Western Isles. Numbers of Black Guillemots increased by only 3% between 1982–91 and 1999–2002, but comparison with earlier surveys is invalidated by subsequent improvements in survey methods.

INDICATORS OF STATE

CAUSES OF CHANGE IN SEABIRD POPULATIONS

Seabirds are long-lived (e.g. a 50-year-old Manx Shearwater was recently recorded on the Copeland Islands, Co. Down), delay breeding until they are several years old, display high rates of annual survival of adults but low rates of post-fledging survival. Breeding population size is most affected by factors that influence adult survival rather than breeding success and post-fledgling survival, unless such effects are sustained over several years. Factors causing reduced adult survival include senescence, disease, reduced food availability, predation, hunting/culling and stochastic events such as oil spills and severe storms. Of these, food availability is the most directly related to the state of the seas. However, food availability tends to have a much more dramatic effect on breeding success than it does on adult survival. Furthermore, breeding success is easier to measure than adult survival and is monitored at many more colonies in the UK and for a wider range of species.

Between 1985 and 1990, seabirds in Shetland, namely Arctic Terns, Arctic Skuas, Great Skuas, Black-legged Kittiwakes and Atlantic Puffins experienced successive years of breeding failure due to the collapse of the local sandeel stock that all these species relied upon to feed themselves and their chicks. Since then, sandeel availability and breeding success has fluctuated. As a result of successive years of poor breeding success and subsequently low recruitment, the breeding populations of Arctic Skuas, Arctic Terns and Black-legged Kittiwakes in Shetland have declined by 42%, 19% and 62% respectively between 1985–88 and the Seabird 2000 census in 1998–2002 (Mitchell *et al*., 2004). Since the completion of Seabird 2000, numbers of Arctic Skuas, Arctic Terns and Black-legged Kittiwakes at monitored colonies in Shetland continue to decline, and look set to do so over the next few years following poor breeding success in successive years between 2001 and 2004 (Mavor *et al*., 2002, 2003, 2004, 2005). The breeding season in 2004 was the poorest on record for all three species, not only in Shetland, but also in

Orkney, with few young fledged across the entire Northern Isles and poor productivity was also experienced at other colonies along the UK's North Sea coast (Mavor *et al*., 2005). The recent breeding failures appear to have resulted mainly from a shortage of sandeels.

Arctic Terns (and all other tern species in the UK) and Black-legged Kittiwakes feed on sandeels just below the surface, while Arctic Skuas steal sandeels from these species (and also from auks) and so are dependant on the ability of other species to find food and therefore tend to exhibit poor breeding success in the same years as their hosts. The survival and body condition of Black-legged Kittiwakes breeding on Foula, Shetland, are associated with sandeel abundance, as are those of their main predator, the Great Skua (Oro and Furness, 2002). Other piscivorous species (auks, European Shags and Great Cormorants) can reach food much deeper below the surface by pursuit diving or plunge-diving (Northern Gannets) and so tend to have a greater ability to obtain enough food to raise chicks, even when fish stocks are low. However, diving species are by no means immune to the effects of food shortages. For instance, on the Isle of May, Firth of Forth, the breeding success of European Shags has been positively correlated with the size of the local sandeel stock (Rindorf *et al*., 2000) and in years of poor sandeel availability up to 60% of the breeding population of shags on the island have deferred breeding. In 2003 and 2004, sandeel shortages around Orkney and Shetland resulted in depressed breeding success of Common Guillemots and Razorbills, more so in 2004 – the poorest breeding season on record for these species, with unprecedented total breeding failure at some colonies (Mavor *et al*., 2005).

Sandeel distribution in UK waters is patchy, with distinct spawning aggregations, resulting from the availability of sandy sediments and the fact that adult sandeels are relatively sedentary, showing only limited movements between areas (Proctor *et al*., 1998; Pedersen *et al*., 1999; Wright *et al*., 2000). The varying fortunes of these distinct sandeel stocks may have led to the observed geographical variation in breeding success (see Mavor *et al*., 2005, for example) of those species that rely on sandeels to feed themselves and their young. In Shetland waters, sandeels are recruited from the advection of larvae from the spawning stock around Orkney, and the collapse of the sandeel stock around Shetland in the mid-1980s was believed to be a result of very low levels of recruitment rather than any effect of fishing (Wright, 1996). Around the mid-1980s, rises in sea surface temperatures (SST) led to a 'regime shift' in the plankton communities in the North Sea (Beaugrand *et al*., 2003) and consequently a reduction in sandeel recruitment (Arnott and Ruxton, 2002). The size of sandeels caught by (and available to) Atlantic Puffins over the Wee Bankie off south-east Scotland decreased significantly over the period 1973–2002 (Wanless *et al*., 2004). It appears that these changes lower down the food chain have had a knock-on effect on seabirds. Frederiksen *et al*. (2004b) found that over-winter survival of adult Black-legged Kittiwakes breeding on the Isle of May during 1986–2002 was lower following warmer winters (i.e. high SST) and that breeding success one year later was significantly reduced. They suggested that the low numbers of 0-group sandeels recruited following a warm winter (cf. Arnott and Ruxton, 2004) would lower the condition of adult kittiwakes going into the following winter, reducing their chance of survival and subsequent breeding success the following spring when they would be feeding on the same depleted cohort of sandeels. Furthermore, the presence of the sandeel fishery during 1990–99 over the Wee Bankie, within range of the Isle of May, was significantly associated with the low breeding success of Black-legged Kittiwakes. Frederiksen *et al*. (2004b) predicted that if SST in the North Sea increased in the future and the sandeel fishery resumed, the kittiwake population on the Isle of May (and perhaps other nearby colonies) would enter into a '*catastrophic decline*'.

Most of the sandeel fishing in the North Sea occurs beyond the foraging range of seabirds in UK colonies, apart from over the Wee Bankie and around Shetland. A precautionary ban was imposed on the Shetland fishery in 1990–95, and subsequent catches were limited to low levels, with a voluntary ban around south Shetland in 2004. Since 2000, when a precautionary ban was imposed on sandeel fishing over the Wee Bankie (as part of an area from north-east Scotland to Northumberland), kittiwake breeding success on the Isle of May showed some signs of improvement, up until 2004 when breeding success was poor (Harris *et al*., in press). At the same time, Common Guillemots on the Isle of May switched from feeding their chicks on sandeels to feeding predominantly on clupeids (e.g. Sprats), which coincided with a decline in breeding success (Harris *et al*., in press).

Commercial fisheries do not always compete with seabirds over fish, and indeed fishing trawlers can be an important source of food for some species. Tasker and Furness (1996) estimated that in the North Sea seabirds consume annually 100,000 tonnes of discards and 70,000 tonnes of offal, produced mainly by the demersal whitefish fishery (i.e. Haddock and Whiting). However, over the last 30 years there has been a general decline in commercial fishing around the UK, leading to lower quantities of offal and discards. Current and future fisheries management practices (e.g. increased mesh sizes, square meshed panels in trawl nets) will result in fewer discards, particularly of small fish. This is likely to affect smaller species of scavenging seabirds most – Great Skuas, Herring Gulls and Lesser Black-backed Gulls – but will have less of an effect on larger species, such as Northern Gannet and Great Black-backed Gulls, that can handle larger fish (Reeves and Furness, 2002). At some colonies, Great Skuas have taken to predating on other seabirds and the proportion of seabirds in their diet is higher in years when fewer discards are produced by the North Sea whitefish fishery and when sandeel stocks are low (another favoured prey of the Great Skua) (Votier *et al*., 2004). The numbers of seabirds taken by Great Skuas can be considerable at some colonies (Phillips *et al*., 1999), and they are having a significant impact on some populations of Arctic Skuas, Black-legged Kittiwakes and Leach's Storm-petrel (Mitchell *et al*., 2004). Furthermore, if both discards and sandeel stocks decrease in the future, as seems likely (see above), the impact of Great Skua predation on the populations of other species will increase, particularly on those already struggling to find food.

Clearly, further work is required to decipher the complicated relationships between fisheries and seabird populations in order to determine the true impact of future changes in fisheries management.

The reduction in food at sea has coincided with an increase in the amount of food provided inland in the form of human waste. Herring Gulls have become increasingly reliant on human waste at rubbish tips, which has no doubt aided breeding success at some colonies and improved over-winter survival of immatures and adults. However, the downside of human waste as a food source is the potential for the spread of disease, and in Northern Ireland (and the Republic of Ireland), botulism is believed to be the main cause of the 96% decline in the number of breeding Herring Gulls that has occurred since the mid-1980s (Madden and Newton, 2004).

Seabird populations in the UK have increased in size over the last century as a direct result of increased protection from hunting and persecution in the UK and overseas. However, human activities still continue to have a detrimental impact on seabirds. For example, seabirds can become accidentally caught in fishing nets and on baited hooks on long-lines. Dunn and Steel (2001) estimated that the Norwegian offshore long-line fleet accidentally caught 20,000 Northern Fulmars in 1997–98 and further studies are required to fully assess the extent of this bycatch across the fleets from Iceland and the Faeroes. Pollution has the most direct and visible impact on seabirds and while organochlorides are no longer present in sufficient quantities to affect seabirds in the UK (Furness, 1993), oil spills continue to kill large numbers. During the last 15 years, two large spills resulting from oil tanker accidents occurred close to the UK coast: the *Braer* (Shetland, January 1993) and *Sea Empress* (Pembrokeshire, February 1996). Thousands of seabirds died, but the impact of both spills was far less than if they had occurred during the breeding season, since most species tend to disperse away from the colonies during the non-breeding season. However, two spills recently occurred in the Bay of Biscay within the non-breeding areas of auks from UK colonies – the *Erika* (Brittany, France, December 1999) and the *Prestige* (Galicia, Spain, November 2002). Both spills killed large numbers of auks, but the majority were immature birds (Camphuysen *et al*., 2002), so that the impact on the breeding population was much less than if the same number of adults had been killed. However, the true impact of this mortality on the breeding colonies in the UK would only be evident several years later when these young birds would have recruited into the breeding population. The very fact that large numbers of seabirds aggregate together to breed makes them very vulnerable to even localised spills during the breeding season.

The interactions described above between SST, plankton, sandeels and seabirds suggest that long-term climate change is likely to have a significant impact on seabird populations. The breeding behaviour of some seabird populations in the UK has already been linked to large-scale climatic fluctuations in the North Atlantic, such as the North Atlantic Oscillation (NAO) (Thompson and Ollason, 2001; Frederiksen *et al*., 2004a). Projected consequences of global warming in UK waters, such as sea level rises, increased storminess and rises in sea/air temperatures are likely to have a direct impact on seabird populations. For instance, rising sea levels may reduce the amount of breeding habitat available for shoreline nesting species such as terns; winter storms can cause large-scale 'wrecks' of seabirds, and summer storms can wash whole colonies from cliffs.

While many seabirds are affected by the state of the seas, some of the greatest impacts on population size are terrestrial. Available nesting habitat can limit colony size and distribution and the presence of land predators can further limit the amount of safe nesting habitat available to ground-nesting species, such as puffins, petrels, shearwaters, gulls, terns and Black Guillemots; so much so that the invasion of some islands by Brown Rats or American Mink has led to the complete extinction of some ground-nesting species (Craik, 1997). Furthermore, migratory species are affected by factors operating outside the UK; for example, declines in the numbers of Sandwich Terns and Roseate Terns are thought to be due in part to trapping along the west coast of Africa, where UK breeding birds spend the winter (Newton, 2004; Ratcliffe, 2004).

MONITORING THE STATE OF SEABIRD POPULATIONS

The Seabird Monitoring Programme (SMP) began in 1986 and is coordinated by the Joint Nature Conservation Committee's Seabird Colony Team. It involves regular monitoring of various aspects of seabird demography, such as population size and breeding success at colonies throughout the UK. The SMP relies on contributions from the country conservation agencies and various conservation NGOs, as well as from dedicated, skilled volunteers. The most detailed monitoring in the SMP is undertaken at several geographically dispersed 'key sites': the Isle of May (south-east Scotland), Fair Isle (Shetland), Canna (north-west Scotland), and Skomer (west Wales). Long-term monitoring of numbers and breeding success is also undertaken on Shetland, Orkney Mainland, St Kilda (north-west Scotland) and in Grampian (north-east Scotland). Monitoring of breeding success of cliff-nesting species is also encouraged by the Joint Nature Conservation Committee at many other colonies, partly by contributing to fieldwork costs of volunteers via the Seabird Group.

As part of the Seabird Monitoring Programme, the Joint Nature Conservation Committee and the Seabird Group collaborate on the Seabird Colony Register (SCR). The SCR is a database containing counts from seabird colonies from all over Britain and Ireland conducted between 1969 and 1998 (counts since 1998 are contained in the new Seabird 2000 database – http://www.searchnbn.net/).

The results from the colonies monitored by the SMP are used to calculate regional and UK trends in population size and breeding success for each species. These trends are updated and published annually in *Seabird Numbe*rs and Breeding success in Britain and Ireland (e.g. Mavor *et al*., 2004). Figures 6.2 and 6.3 show trends in UK population indices of three diving species and three surface-feeding species respectively. The lines plotted take 1986 as the baseline at 100% and present changes as a percentage of this; thus if the index rises by 50% from the baseline, on average the population will have increased by 50%.

Annual population indices data from the SMP contribute to one of the UK Government's *Quality of Life Counts* (i.e. *Populations of wild birds*) that form the UK's Headline Indicator H13: Wildlife (http://www.sustainable-development.gov.uk/indicators). The SMP also contributes to the biodiversity indicator *M1: Populations of coastal birds and seabirds in England* as part of Defra's Biodiversity Strategy for England (http://www.defra.gov.uk/wildlife-countryside/ewd/biostrat/#indicators). It is debatable whether or not such indicators would provide an accurate indication of the state of the sea. The UK *H13: Wildlife* indicator is composed of data from 13 seabird species combined with 98 other bird species from terrestrial and freshwater habitats, so is unlikely to be sensitive to trends in seabird numbers and hence changes in the marine environment. However, the *M1* biodiversity indicator for England combines population size indices from nine species, with

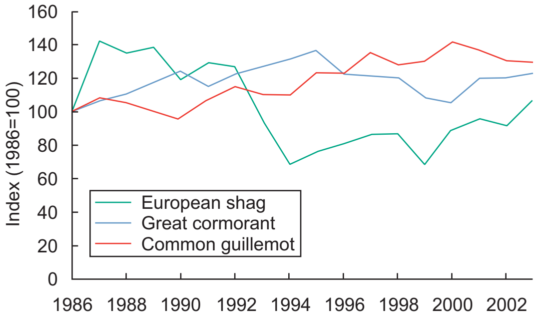

Figure 6.2. UK population trends of diving seabird species (1986–2003)

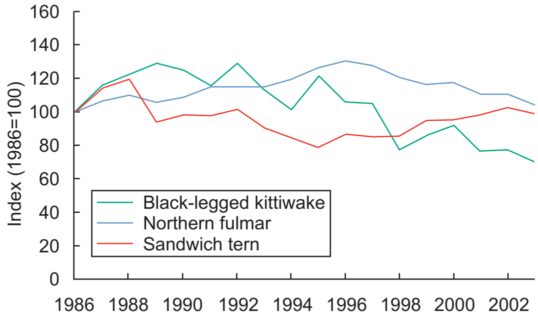

Figure 6.3. UK population trends of surface-feeding seabird species (1986–2003)

separate indicators for *surface feeding fish-eaters* (Black-legged Kittiwakes; Common, Arctic, Little and Sandwich Terns) and *sub-surface feeding fish-eaters* (European Shag, Common Guillemot and Great Cormorant). While these species groupings appear ecologically based, they may not necessarily be appropriate for indicating the state of the sea, since the factors that affect the population size of the different species within each indicator do not all originate from the marine environment. For instance, trends in the numbers of Black-legged Kittiwakes and Arctic Terns breeding in the UK are greatly affected by the availability of their main prey, sandeels, which is in turn determined by plankton populations, oceanography, fishing and climate (see above); hence population trends in Kittiwakes and Arctic Terns may provide useful indicators of the state of the sea. However, trends in the numbers of Common, Little and Sandwich Terns breeding in the UK appear to be more greatly affected by site-specific factors such as predation and nest site quality and by persecution overseas (in the case of Sandwich Terns), rather than by the wider marine environment (Mitchell *et al*., 2004); and so may not provide much indication of the state of the UK's seas *per se*.

All seabird species breeding in the UK are relatively long-lived and late-maturing species. Hence it may take several years for environmental changes affecting their breeding performance to have a measurable effect on the size of their breeding population. Therefore an annual measure of breeding success, as collected by the SMP, would give a more immediate indicator of the state of the sea and perhaps provide an early warning of likely future population change.

PROGRESS TOWARDS ENVIRONMENTAL OBJECTIVES

ECOLOGICAL QUALITY OBJECTIVES (ECOQOS)

The Oslo–Paris Convention (OSPAR) is testing a system of Ecological Quality Objectives (EcoQOs) in the North Sea. The first seabird-related EcoQO being developed relates to the proportion of oiled common guillemots among those found on North Sea beaches. The Netherlands is the lead country for this objective and has used available information on this proportion from Orkney and Shetland. The Netherlands has yet to define what it views as necessary sampling for other parts of the UK's North Sea coast. The second EcoQO under testing is using Black-legged Kittiwake breeding success as an indicator of sandeel availability near their colonies. The OSPAR commission is also reviewing other possible metrics for development into seabird-related EcoQOs, including the number of plastic particles in northern fulmar stomachs and trends in seabird populations. The future of the EcoQO programme will be reviewed in 2005.

Overall there is little progress on EcoQOs at this time (December 2004).

BIRDS DIRECTIVE

Since its inception in 1979, the EC Birds Directive (79/409/EEC) has provided the framework for the protection, management and control of all species of naturally occurring wild birds found in EU Member States; these include all those species listed on Annex I of the Directive, and also regularly occurring migratory (ROM) species not listed on Annex I. As such, all seabird species, except Black Guillemot, may be accorded protection under the provision of the Birds Directive within sites called Special Protection Areas (SPA). These form part of an ecologically coherent network of protected sites known as Natura 2000.

Sites may qualify for SPA designation as a result of a species population size reaching a qualifying threshold; for Annex I species this equates to 1% of the national (GB or All-Ireland) population, and for ROM species this equates to 1% of the international (biogeographical) population. Additionally, sites may qualify as a result of an assemblage of seabirds (exceeding 20,000 individuals).

Although the Birds Directive applies to the protection of these species 'in the geographical sea and land area', most progress has been made in the terrestrial, freshwater and estuarine environments (Stroud *et al.*, 2001) with the designation of 95 terrestrial seabird SPAs as a result of their qualifying numbers of one or more seabird species and/or a qualifying seabird assemblage – see Table 6.2 and Figure 6.4. The UK conservation agencies are assessing the status of these sites to meet common standard monitoring reporting deadlines in July 2005. There is currently no information available on the status of these sites.

In order to support the application of the Birds Directive in the marine environment (Johnston *et al.*, 2001), the Joint Nature Conservation Committee (in collaboration with country conservation agencies) is currently working to identify seaward boundary extensions to existing seabird colony SPAs; important inshore areas for seaducks, divers and grebes outwith the breeding season; offshore areas used by marine birds (probably for feeding but also for other purposes); and any other important areas not included in the previous three strands of work.

To date significant progress has been made with respect to identification of extensions to existing SPAs for Northern Gannet, Common Guillemot, Razorbill and Atlantic Puffin (McSorley *et al.*, 2003; Webb, 2004). Further work is being carried out for possible seaward boundary extensions to existing Red-throated Diver and Manx Shearwater SPAs. Additionally, Carmarthen Bay has been designated as the first wholly marine UK inshore SPA for Black Scoter (CCW, 2002), and an inshore SPA has been proposed at Liverpool Bay (Webb *et al.*, 2004). Further work will be carried out on data from other UK inshore areas. Methods for site selection and designation of inshore SPAs are presented in McSorley *et al.* (2005) and Webb and Reid (2004). Identification of sites in the offshore environment commenced in 2004; finalisation of the methodology and identification of possible aggregation areas for further investigation will be completed by December 2005.

Table 6.2. The number of Special Protection Areas (SPAs) qualifying by supporting breeding seabird populations of national and/or international importance; or a mixed-species seabird assemblage of over 20,000 breeding adults

Species	No. of SPAs
Northern Fulmar	25
Manx Shearwater	4
European Storm-petrel	9
Leach's Storm-petrel	6
Northern Gannet	10
European Shag	13
Great Cormorant	7
Arctic Skua	7
Great Skua	9
Mediterranean Gull	5
Black-headed Gull	4
Common Gull	3
Herring Gull	12
Lesser Black-backed Gull	10
Great Black-backed Gull	6
Black-legged Kittiwake	33
Sandwich Tern	16
Roseate Tern	7
Common Tern	22
Arctic Tern	17
Little Tern	27
Razorbill	19
Common Guillemot	34
Atlantic Puffin	21
Seabird assemblage	34

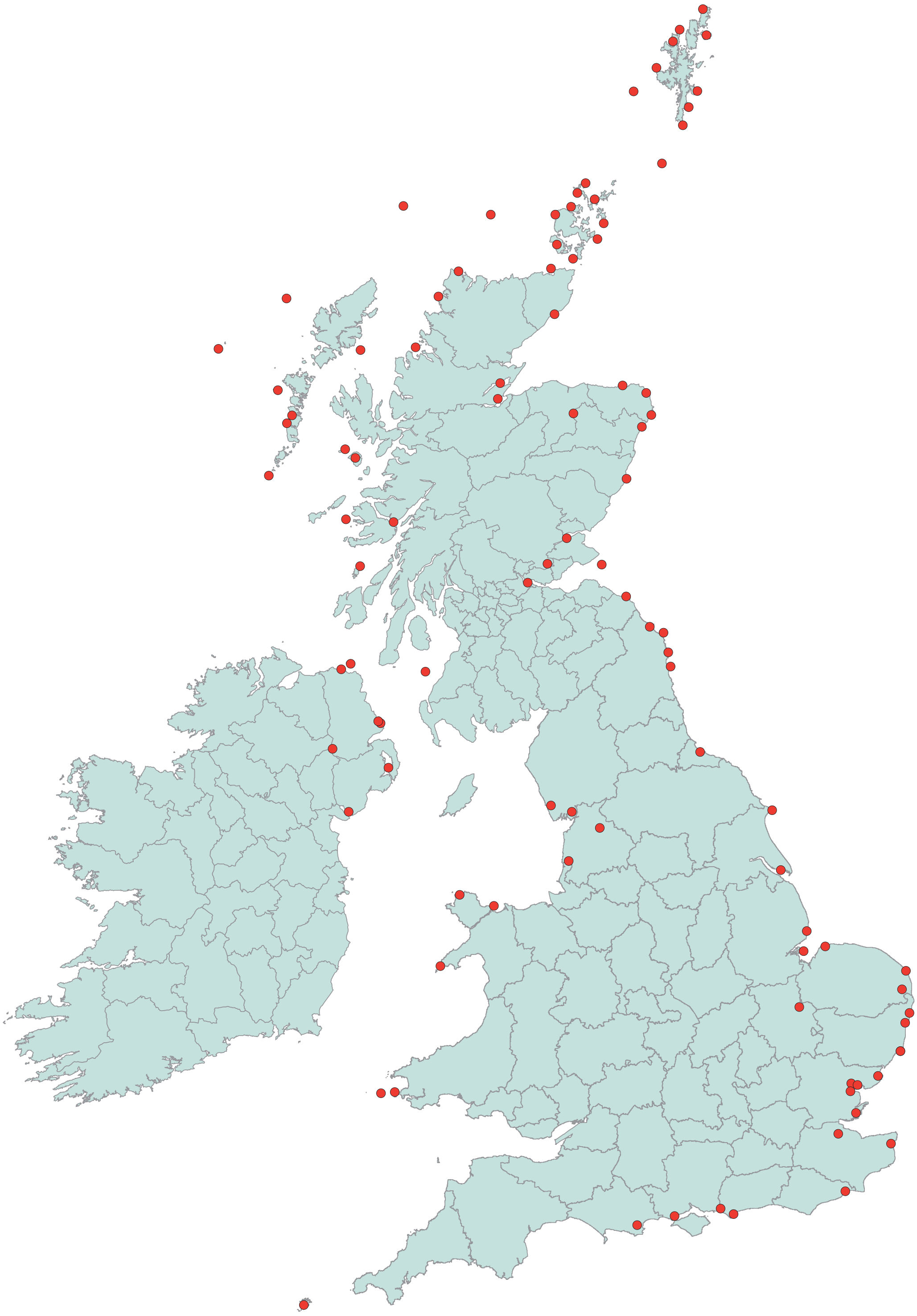

Figure 6.4. Sites designated as Special Protection Areas due to their qualifying interest in one or more seabird species and/or their seabird assemblage

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7. Glossary

aggregation Organisms (usually referring to of the same species) living closely together, but not physically connected (cf. 'colony').

anthropogenic Produced by human activity.

azoic Devoid of animal life.

Baseline A determined standard against which things are measur"ed or compared.

benthos Those organisms attached to, or living on, in or near, the seabed, including that part which is exposed by tides as the littoral zone (based on Lincoln and Boxshall, 1987).

biogenic Literally 'made by living things' i.e. biogenic reefs which are solid, massive structures which are created by accumulations of organisms, usually rising from the seabed, or at least clearly forming a substantial, discrete community or habitat which is very different from the surrounding seabed. The structure of the reef may be composed almost entirely of the reef building organism and its tubes or shells, or it may to some degree be composed of sediments, stones and shells bound together by the organisms. Biogenic reefs tend to be created by the following species: *Sabellaria alveolata, S. spinulosa, Modiolus modiolus, Mytilus edulis* and *Serpula vermicularis*.

biogeochemical The study of the relationship between the geochemistry of a region and the animal and plant life in that region.

biomass The total quantity of living organisms in a given area, expressed in terms of living or dry weight or energy value per unit area.

biota The plant and animal life of a particular site, area, or period.

biotope 1) The physical 'habitat' with its biological 'community'; a term which refers to the combination of physical environment (habitat) and its distinctive assemblage of conspicuous species. MNCR uses the biotope concept to enable description and comparison. 2) The smallest geographical unit of the biosphere or of a habitat that can be delimited by convenient boundaries and is characterised by its biota (Lincoln, Boxshall and Clark, 1982).

bycatch the catch of non-target species and undersized fish of the target species. Bycatch of non-target species is usually discarded.

circalittoral The subzone of the rocky sublittoral below that dominated by algae (the infralittoral), and dominated by animals. No lower limit is defined, but species composition changes below about 40 m to 80 m depth, depending on depth of the seasonal thermocline. This subzone can be subdivided into the upper circalittoral where foliose algae are present and the lower circalittoral where they are not (see Hiscock, 1985). The term is also used by Glémarec (1973) to refer to two étages of the sediment benthos below the infralittoral: a "coastal circalittoral category with a eurythermal environment of weak seasonal amplitude (less than 10°C) varying slowly" and a "circalittoral category of the open sea with a stenothermal environment".

Congeneric belonging to the same genus.

Corallogenic structure in which stony corals are the major constituent.

cSAC candidate Special Area of Conservation (i.e. submitted to European Commission).

demersal Living at or near the bottom of a sea or lake, but having the capacity for active swimming (from Lincoln, Boxshall and Clark, 1982).

depauperate arrested in growth or development.

diapause A period during which growth or development is suspended and physiological [Being in accord with or characteristic of the normal functioning of a living organism] activity is diminished, in response to adverse environmental conditions.

EcoQO the desired level of the ecological quality relative to predetermined reference levels.

Euphotic of, relating to, or being the uppermost layer of a body of water that receives sufficient light for photosynthesis and the growth of green plants.

eutrophication The over-enrichment of an aquatic environment with inorganic nutrients, especially nitrates and phosphates, often anthropogenic (e.g. sewage, fertiliser run-off), which may result in stimulation of growth of algae and bacteria, and can reduce the oxygen content of the water.

exceedance The amount by which something, especially a pollutant, exceeds a standard or permissible measurement.

Fjardic A series of shallow basins connected to the sea via shallow, sometimes intertidal, sills. Fjards are found in areas of low-lying ground which have been subject to glacial scouring. They have a highly irregular outline, no main channel and lack the high relief and U-shaped cross-section of fjordic sea lochs.

Fjordic a long narrow inlet of the sea between steep cliffs.

food web a community of organisms where there are several interrelated food chains.

gadoid fish of the cod family e.g. cod, haddock, Norway pout, Pollack, saithe (coley), whiting, pout whiting and others.

geomorphology The branch of geology concerned with the structure, origin and development of topographical features of the earth's crust.

infauna Benthic animals which live within the seabed.

infralittoral A subzone of the sublittoral in which upward-facing rocks are dominated by erect algae, typically kelps; it can be further subdivided into the upper and lower infralittoral (based on Hiscock, 1985). The term is also used by Glémarec (1973) to refer to areas (étages) with a eurythermal environment of great seasonal and also daily and tidal amplitude.

inshore close to a shore i.e. within 12 nautical miles

intertidal The area of the shore between the highest and lowest tides (from Lewis 1964) (cf. 'littoral').

lagoon (saline) A shallow body of coastal salt water (from brackish to hypersaline) partially separated from an adjacent sea by a barrier of sand or other sediment, or less frequently, by rocks (based on Ardizzone et al. 1988). Three features serve to identify a coastal lagoon:
1) the presence of an isolating barrier beach, spit or island;
2) the retention of all or most of the water mass within the system during periods of low tide in the adjacent sea;
3) the persistence of natural water exchange between the lagoon and the parent sea - by percolation through and/or overtopping of the barrier, through inlet/outflow channels, etc. - permitting the lagoonal water to remain saline or brackish.

As defined for the EC Habitats Directive, lagoons are "Expanses of shallow coastal salt water, of varying salinity and water volume, separated from the sea by sand banks or shingle, or, less frequently, by rocks. Salinity may vary from brackish water to hypersalinity depending on rainfall, evaporation and the addition of seawater from storms or from temporary flooding by the sea in winter" (European Commission, 1995)

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Five lagoon types have been identified in Great Britain for the identification of Sites of Special Scientific Interest (Joint Nature Conservation Committee 1996).
(i) Isolated saline lagoon. These are pools which are completely isolated from the sea by a barrier of rock or sediment. No seawater enters the pool by percolation, the only input of salt water occurs by limited groundwater seepage (such as in some dune pools), by overtopping of the barrier (sill) on extreme high water spring tides, or by salt water inundation during storm events.
(ii) Percolation saline lagoon. These pools are separated from the sea by a permeable barrier of shingle or pebbles and small boulders. Sea water exchange occurs through the barrier to varying degrees dependent on the permeability of the barrier.

(iii) Sluiced saline lagoons. These are lagoons where the ingress and egress of water from the lagoon to the open sea is modified by human mechanical interference.
(iv) Silled saline lagoons. These are in many respects similar to some examples of sluiced lagoons. They are generally rocky basins which have a sill between mean high water of spring tides and mean low water of spring tides.
(v) Saline lagoon inlets. These are saline lagoons where there is a permanent connection with the sea.
Cf. ‘pond (coastal)’.

littoral The area of the shore that is occupied by marine organisms which are adapted to or need alternating exposure to air and wetting by submersion, splash or spray. On rocky shores, the upper limit is marked by the top of the *Littorina*/*Verrucaria* belt and the lower limit by the top of the laminarian zone (Lewis 1964). It is divided into separate subzones, particularly marked on hard substrata. Cf. ‘intertidal’.

long-line a method of fishing with baited hooks. An inshore cod long-line for example has hooks set on short (ca. 0.5m) lengths of line-‘snoods’ attached to the main line at intervals of 2-5m. The total length of the line can range from 2-300m to several km in length.

macrobenthos The larger organisms of the benthos, exceeding 1 mm in length (from Lincoln & Boxshall 1987); often applied to organisms > 0.5 mm. Cf. ‘meiobenthos’, ‘microbenthos’.

macrofauna Animals exceeding 1 mm in length (Lincoln and Boxshall, 1987) or retained on a 1 mm or 0.5 mm sieve; often applied to organisms >0.5 mm. Cf. ‘meiofauna’, ‘microfauna’.

maerl Twig-like unattached (free-living) calcareous red algae, often a mixture of species and including species which form a spiky cover on loose small stones - ‘hedgehog stones’.

megafauna large or relatively large animals.

meroplankton Temporary plankton consisting of pelagic stages of organisms which also have benthic stages. Mainly the larvae of sedentary organisms. (From Baretta-Bekker, Duursma and Kuipers 1992). Cf. holoplankton.

Mesoplankton Intermediate sized plankton from about 200 micrometers to 2 centimetres.

microplankton *Phytoplankton* whose lengths range from 50 to 500 μm.

mudflat An expanse of mud or muddy sediment in the intertidal zone. The 1991 CORINE biotopes manual (Commission of the European Communities, 1991) defines ‘Mud flats and sand flats’ as “Sands and muds, submerged for part of the tide, devoid of vascular plants, but usually coated by blue algae and diatoms.” The EC Habitats Directive ‘mudflats and sandflats not covered by seawater at low tide’ uses the same definition (European Commission, 1995).

neritic Referring to coastal waters overlying the continental shelf (0 m to 200 m below chart datum) (based on Baretta-Bekker, Duursma & Kuipers 1992).

Offshore The area from 12 nautical miles out to the Continental Shelf limit.

Ontogenic The origin and development of an individual organism from embryo to adult.

pelagos Descriptive of organisms that inhabit open water, as opposed to the sea floor.

phenology The study of cyclic and seasonal natural phenomena, especially in relation to climate and plant and animal life.

physiographic naturally formed features of the earth’s surface.

phytoplankton Phytoplankton are free-floating microscopic plants which, having little mobility, are distributed by ocean currents, typically comprising suspended or motile microscopic algal cells such as diatoms, dinoflagellates and desmids (based on Lincoln & Boxshall, 1987).

Picoplankton Very small plankton typically between 0.2 and 2 micrometers and are commonly called ‘marine bacteria’.

Plankton Plankton are small aquatic organisms (animals and plants) that, generally having no locomotive organs, drift with the currents. The animals in this category include *protozoans*, small crustaceans, and the larval stages of larger organisms while plant forms are mainly *diatoms*.

piscivorous Habitually feeding on fish.

radionuclides A nuclide [type of atom specified by its atomic number, atomic mass, and energy state] that exhibits radioactivity.

recruitment (population biology) Term used for the arrival of young in a given population per unit of time (based on Baretta-Bekker, Duursma and Kuipers, 1992).

relict (species) A species believed to have been previously more widely distributed but now restricted to a limited number of locations where populations are probably self-sustaining, for example, *Thyasira gouldi, Leptopsammia pruvoti*.

saltmarsh Areas of alluvial or peat deposits, colonised by herbaceous and small shrubby terrestrial vascular plants, almost permanently wet and frequently inundated with saline waters (from Long and Mason 1983).

sandflat An expanse of sand of sandy sediment in the intertidal zone. For definition under the EC Habitats Directive, see 'mudflat'.

seamount an underwater mountain rising above the ocean floor.

Sensitive Marine Areas Sensitive Marine Areas are non-statutory marine areas that are nationally important and notable for their **natural** marine animal and plant communities or which provide ecological support to adjacent statutory sites.

sublittoral The zone exposed to air only at its upper limit by the lowest spring tides, although almost continuous wave action on extremely exposed coasts may extend the upper limit high into the intertidal region. The sublittoral extends from the upper limit of the large kelps and includes, for practical purposes in nearshore areas, all depths below the littoral. Various subzones are recognised. (Based on Hiscock, 1985.) Cf. 'subtidal'.

subtidal A physical term for the seabed below the mark of Lowest Astronomical Tide (cf. 'sublittoral').

thermocline A horizontal boundary layer in the water column in which temperature changes sharply with depth (based on Lincoln and Boxshall, 1987).

turbidity created by stirring up sediment or having foreign particles suspended ultraplankton whose lengths range from 0.5 to 10 μm.

VMCA voluntary marine consultation area. A non-statutory nature conservation designation identifying areas of nature conservation interest for which widespread consultation is desirable before any development takes place.

zonation The distribution of organisms in distinctive belts on the shore, in the sublittoral, due to gradients in environmental factors (cf. 'gradient').

zooplankton The animals that swim in mid water but drift to-and-fro with the currents.